COST EFFECTIVE EU TRANSPORT SAFETY MEASURES

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The European Transport Safety Council

The European Transport Safety Council (ETSC) is an international non-governmental organisation which was formed in 1993 in response to the persistent and unacceptably high European road casualty toll and public concern about individual transport tragedies. Cutting across national and sectoral interests, ETSC provides an impartial source of advice on transport safety matters to the European Commission, the European Parliament and, where appropriate, to national governments and organisations concerned with safety throughout Europe.

The Council brings together experts of international reputation on its Working Parties, and representatives of a wide range of national and international organisations with transport safety interests and Parliamentarians of all parties on its Main Council to exchange experience and knowledge and to identify and promote research-based contributions to transport safety.

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EXECUTIVE SUMMARY

This ETSC Review gives a cross-modal analysis of cost-effective measures aiming to improve transport safety. However, since road transport represents by far the greatest transport safety problem in all European countries with around 97% of all transport fatalities occurring in the road sector, particular emphasis is given to road transport.

ROAD TRANSPORT

For the road mode the results of a cost-benefit analysis of five ‘promising’ road safety measures ready for introduction by the European Union are presented:

- Daytime running lights (DRL)
- Random breath testing: best practice guidelines
- Audible seat belt reminders
- Use of EuroNCAP as an incentive for developing safer cars
- Road safety engineering: best practice guidelines

The costs of a measure are understood as the social costs of all means of production (labour and capital) that are employed to implement the measure; therefore they will be called implementation costs. The effects of a measure are understood as any change in social welfare (positive or negative) that is the result of that measure (intended or not). The aim of a measure is to decrease the damage caused by road accidents which means that the effects to take into account first are the safety effects.

Daytime running lights (DRL)

This countermeasure is to be understood as a legal obligation for all motor vehicles in the 15 EU-countries to drive with low beam headlights or (but more as an exception) with special DRL lamps.

The analysis shows that the introduction of DRL in European countries could lead to an annual reduction of 2,800 fatalities. The calculation of the cost/benefit ratio also illustrates a favourable result: the costs of DRL are considerably lower than the benefits (value 1 : 4.4). Furthermore, the cost/benefit ratio could be even more favourable if special DR-lamps equipped with economical bulbs were installed, in which case it would increase to 1 : 6.4.

Random breath testing: best practice guidelines

This measure is to be understood as a set of “best practice” guidelines for the responsible police authorities in EU member states. Such guidelines should aim at substantially and permanently increasing the current level of enforcement in the area of drink-driving. Furthermore, they should promote particular enforcement strategies that have proven to be effective.

This study shows that increasing RBT to a frequency of 1 test per 16 inhabitants (current

EU average) in every member state will improve road safety considerably (annually 2,000–2,500 fatalities) and in a very cost-effective way. However, it also points out that this only constitutes a first step of an effective policy against drink-driving. There is plenty of space for a further increase of RBT. Furthermore, part of the current testing is not done randomly and could be transformed into RBT without additional costs. The frequency of 1 in 16 can also be increased considerably.

Audible seat belt reminders

An audible seat belt reminder is a device that gives a sound warning whenever a seat is occupied, but the seat belt is not fastened.

Taking into account injuries as well as fatalities it is shown that the present value of the benefits of requiring audible seat belt reminders for the front seats of cars in the European Union amounts to 66,043 million Euro. The present value of the costs amounts to 11,146 million Euro, giving a cost benefit ratio of 1:6. The benefits of audible seat belt reminders for front seats thus clearly exceed the costs.

Use of EuroNCAP as an incentive for developing safer cars

The European New Car Assessment Programme (EuroNCAP) tests the crashworthiness of new cars with respect to front and side impacts and pedestrian accidents.

Evidence suggests that car manufacturers do monitor EuroNCAP test results closely and seek to improve models that do not perform well. Its beneficial effects are accentuated by the fact that models with an improved crash test performance are not necessarily priced much higher than earlier ones and that EuroNCAP has relatively low operating costs (slightly more than 1 million Euro per year).

While a precise analysis is difficult, the evidence presented in this report does indicate that EuroNCAP is contributing to an improvement in vehicle crashworthiness, likely providing benefits significantly greater than the cost to society of achieving these improvements.

Road safety engineering: best practice guidelines

The essential elements of a systematic approach to road safety engineering are outlined here. As a first step it is necessary to define the elements of the road system that are suitable for safety analysis. Then the distribution of accidents needs to be analysed for a suitable period of time for each set of elements. If there is systematic variation in the number of accidents, a performance function needs to be fitted to identify sources of that variation.

A safety performance function will typically not include the effects of all sources of systematic variation in the number of accidents. Some of the omitted sources of systematic variation in the number of accidents will be factors that are more or less specific to particular locations of the road system. The effects of these factors will be modelled by means of the empirical Bayes method.

Having estimated the expected number of accidents for each element of the road system, the logical next step is to define hazardous road locations. Once this has been done, a road safety audit or a detailed analysis of accidents needs to be conducted. At many hazardous road locations, low cost measures will solve the problem, though a few may need more expensive solutions. Looking at low cost measures which have been introduced in Norway impressive cost-benefit ratios are obtained, often exceeding one to ten. The report concludes that the Norwegian experience should be transferable to other European countries, especially if one bears in mind that Norway is a high-cost country with a comparatively good road safety record.

NON-ROAD MODES

A proper cost-benefit analysis could not be carried out for these modes given the scarce amount of time and financial resources. Furthermore, cost-benefit analyses are not commonly used in the modes other than road because decisions for the introduction of safety measures are made more on the grounds of practicality and improved system function, whenever the specific safety elements cannot be estimated or quantified. Nevertheless, a short description of measures which in principle are cost-effective will follow.

Rail

For rail transport few measures with an obvious safety improving potential can be identified as a result of railways generally being a very safe mode of transport. Not many accidents occur and there has been a constant decrease in the number of fatal accidents over the years.

The principal cost-effective safety measure identified is the installation of barriers on level crossings. However, a full cost-benefit analysis cannot be conducted due to missing data. The study should hence only be seen as tentative.

Furthermore, the following measures are given very brief consideration:

- On-board detectors of heated bearings and axle failures
- Fencing at stations to prevent passengers from taking short-cuts between platforms
- Door improvements to prevent passengers from falling out of moving trains
- Measures to prevent trains from colliding with maintenance vehicles
- Breaking the electric tension over parked railcars

Maritime

The complex distribution of competences between global, European and national authorities has implications for carrying out cost benefit analyses in the maritime sector. Due to the uncertainties that evolve from such a structure, a CBA does not necessarily qualify as the arch instrument of decision making within maritime safety policy. Consequently, the maritime chapter merely seeks to outline some of the principles which underpin CBAs in the maritime sector. It does so by briefly looking at three measures: a monitoring network based on an Automated Identification System (AIS) along the European coast, the reporting of dangerous goods as well as an Emergency Towing Vessel (ETV).

The above examples illustrate that any cost benefit analysis in the maritime safety sector faces a series of problems, mostly due to the complexity of involved parties. But they also show that CBAs are indeed possible and can quite often provide a fair estimate of the effectiveness of a particular measure. Past experience has shown that global, European and national authorities have reached decisions partly based on the results of CBAs. However, many governments have also passed legislation on measures that were considered “not cost-effective”. This practice shows that CBAs are often just one out of many instruments providing the basis for sound safety policy making.

Still, also within maritime safety, CBAs are a crucially important part of Formal Safety Assessments (FSA) as adopted by the IMO. In order to ensure the use of appropriate data and make possible the consideration of all costs and benefits of a particular measure, maritime authorities have to provide easily accessible databases as well as the resources necessary to conduct a sound analysis.

Air

In the aviation sector there is an increasingly broad consensus on the need to improve safety, such that the absolute number of accidents per year does not increase. This is considered necessary to prevent that increasing numbers of accidents lead to a perception of deteriorating safety and a subsequent decline in demand for air travel. As a consequence, current thinking about safety improvement measures is not necessarily about identifying safety measures with an individual positive return on investment and implementing those, but about identifying the set of safety measures that will together deliver sufficient safety improvement to compensate for traffic growth. If more safety improvement is expected from the identified set of safety measures than is needed to compensate for traffic growth, safety measures are prioritised based on cost benefit considerations. Thus, while the costs of accidents, which are increasing strongly, do play a role in the considerations around safety improvement programmes, these costs do not constitute the main driving force behind the industry wide safety improvement initiatives.

INTRODUCTION

Transport crashes in the EU killed about 39,200 EU citizens in 2001, caused over 3.3 million casualties and cost over 180 billion Euros, around twice the total EU budget for all activity.

As part of the current programme of activity which receives matched funding from the European Commission, the European Transport Safety Council has brought together independent experts from across the EU to identify a series of cost-effective EU transport safety measures which, if applied, could give a substantial contribution to the reduction of the number and severity of transport crashes in the European Union.

This ETSC Review is of a cross-modal character. However, it takes into account that road transport represents by far the greatest transport safety problem in all European countries with around 97% of all transport fatalities occurring in the road sector. Thus, particular emphasis is given to road transport and no attempt has been made to standardise the analysis of road and non-road measures.

Section 1 of this Review looks at five cost-effective EU road safety measures. ETSC believes that the implementation of these measures, which are ready-to-go, could give a substantial contribution to reaching the ambitious EU target of halving road deaths by the year 2010. Moreover, a swift implementation of these measures from 2004 onwards will increase their likely benefits because in an enlarged EU the relative costs per capita will decrease.

It needs to be mentioned that this road chapter, intentionally, does not consider speed reduction measures. The absence of speed reduction measures is due to a simple reason: countermeasures to speed are broad and comprehensive and cannot easily be subjected to a proper cost-benefit analysis within the scope of this Review.

Sections 2, 3 and 4 of this Review, then, deal with the rail, maritime and air modes respectively. They show that cost-benefit analyses are not commonly used in these three modes because decisions for the introduction of safety measures are made more on the grounds of practicality and improved system function, whenever the specific safety elements cannot be properly estimated or quantified.

Finally, in Appendix 1, the Review contains an update of ETSC's estimates of the costs of transport accidents and the value of safety from 1995-prices to 2000-prices.

1 COST EFFECTIVE EU ROAD SAFETY MEASURES

1.1 INTRODUCTION

This Chapter presents the results of a cost-benefit analysis of five ‘promising’ road safety measures that are ready for introduction by the European Union. The five road safety measures are:

- Daytime running lights (DRL)
- Random breath testing: best practice guidelines
- Audible seat belt reminders in the front seats of cars
- Use of EuroNCAP as an incentive for developing safer cars
- Road safety engineering: best practice guidelines

These measures are within the competence of the EU. Each measure will be specified taking into account the present jurisdiction and practical instrumentation of the European institutions. For this reason the measures on random breath testing and road safety engineering will be defined in terms of guidelines for the national authorities in charge.

The cost-benefit analysis will take into account all social costs and effects of each measure (positive or negative, intended or not) to whomever they may accrue within the boundaries of the EU (any group of private citizens, any private or public organisation). This is because a *social* CBA is aimed at and not a *private* one.

1.1.1 Definition of the countermeasures

Daytime running lights (DRL)

This countermeasure is to be understood as a legal EU obligation for all users of motor vehicles and mopeds to drive at daytime with low beam headlights. New cars, trucks and motorcycles will have to be equipped with an automatic switch, either for the existing low beam headlights or in combination with the installation of special DRL lamps. As a result, all vehicles that are equipped with such switches will always drive with these lights on, at any time of day and year, on any road. In all existing vehicles the headlights will have to be switched on and off manually or automatically if an automatic switch has been installed through retrofit. This obligation comes into force from a certain moment for all vehicles concerned.

Random breath testing: best practice guidelines

This measure is to be understood as a set of best practice guidelines for the responsible authorities in EU member states in the area of controlling drink driving with random breath testing.

The guidelines should aim at a substantial and permanent increase of the current level of enforcement (by a factor of about three); furthermore, they should promote particular enforcement strategies that have proven to be most effective. Besides a high probability of being controlled (which demands frequent police interventions) a large number of road users should be exposed to enforcement activities that are unpredictable, well publicised, and highly visible.

It is supposed that the guidelines are effective and create the intended amount, duration, and type of enforcement and publicity.

Audible seat belt reminders in the front seats of cars

An audible seat belt reminder is a device that gives a sound warning whenever a seat is occupied, but the seat belt is not fastened. This review refers to seat belt reminders in the front seats of cars. Reference will be made to a simple continuous reminder. This is a device that gives a warning as long as the seat belt is not worn, but it is not designed with an ignition interlock function.

Use of EuroNCAP as an incentive for developing safer cars

The European New Car Assessment Programme (EuroNCAP) tests the crashworthiness of new cars with respect to front and side impacts and pedestrian accidents. Results are stated in terms of stars: five stars (four stars in case of pedestrian ratings) represents the best performance, zero stars the worst performance. The EuroNCAP programme is intended to influence road safety through a number of causal pathways, the most important of which include providing car manufacturers with an incentive to develop safer cars, encouraging more cars to be tested in the programme and encouraging more countries to join EuroNCAP.

Road safety engineering: best practice guidelines

Here, guidelines intended to help highway agencies to effectively implement safety management measures for the road system of their responsibility will be outlined.

1.1.2 Definition of costs and effects

The costs of a measure are understood as the social costs of all means of production (labour and capital) that are employed to implement the measure; therefore they will be called implementation costs. Transfers (flows of money from one group to another that are not paid in exchange for goods or services) should not be taken into account because they do not affect social welfare: the loss of welfare for the paying party is compensated by the increase in welfare for the receiving party. Fines for traffic offences are an example of transfers between road users and the government.

The effects of a measure are understood as any change in social welfare (positive or negative) that is the result of that measure (intended or not). Road safety measures can produce three kinds of effects: safety, mobility, and environmental.

The aim of the measure is to decrease the damage caused by road accidents. Therefore the effects to take into account first are the safety effects: (the change of) the number of fatalities, seriously injured, slightly injured and possibly the damage to vehicles and fixed roadside objects. For practical reasons only the effect on the number of fatalities and fatal accidents will be considered in this review. As will be explained below, in most cases the change in fatal accidents can be used as a proxy for a change in all accidents. As a consequence it will not be necessary to separately value the change of injuries and damage to vehicles.

Many road safety measures also affect the amount and/or speed of travel. In theory these mobility effects can be caused by any measure that increases the cost of travel, as in the case of daytime running lights. The additional costs of these measures, however, are invisible and low in relation to the operational costs and purchase price of vehicles. Hence their mobility effects will be ignored.

Drink driving control primarily intends to prevent people from drinking more than the permitted amount of alcohol before driving, and not to prevent them from driving after drinking over the limit. If this aim is achieved, mobility will not be affected. Some people, however, will feel forced to choose another place to drink or another transport mode. This implies some minor losses of mobility benefits which will be ignored in this CBA. Moreover, one could argue that a loss of mobility benefits that have been acquired illegally (driving over the BAC limit) should not be considered as a social loss.

An increase in the use of fuel as arises with DRL will affect the environment because emissions of exhaust gases rise. These environmental effects should also be taken into account.

1.1.3 Estimation and valuation method of costs and effects

All costs and effects are valued at the price level 2000 and exclude VAT; price data from previous years are corrected for an inflation-rate of 1.7 % per year. Future effects and implementation costs (e.g. maintenance and additional fuel costs) are discounted against a rate of 5% per year (EC, 2002).

The safety effects will be expressed in the number of fatalities while environmental effects will be stated as a certain proportion of the total costs of pollution by road transport in the relevant EU-countries (CEC, 1995).

A fatality saved will be valued according to the improved “1 million Euro rule”. This rule was introduced by the European Commission in 1997. The monetary value includes not only the prevented costs of the fatality itself, but also of a proportional share of injuries and vehicle damage; the prevented immaterial damage from death and injury (pain, grief, suffering, etc) is excluded[1]. The value of 1 million Euro is calculated on the basis of data for 1995. Two improvements were introduced to the “1 million Euro rule”: the first, made by an ETSC working party (ETSC, 1997b), consisted in adding the damage of the non-reported accidents and a value of the prevented immaterial damage; the second (see Appendix 1) constituted updating the value to the price level of 2000, for the purpose of which a weighed correction factor of 13.3% was calculated on the basis of the consumer price index and the gross domestic product index (Elvik, 2002). The first improvement led to a result of 3.6 million Euro per fatality saved, the second to an amount of 4.050 million Euro.

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1 The calculation includes values for serious and slight casualties based on the rations of fatal : serious : slight of 1: 11 : 66 (see also Appendix 1).

1.2 DAYTIME RUNNING LIGHTS (DRL)

This countermeasure is to be understood as a legal obligation for all motor vehicles in the 15 EU-countries to driving with low beam headlights and (but more as an exception) with special DRL lamps. For the calculation, Sweden, Finland and Denmark are excluded (in the number of fatalities as well as in the number of vehicles) because these countries already require compulsory use of DRL.

Besides these, in some other EU-countries such as Austria, the Netherlands, and Germany a lot of road users (cars, vans, and trucks) use DRL on a voluntary basis. Since the exact number of people doing so is unknown, it is assumed that DRL usage is on average 10% in the other 12 remaining EU countries. Motorcycles and mopeds are included in this CBA, but for the latter Sweden, Finland and Denmark are also excluded

Passenger cars and trucks
For the calculation it is assumed that an automatic light switch is installed in new vehicles from 1 January 2000 onwards. This means that in all older vehicles, the low beam headlights have to be switched on manually with the exception of those having been equipped with an automatic switch through retrofitting. It is assumed that 15% of the owners of existing vehicles decide to install an automatic light switch for reasons of convenience (to avoid forgetting to switch the lamps on and off) leaving 85% having to do so manually.

The installation of *special DRL lamps* in new vehicles (according to ECE-regulation n. 87) can be seen as a change in a car's front design, allowing the conclusion that for C/B calculation only the costs of an automatic light switch need to be taken into account. Furthermore, the installation of DRL lamps in existing vehicles has to be seen as a marginal phenomenon which can be neglected for the C/B calculation.

It also needs to be noted that fitting special DRL lamps would have the advantage of consuming about 38% less fuel than would be required were low beam headlamps be utilised, therefore also leading to lower levels of pollution. This comes as a result of special DRL using less power (2 * 21 W instead of 2 * 55 W). For this type of lamps an extra calculation has been made and the results have been added to the final outcome (the cost/benefit ratio).

Motorcycles and mopeds
Another aspect needing consideration is the use of DRL on motorcycles and mopeds. Here, two aspects are of importance: the current use of DRL and how this affects the calculation of the costs of full use of DRL, and the actual conspicuity of motorised two-wheelers with the current state-of-play.

Concerning the former, current use of DRL, different EU countries already require compulsory use of DRL for motorcycles and, in addition to this, voluntary use is high. Exact figures for the EU countries are missing, but it is fair to say that at least 50% of motorcyclists ride with DRL. The costs for 100% DRL use had to be calculated with the exception of those member states where this is already mandatory: Sweden, Finland and Denmark. As riders of mopeds hardly use DRL, full costs had to be calculated for this category.

Regarding the latter, organisations of motorcycle riders such as the FEMA have objections against the compulsory DRL measure. They see a risk of the conspicuity of motorcycles already using DRL now being reduced by a mandatory introduction of DRL for all motor vehicles. However, empirical evidence is not clear about this. On the one hand there is arguably the effect of diminishing the perception of motorcycles which may result in more multiparty daytime accidents involving motorcyclists. But on the other hand, the perception of cars by motorcyclists may be improved by an increase of DRL use by other motor vehicles. This may reduce the number of multiparty daytime accidents involving motorcyclists. It is assumed that both effects balance each other, and that no changed DRL effect for motorcyclists can be expected (Koornstra et al, 1997).

For mopeds the situation is different. In the calculation of the effect of mandatory introduction of DRL (see Par. 1.2.1) mopeds were not considered as a different group to motor vehicles since it is based on mopeds not using DRL. The assumption made sees mopeds using DRL as a positive outcome for road safety. However, the actual magnitude of this effect is unknown, but, due to the small share of mopeds relative to all motor vehicles, this carries less weight. Hence, for the calculation of the benefits of DRL, mopeds are not taken into account.

1.2.1 Benefits

The safety effects of this measure will show during the whole lifetime of the DRL-automatic switch in cars, which is assumed to stretch over a period of 12 years. The fatality reduction over this whole period will be valued according to the (improved) 1 million Euro rule.

Two main meta-analyses of studies on the effects of DRL on cars have been carried out. Whilst the first, a study by SWOV (Koornstra et al., 1997), looks at safety effects as well as economic costs and benefits, the second, a study by TOI (Elvik, 1996), only considers the former.

The TOI-study concluded that the introduction of DRL would lead to a reduction in *the number of multiparty daytime accidents* of between 10 to 15%, the SWOV-study found a reduction of 12.4%. The latter found furthermore that the amount of *injured persons* decreased by 20%. The fact that the DRL-effect on casualties is higher than on multiparty daytime accidents can only be explained by lower collision speeds in near accidents involving DRL-using motor vehicles. Based on this explanation, the effect on fatalities should be higher than on casualties. Although the SWOV-study does reach this conclusion (with a 24.6% reduction), the present ETSC-study takes a more conservative approach by assuming the effect of DRL on fatalities to be 20%.

In the TOI- as well as in the SWOV-study, the reductions found are the intrinsic safety effect of DRL: this is the effect of a change in DRL use by motor vehicles from 0% to 100%. The observed effects of DRL will therefore differ from the intrinsic effect when DRL usage is not 0% at the start and/or not 100% at the end of the observation. In the case of the calculation for the EU countries, all countries are excluded with a full use of DRL nowadays. In both studies, countries with a voluntary use of DRL are excluded due to the absence of data on the average use of DRL during the whole year. As already stated, in this study a voluntary average use of 10% is assumed for the EU countries without compulsory DRL. Furthermore, it is assumed that the obligation will result in 90% use of DRL.

1.2.2 Specifications of benefits

The total number of fatalities in EU-countries is known, but regarding DRL only the fatalities which can be prevented in daytime are relevant. Different studies of countries involved in the meta-analysis of the SWOV study contain a differentiation of fatalities in single daytime, multiparty daytime, single night time, and multiparty night time. Based on these figures it is assumed that about 50% of the total number of fatalities occur in multiparty daytime accidents. However, after the publication of the SWOV report in 1997, additional German and French data was obtained. For Germany, 38% of the total number of fatalities occur in multiparty daytime accidents. The French data is less clear, but a rough calculation shows this proportion to lie at about one third. Since France and Germany account for about 40% of all EU-fatalities, the SWOV report was revised in this aspect with the remark that these 40% are a conservative estimation (see Erratum in the SWOV report; Koornstra et al, 1997).

After this correction, new information was obtained from the Southern member states, Spain and Italy. The data showed that in these countries more fatalities arise in night time than in daytime accidents, all of which suggested that an overall percentage of 40% might be plausible for the EU (a more conservative estimate seems out of the question). Hence for the present ETSC study it is estimated that 40% of the total EU-fatalities occur in DRL-relevant accidents.

The number of road accident fatalities in EU countries (excluding Denmark, Finland and Sweden) is 39,265 (IRTAD; figures for 2000 only constitute best guesses for countries without recent data). Taking into account an average 90%-use of DRL in the remaining member states, this number should be reduced by 10%, which was done in the calculation of the "Reduction of fatalities".

1.2.3 Costs

There are different costs for using DRL. The breakdown of these is:

- The costs of automatic light switches: all new cars and 15% of the existing car fleet. It is assumed that all switches have a technical lifetime similar to that of a car. Furthermore, it is assumed that each year 8% of the existing car-fleet is replaced by new cars. The same is assumed for vans, trucks and motorcycles. It is assumed that the automatic light switches will not be installed in mopeds.
- Maintenance and repair costs of automatic light switches during lifetime.
- Fuel costs owing to switching on low beams during the daytime.
- Additional replacement costs of bulbs related to the wear and tear of the bulbs during daytime.
- Environmental effects.

Since all these costs are small and invisible and will be paid by the vehicle owners, it is assumed that they do not affect mobility.

1.2.4 Specifications of costs

Number of vehicles in EU countries and their kilometres (IRTAD)

- Number of cars: 170.9 million (excluding Denmark, Finland and Sweden), with an average of 14,317 km per car per year: total 2,450 billion km per year.
- Number of vans and trucks: 24.0 million (excluding Denmark, Finland and Sweden), with an average of 50,000 km per vehicle per year: total 1,200 billion km per year.
- Number of motorcycles: 11.9 million (excluding Denmark, Finland and Sweden), with an average of 5,500 km per motorcycle per year: total 65 billion km per year.
- Number of mopeds: 14.4 million with an average of 2,300 km per moped per year: total 33 billion km per year.

Source: year 2000; IRTAD with best guesses for countries without (recent) data.

Automatic light switches
The price for a switch in a new vehicle is estimated at € 5. The price of retrofitting amounts to approximately € 50 including installation costs per vehicle.

Maintenance and repair costs of automatic light switches
During its lifetime the costs per vehicle are estimated at € 15.

Additional fuel costs due to DRL
In most of the calculations of extra fuel consumption due to the use of DRL, a percentage of 1 or 2% of the total amount of fuel consumption is used, related to the average fuel consumption of cars and trucks. However, due to the large differences in fuel consumption by for example cars and trucks, this method is unsatisfactory. As the extra DRL fuel consumption is independent of the standard fuel consumption of vehicles, it is better to use the time that a vehicle participates in traffic.

Following the BASt-method for the calculation of extra fuel consumption due to the use of DRL, the following data is relevant (Pullwitt & Morian, 1997):

- specific fuel energy adjusted for the losses due to thermal inefficiency of an engine: 250 g /kWh; the density of fuel is 0.75 kg/l, so the specific fuel energy is 0.33 l/kWh.
- performance of a generator: 50%
- bulb capacity:
  - cars: 150 W
  - vans: 150 W
  - trucks: 250 W
  - motorcycles: 75 W
  - mopeds: 50 W

With this data, the extra fuel consumption by DRL is thus:
- cars and vans: 0.1 l/h (calculation: 0.33 l/kWh * 0.150 kW / 50%)
- trucks: 0.17 l/h (calculation: 0.33 l/kWh * 0.250 kW / 50%)

→ weighted average vans and trucks: 0.12 l/h.
- motorcycles: 0.05 l/h (calculation: 0.33 l/kWh * 0.075 kW / 50%)

- mopeds: 0.03 l/h (calculation: 0.33 l/kWh * 0.050 kW / 50%)

With the values calculated for cars, vans and trucks, the fuel consumption during the time DRL are being used is 3% for a car with a standard fuel consumption of 6.7 l/100 km (1:15) and 1.2% for a van or truck with a standard fuel consumption of 20 l/100 km (1:5).

The value of 0.1 l/h for cars means that fuel consumption for DRL is 0.1 l if the vehicle is driving one hour in traffic. During this time the distance travelled is 50 km on average for all types of roads. If the annual number of motor vehicle kilometres is known and this number is divided by 50 km, it is possible to determine the total number of hours travelled during daytime and night time. 55% of the travel in terms of distance occurs during daytime (Koornstra et al, 1997).

For motorcycles the average driven kilometres per hour in traffic is the same as for cars. For mopeds a distance of 30 km can be assumed. For motorcycles and mopeds the number of hours travelled during daytime compared to that travelled at night is higher than for cars. Figures are missing, but a division of 85% - 15% (day – night) seems adequate.

Correction of twice 10% for cars, vans and trucks
A correction of 20% of the costs has to be made. Above it was assumed that 10% of car users already utilise DRL on a voluntary basis (EU member states without Denmark, Finland and Sweden). The other correction of 10% deals with the assumption of 90% use after the obligation. The value for both these corrections in the calculation is thus 0.8 (80%).

Correction for motorcycles of 50%
It was assumed that 50% of motorcyclists already use DRL on a voluntary basis (EU member states without Denmark, Finland and Sweden). Hence, under the assumption that 100% of motorcycle riders will use DRL for their own safety, the value for the corrections in the calculation is the 0.5 (50%).

Correction for mopeds of 50%
The willingness of moped riders to use DRL is assumed to be relatively low, at around 50%. The value for correction is thus 0.5 (50%).

<u>Calculation for cars</u>
The yearly DRL-fuel consumption is:

2,450 billion km / 50 km * 80% * 55% * 0.1 l = 2.15 billion litres

With an average fuel price per litre in EU countries of € 0.32 (excluding tax and VAT), the fuel costs for DRL for cars are € 0.69 billion.

<u>Calculation for vans and trucks</u>
The DRL-fuel consumption is:
1,200 billion km / 50 km * 80% * 55% * 0.12 l = 1.3 billion litres

Given a fuel price (gas oil) of € 0.24 per litre (excluding tax and VAT), the fuel costs for DRL for vans and trucks are € 0.31 billion.

Calculation for motorcycles
The yearly DRL-fuel consumption is:

65 billion km / 50 km * 50% * 85% * 0.05 l = 28 million litres

With an average fuel price per litre in EU countries of € 0.32, the fuel costs for DRL for motorcycles are € 9.0 million.

Calculation for mopeds
The yearly DRL-fuel consumption is:

33 billion km / 30 km * 50% * 85% * 0.03 l = 14 million litres

With an average fuel price per litre in EU countries of € 0.32, the fuel costs for DRL for mopeds amount to € 4.5 million.

Additional costs as a result of the wear of the bulbs during daytime use
The replacement rate for bulbs increases by a factor of 2 due to DRL. The additional bulb costs are € 6 per car per year (Koornstra et al, 1997). Here, a correction of 0.8 for the whole vehicle park is needed as well. Hence, it is assumed that for motorcycles and mopeds an additional € 2 per year have to be paid.

Environmental effects
The costs of pollution arising as a result of fuel emissions in road transport in the EU are estimated to amount to € 20 billion per year (CEC, 1995). Although the annual number of motor vehicle kilometres has increased since the time of this estimation, the fact that cars having come onto the market since then cause less pollution is assumed to offset this. Thus, in our base year 2000, the total costs of pollution are assumed to remain the same (€ 20 billion per year).

The additional contribution due to DRL-use for all vehicles (cars, vans and trucks) is about 1.0%[2] of these total costs and results in expenses of € 0.20 billion per year.

1.2.5 Results

Results for DRL with standard low beam headlights (2 * 55W)

Reduction of fatalities
The reduction of fatalities is calculated as follows:

the number of fatalities * the average 90%-use of DRL * the 40% of the DRL-relevant accidents * the 20%-effect of DRL for fatalities.

The reduction in figures:

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2 The weighted average DRL-fuel consumption for all vehicles (varying from approximately 3% to 1%) multiplied with 0.55 for DRL-use during daytime (=approximately 2.3 * 0.55 * 0.8 = approximately 1.0%).

39,265 * 0.90 * 0.40 * 0.20 = 2,827 fatalities (for one year)

Present Value Fatalities

PV death * Value death = 25,057 * € 4.05 million = € 101 billion (over 12 years)

Present Value Costs
€ 23 billion (over 12 years)

Cost/benefit ratio
1 : 4.4

Net Present Value
€ 79 billion over 12 years (as average € 6.5 billion per year).

<u>Results for DRL with the special DR-lamps (2 * 21W)</u>

Reduction of fatalities
The same

Present Value Fatalities
The same

Present Value Costs
€ 16 billion (over 12 years)

Cost/benefit ratio
1 : 6.4

Net Present Value
€ 86 billion over 12 years (as average € 7 billion per year).

1.2.6 Conclusion

The introduction of DRL in European countries could lead to an annual reduction of 2,800 fatalities. The calculation of the cost/benefit ratio also leads to a favourable result: the costs of DRL are considerably lower than the benefits (value 1 : 4.4). Furthermore, the cost/benefit ratio could be even more favourable if special DR-lamps equipped with economical bulbs were installed, in which case it would increase to 1 : 6.4.

1.3 RANDOM BREATH TESTING: BEST PRACTICE GUIDELINES

This measure is to be understood as a set of "best practice" guidelines for the responsible police authorities in EU member states.

Such guidelines should aim at substantially and permanently increasing the current level of enforcement in the area of drink-driving. Furthermore, they should promote particular enforcement strategies that have proven to be effective.

Numerous studies have been undertaken on the effectiveness of various methods of law enforcement that prevent driving over a certain BAC limit. The results have been reviewed recently in EU projects (Gadget and Escape) and by an ETSC Working Party (ETSC, 1999). These reviews have shown that random breath testing (RBT) is a very effective instrument to deter drivers from drink-driving, hence improving road safety. It should thus be integrated into a strategy that aims at reaching a high probability of being stopped and tested by exposing a large number of road users to unpredictable, well publicised, and highly visible road side checks. RBT is not the only instrument to control drink-driving; other instruments will be dealt with in the concluding paragraph of this section.

Evaluation studies of RBT do not always look at the type and amount of sanctions inflicted on offenders and they seldom control these. Therefore, this variable will be disregarded. In general, however, it is known that punishment is a necessary precondition for deterrence, but that the type and severity of sanctions add little to the (general) deterrence effect of enforcement.

This Cost Benefit Analysis assumes that the guidelines for the police are effective and indeed create the intended amount, duration, and type of enforcement and publicity. It is assumed that all legal conditions are met: a legal BAC limit and the authority for RBT by the police.

In fact, all EU members do have legal BAC limits, mostly of 0.5 mg/ml. Exceptions are the UK, Ireland and Luxembourg (with 0.8 mg/ml) and Sweden (with 0.2 mg/ml). These differences will be neglected.

In most EU countries the police are entitled to use the instrument of RBT, with the exception of Germany, the UK, and Ireland. It is assumed that in practice the police in these last three countries are able to take breath tests from drivers that are selected from traffic not altogether randomly.

For a C/B analysis at EU level of increased enforcement of this type, it is necessary to use quantified data clarifying:

- the baseline situation: the current number of drivers over the limit, the current number of fatalities over the limit and the current number of screening tests;
- the new measure: the increased number of screening tests and their costs;
- the impact of this measure: the decreased number of drivers over the limit and of fatalities.

Little data is available on the baseline situation and it is often of limited quality. We will try to estimate the situation in an "average" EU country. The reviews of the evaluation studies into RBT provide little information on the specific conditions of the experiments (the baseline situation) and on the exact (change of) enforcement level; data on costs are practically non-existent. We will make a "best estimate" of the enforcement level and its impact.

1.3.1 Baseline situation

The number of *fatalities over the limit* is under-reported in the accident registration of all EU countries, and in each country to an unknown, but probably different, extent. A questionnaire by the High Level Working Group on Alcohol, Drugs and Medicines revealed figures for the year 1996 that varied between 8 % (Netherlands) and 35% (France) (Wilding, 2000).

A study by Stewart et al. (undated) did present an international comparison of *alcohol involvement in fatal crashes* showing figures for amongst others nine EU countries between 3% (Sweden) and 41% (France and Spain).

Another recent comparative study in Sweden, the United Kingdom and the Netherlands (the EU Sunflower project) outlined the share of fatal accidents with a driver over the limit and the share of driver fatalities over 1.0 mg/ml (table 1). These figures are estimates that correct for under-reporting and refer to the year 2000 (Koornstra et al., 2003).

	S (%)	UK (%)	NL (%)
Fatal accidents with driver over the legal limit	10	14	13
Driver fatalities with BAC > 1.0 mg/ml	14	20	17

Table 1: Alcohol involvement in fatal accidents and fatalities in 3 countries, in 2000 (percentage of all fatal accidents and percentage of all driver fatalities, respectively).

The shares of alcohol-related fatal accidents are difficult to compare with the standard data from countries because of the variety of legal BAC limits (Sweden 0.2; UK 0.8; Netherlands 0.5 mg/ml). Taking the standardised data of the offenders given by Table 1 (Driver fatalities with BAC > 1.0 mg/ml) the shares of alcohol-related driver fatalities can be compared better. It is plausible to assume that the differences between the countries are to a large extent explained by the level of *drink-driving*. On this subject even less data is available. The final report of the Escape project gives the details of RBT programmes in three Scandinavian countries (Finland, Sweden, Norway) that produced less than 1% of offenders. In the Netherlands roadside surveys during weekend nights found 4.5% of offenders. Another Dutch study (a case-control study in the Tilburg region) showed 1.5% of offenders during the whole week and year (Mathijssen et al., 2002). Results from RBT programmes in other European countries show 1-30% of offenders (Mäkinen & Zaidel, 2002). For several reasons these figures are difficult to compare (selection procedure of drivers, time of day, day of week, screening device).

The final report of the Escape project concludes that for the EU as a whole, a rough average of about 3% of journeys are associated with an illegal BAC, but about 30% of injured drivers are under the influence of alcohol. However, the estimates of respectively 3% and 30% can be questioned. Scandinavian figures that demonstrate less then 1%

drink-drivers can be taken as an indication of the lowest level of drink-driving in the EU. The Netherlands can be considered as an example of an average level of drink-driving, showing 1.5% of offenders. A third group of countries will have a higher level of about 3% of drink-drivers. For the EU as a whole, 2% could thus be seen as a rough average as well.

A proportion of 30% of injured drivers resulting from 3% of drink-drivers is a rather conservative estimate. The only European case-study on the risk of alcohol in traffic has recently shown much higher risks (Mathijssen et al., 2002): about 1.5% of drivers over the legal limit of 0.5 mg/ml were associated with about 25% of the seriously injured drivers. 2% drink-drivers will undoubtedly result in much more injured drivers than 25%, and even more fatally injured drivers (it is a well established fact that the proportion of alcohol fatalities is higher than that of alcohol injuries). It is thus estimated here that from the EU average of 2% drink-drivers, about 40% of the driver fatalities will result.

Estimations of the number of *screening tests* per year have been collected by Zaidel for the Gadget-project and cited also in his Working Paper on the Escape project (Zaidel, 2001); Koornstra et al. (2003) collected data for the Sunflower-project (see table 2).

Country	**Screening tests (x 1,000)**	**Inhabitants (x 1,000,000)**	**Tests per inhabitant**	**Year**	**Source**
Austria	100	8.0	1 in 80	1998?	Zaidel
Finland	1,400	5.1	1 in 4	1998?	Zaidel
France	7,200	58.0	1 in 8	1998?	Zaidel
Greece	260	10.7	1 in 40	1998?	Zaidel
Ireland	17	3.7	1 in 220	1998?	Zaidel
Netherlands	1,000	16.1	1 in 16	2000	Koornstra
Spain	1,400	39.4	1 in 30	1998?	Zaidel
Sweden	1,000	8.9	1 in 9	2000	Koornstra
UK	900	60.1	1 in 67	2000	Koornstra
Total	13,277	210	1 in 16		

Table 2: Yearly number of screening tests per inhabitant in EU countries, 1998-2000.

Which part of these tests is taken from randomly selected drivers is unknown. It is certain that the share of selective tests (taken from drivers who were suspected of drink-driving beforehand, or who were involved in accidents) is quite substantial. This applies especially to countries where the police are not entitled to use the instrument of RBT (Germany, Ireland, UK). For the Netherlands it is estimated that about 70% of tests are taken randomly (Mathijssen, 2003). Yet for practical reasons it is assumed that all screening tests in table 2 are taken randomly.

Although these figures are of limited quality, it is evident that the probability of being tested varies a lot between the countries. Roughly two groups can be distinguished: the first, with a high level of enforcement encompasses Finland, France, the Netherlands, and Sweden with a total of 88.1 million inhabitants and an average of 1 test per 8 inhabitants; the second, with a low enforcement level contains the other five countries totalling 121.9 million inhabitants and an average of 1 test per 50 inhabitants. The overall average (1 in 16 inhabitants) will be used as a rough estimate for the whole EU. It is assumed that this average is not affected by the six missing countries (Belgium, Denmark, Germany, Italy, Luxembourg, and Portugal) that account for about 170 million inhabitants. Furthermore, it is assumed that, as in the other nine member states, 42% of the inhabitants, i.e. 71 million people, are exposed to a high enforcement level (on average 1 test per 8 inhabitants) and the remaining 99 million people to a low enforcement level (1 test per 50 inhabitants).

Conclusion
For the purpose of this CBA, two alternative sets of assumptions are made. The first is that 3% of all journeys in the EU are made by drivers exceeding the legal BAC limit and that 30% of driver fatalities are over the legal limit. The second sets out that 2% of drink-drivers are associated with 40% of the driver fatalities. Furthermore, it is assumed that the current probability of being breath-tested in the EU is on average of 1 in 16 inhabitants.

1.3.2 Increased enforcement and its target group

Priority will be given to increasing the frequency of breath testing in the countries that belong to the group of 'low frequency testers', where currently 1 in 50 inhabitants are tested. It is proposed to triple this rate so as to reach an average in each of these countries of 1 test per 16 inhabitants. It is assumed that the other countries (the 'high frequency testers') maintain their current level of enforcement, which is at least 1 test per 16 inhabitants (and on average 1 in 8).

This approach is chosen for several reasons, outlined in the final report of the Escape-project. Research has indicated that changes in behaviour, and sometimes accident reductions, are achieved when the intensity of enforcement is increased by at least a factor of three. However, since at the same time, the marginal effect of increasing enforcement is gradually declining, it could prove to be more efficient to concentrate efforts on areas with a lower baseline level of enforcement. This argument is strengthened by the fact that the costs of tripling the enforcement intensity are higher when the baseline is higher.

Below, the number of additional tests required to reach an enforcement level of 1 in 16 inhabitants is estimated for each of the badly performing member states (average rate of 1 in 50). The figures are summarised in Table 3.

	Inhabitants (x million)	**Fatalities**	**Current tests (x1,000)**	**Extra tests (x1,000)**	**Total tests (x1,000)**
Countries with registered frequency (A, E, GR, IRL, UK)	121.8	12,746	2,677	4,936	7,613

Areas with estimated frequency (58 or 56% in B, D, DK, I, L, P)	98.8	9,920	1,976	4,199	6,175
Total		22,666	4,653	9,135	13,788

Table 3: Estimated numbers of screening tests and fatalities in countries with a low enforcement level, 2000.

In paragraph 1.3.1 reference was made to 9 EU countries with known RBT-frequencies. For the group of five countries with known (low) test frequencies (Austria, Spain, Greece, Ireland and the UK), encompassing 121.8 million inhabitants, 2,677 million breath tests are taken a year (1 in 50 inhabitants). Increasing this frequency to 1 in 16 requires an additional 4,936 million tests which brings the total to 7,613 million tests.

For the six remaining EU countries (Belgium, Germany, Denmark, Italy, Luxembourg and Portugal) the test frequencies are not known. It is assumed that of the 170 million people living in these countries the same proportion is exposed to a low test rate of 1 in 50 as in the group of nine countries with known RBT frequencies (i.e. 122/210 or 58%). From this follows that, in this group of six, another 1,976 million tests are currently taken from 98.8 million inhabitants. Increasing this rate to 1 in 16 would require an additional 4,199 million tests, to bring the total to 6,175 million.

Thus, in the whole low frequency area, an increase of 9.135 million tests in addition to the current number of 4,653 million would be required to reach the desired level of 13,788 million.

According to the same principles an estimation has been made of the number of fatalities in the low test frequency areas in 2000. For the group of five countries with known low RBT frequencies the number of road accident fatalities amounts to 12,746, 56% of the total of all nine countries with registered RBT figures. For the low test frequency areas with unknown RBT figures, the number of road accident fatalities is estimated at 9,920 (56% of the registered number in these countries). This makes a total of 22,666 road accident fatalities. The figures are also presented in Table 3.

Following the assumption that 30% of road accident fatalities are alcohol related this would imply that 6,800 road deaths are the result of a BAC above the legal limit. If one chooses the alternative assumption of 40% of road deaths being alcohol related this figure would increase to 9,066.

1.3.3 Safety effects

In an Escape Working Paper Rune Elvik (2001) has carried out a meta-analysis of 26 evaluation studies on drink-driving law enforcement (enforcement alone or in combination with another measure, most often an accompanying campaign). The best estimated outcome was a percentage change in the number of all *fatal accidents* of 9% (with a 95% confidence interval ranging from -11 to -6%). The precise increase in enforcement was not mentioned.

The author provides additional details when submitting the results of the meta-analysis to a cost-benefit analysis of traffic police enforcement in Norway. He states that, in general, the results of the evaluation studies used in the meta-analysis refer to substantial increases in the amount of enforcement, often by a factor of 5 to 10. Elvik also elaborates the declining marginal effects of successive increases in enforcement, reaching the following conclusions: an increase of RBT by a factor of 2 would yield 20% of the theoretically possible maximum potential benefits (a complete elimination of drink-driving); an increase by a factor of 3 would yield 30% of these maximum benefits; a factor of 6 would yield 45% and a factor of 10 would yield 60%. The author assumed these positive effects to be concurrent with the actual enforcement activity. They thus would not persist after enforcement has ceased.

So, according to Elvik's approach for Norway, the tripling of the enforcement level in the areas with low frequency RBT would reduce the number of *alcohol related fatalities* by 30%, for as long as the enforcement lasts.

A Dutch study, carried out in 1988/89, not comprised in the above mentioned meta-analysis, reached a similar conclusion. In an experiment in the city of Leiden, random breath testing was doubled. As a result, the number of offenders decreased from 8.1 to 6.0%, a reduction of 25% (Mathijssen, 1991). This is slightly more than the 20% reduction that is assumed by Elvik with an RBT increase by a factor of 2.

Based on the above data, various estimates of the reduction of fatalities resulting from extra RBT in areas with low enforcement levels have been made. The results are presented in table 4.

Fatalities (1)	**Alcohol related fatalities (2)**		**Effects of extra RBT**		
	proportion (%)	Numbers	3x increase	3x increase	2x increase
			30% decrease of (2)	9% decrease of (1), with range	25% decrease of (2)
22,666	30	6,800	2,040	2,040 (1,360- 2,493)	1,700
22,666	40	9,066	2,720	2,040 (1,360- 2,493)	2,267

Table 4: Annual reduction of fatalities resulting from increased RBT-frequency in areas with low enforcement level, 2000.

Conclusion

Table 4 shows that a tripling of the enforcement level leads to a minimum reduction of fatalities of 2,040 per year (under the assumption that 30% of road accident deaths are alcohol related) and a maximum of 2,500[3] less fatalities per year (under the assumption that 40% of road accident deaths are alcohol related).

1.3.4 Benefits and costs

The benefits and costs will be calculated on the basis of two sets of assumptions:

3 This figure is deduced from the two estimations presented in Table 4: 2,720 and the range 1,360 – 2,493.

(I) 3% drink-drivers and 30% alcohol related fatalities;
(II) 2% drink-drivers and 40% alcohol related fatalities.

Benefits
(I) A reduction of 2,040 fatalities on an annual basis, valued at 8,262 million Euro (applying the improved 1 million Euro test at a value of 4.050 million Euro per death).
(II) A reduction of 2,500 fatalities on an annual basis, valued at 10,125 million Euro.

Costs

Costs of police at the road-side
A number of 9,135 million random breath tests will be taken annually in addition to the current number of 4,653 million tests.
In one person-year, 180 days can be spent on road side testing, included travelling
(in addition, 60 working days are available for training, sickness, planning, and other organisational activities)
In one person-year, 16,200 tests can be conducted {180 (days/year) * 6 (hours/day) * 15 (tests/hour) = 16,200 tests}.
Thus, for 9,135 million extra tests, 564 person-years are needed.
The personnel costs (including overhead) are estimated at 100,000 Euro per person-year:
- salary for employee 25,000 Euro
- salary for employer 50,000 Euro
- overhead (housing, vehicles, support staff, management) 100%
Thus, 564 person-years cost 56.4 million Euro per year.

Breath testing equipment costs
To conduct 16,200 breath tests one needs 1 device costing 750 Euro and 20,000 mouthpieces costing 0.25 Euro, in total 5,750 Euro.
Costs of 9,135 million breath tests: 3,243 million Euro (564 x 5,750 Euro).

Costs of publicity
Publicity has been proven to be an essential element of RBT (Elvik, 2001). Part of it will be free publicity: articles and police communications in newspapers about forthcoming roadblocks and about the results of performed actions. Another part will be commercial publicity campaigns. If the low enforcement areas comprise 9 countries and a publicity campaign costs 2 million Euro per country, the costs of publicity amount to 18 million Euro.

Costs of administration of justice
The additional testing will produce extra offenders who will (have to) be prosecuted and sentenced. This means extra work for the prosecution and (in some cases) for courts. However, this extra workload will be tempered because of the general deterrent effect of the tripled RBT. For our two sets of assumptions the following cost estimations can be made:

(I) If 3% of the drivers are over the permitted BAC limit, and currently 4,653 million tests are carried out, then 140,000 offenders are being detected. Because of the additional RBT, the number of drink-drivers will decrease by 30% to 2.1 % of all drivers. In future, 13,788 million tests will be taken, detecting 290,000 offenders, thus an increase of 150,000. The costs of administration of justice are estimated at 1,000 Euro per offender, so 150,000 extra offenders cost 150 Million Euro per year.

(II) If 2% of the drivers exceed the allowed BAC limit, and currently 4,653 million tests are taken, then 93,000 offenders are being detected. Because of the additional RBT, the number of drink-drivers will decrease by 27.5% to 1.45% of all drivers. In future 13,788 million tests will be taken and 200,000 offenders will be detected, thus 107,000 extra. The costs of administration being estimated at 1,000 Euro per offender means that 107,000 extra offenders cost 107 million Euro per year. The benefits and costs under each of the two assumptions (I and II) are summarised in table 5.

Benefits	**Assumption I**	**Assumption II**	**Costs**	**Assumption I**	**Assumption II**
Value of less fatalities	8,262	10,125	Police personnel	56.4	56.4
			Equipment	3.2	3.2
			Publicity	18	18
			administration of justice	150	107
total	8,262	10,125	Total	227.6	184.6
B-C	8,034	9,940			
Cost : Benefit Ratio	1 : 36	1 : 55			

Table 5: Benefits and costs of increased enforcement per year (million Euro).

1.3.5 Conclusion

Increasing RBT to a frequency of 1 test per 16 inhabitants for the whole EU will improve road safety considerably (annually 2,000 – 2,500 fatalities) and in a very cost-effective way. However, this only constitutes the first step of an effective policy against drink-driving. There is plenty of space for a further increase of RBT. Part of the current testing is not done randomly and could be transformed into RBT without additional costs. But the frequency of 1 in 16 can also be increased considerably. Testing frequencies of up to 1 test per 3 inhabitants may appear out of bounds at present, but they have been brought into practice in Australia where they have proven to be effective and efficient.

One should realise, however, that this policy will not lead to the elimination of the hard core of the problem: drivers with high BAC (over 1.3 mg/ml). They constitute a very small proportion of the drink-driving population, but are responsible for a very large proportion of alcohol related fatalities, especially when they combine the consumption of alcohol with illicit drug use. From the Dutch case study it is estimated that less than 0.5% of the driving population can be associated with more than 20% of serious road injuries (Mathijssen, 2002).

To detect the combined use of alcohol and illicit drugs, blood samples should be taken. In practice this could take the form of bringing all drivers with a BAC of over 1.3 mg/ml to a police station to take a blood sample. A major part of the drivers with these high BAC is probably addicted to alcohol and perhaps also to illicit drugs. The policy of general deterrence by the use of RBT thus will not work for this group, rendering it necessary to treat their addiction problems. In various countries, effective treatment methods are being applied or are under development.

1.4 AUDIBLE SEAT BELT REMINDERS

An audible seat belt reminder is a device that gives a sound warning whenever a seat is occupied, but the seat belt is not fastened. This review refers to seat belt reminders in the front seats of cars. A simple continuous reminder will be assumed. This is a device that gives a warning as long as the seat belt is not worn, but it is not designed with an ignition interlock function.

According to a study by the Swedish Road and Transport Research Institute (Larsson and Nilsson 2000), the cost of a continuous seat belt reminder for the front seats in a car is SEK 500. This corresponds to about 60 Euro at 2000 prices, adjusted to average purchasing power parity for the Euro-area.

Larsson and Nilsson estimate that an audible seat belt reminder for the front seats can raise seat belt wearing among front seat occupants to 97%. The same assumption will be made in this analysis. Data on current seat belt wearing rates in the European Union are incomplete. Wearing rates have been estimated on the basis of a previous ETSC research review (ETSC 1996a) and a recent OECD report on road safety management and implementation strategies (OECD 2000). Table 6 summarises the assumptions that have been made regarding seat belt wearing rates.

Each country has been given a weight, used to compute the average wearing rate for seat belts for the whole European Union. The weight given to each country is proportional to the number of passenger cars registered in that country. The weights sum to 1. The weighted mean wearing rate for seat belts in the European Union is 76% for front seat occupants and 46% for rear seat occupants. The wearing rate for front seat occupants can be increased to 97% if all cars have audible seat belt reminders.

Country	Wearing rate, front seats (%)	Wearing rate, rear seats (%)	Relative weight for EU-average
Austria	70	35	0.023
Belgium	55	25	0.026
Denmark	70	33	0.010
Finland	87	66	0.012
France	85	45	0.155
Germany	95	75	0.242
Greece	45	9	0.018
Ireland	53	10	0.007
Italy	50	10	0.177
Luxembourg	55	25	0.000
Netherlands	75	47	0.037
Portugal	45	10	0.030
Spain	61	20	0.099
Sweden	85	74	0.022
UK	93	75	0.141

Table 6: Seat belt wearing rates in the European Union. Percentage of car occupants wearing seat

belts. Based on ETSC (1996) and OECD (2000).

The reason for considering the front seats only is that the huge majority of fatally injured car occupants sit in the front seats. Hence, it is more cost-effective to install seat belt reminders in the front seats only than to install them for all seats in a car.

According to the IRTAD database 23,781 car occupants were killed in road accidents in the European Union in 2000 (or the most recent year available before the year 2000). It is assumed that 85% were front seat occupants, the remaining 15% rear seat occupants.

Reliable statistics on the use of seat belts among accident victims cannot be obtained. Even in countries that try to record such information, reporting is very incomplete and unreliable. It is, however, possible to estimate the wearing rate for seat belts among fatal accident victims by relying on assumptions based on research. Assumptions need to be made with respect to:

1. The relative accident involvement rate of drivers who do and those who do not wear seat belts respectively.
2. The protective effect of seat belts when worn.
3. The relationship between driver and passenger seat belt wearing rates.

Based on Evans (1991) it is assumed that drivers who do not wear seat belts have a relative accident involvement rate of 1.5 compared to drivers who wear seat belts, i. e. a 50% higher accident involvement rate. Furthermore, it is assumed that seat belts reduce the probability of a fatal injury by 50%. Finally, it is assumed that driver and passenger seat belt wearing rates are perfectly correlated. By relying on these assumptions, it can be estimated (see Appendix 2) that roughly 50% of fatally injured front seat car occupants in the EU did not wear seat belts. The number of front seat car occupants killed in the European Union according to seat belt usage thus becomes:

Front seat occupants wearing a seat belt:	10,107
Front seat occupants not wearing a seat belt:	10,107

The maximum potential wearing rate is 97%, for all car occupants and all seating positions combined. This means that a maximum of 9,652 of front seat occupants currently not wearing a seat belt would then do so. It has then been assumed that the remaining 3% not wearing seat belts are involved in fatal accidents 1.5 times as often as those who wear seat belts.

Based on a review of evaluation studies (Elvik, Mysen and Vaa, 1997) it is assumed that wearing a seat belt reduces the fatality rate by 50% for front seat occupants. The number of fatalities that can be prevented by the universal use of audible seat belt reminders in front seats can thus be estimated to 9,652 * 0.5 = 4,826.

In addition to preventing fatalities, seat belt reminders will avoid a number of serious or slight injuries. The number of injuries that can be prevented cannot be estimated very precisely as official accident statistics are incomplete in all EU-countries. According to a previous ETSC research review (ETSC 1997b), there were, around the year 1995 about

45,000 fatalities on EU roads, about 505,000 serious injuries and about 2,950,000 slight injuries. The costs of these injuries, including a valuation of lost quality of life, were estimated to be 1,116,700 Euro (1995) for a fatal injury, 110,400 Euro for a serious injury and 2,400 Euro for a slight injury. Total costs of injuries were estimated to about 113 billion Euros.

One way of including the benefits of a safety measure in preventing serious and slight injuries, in the absence of reliable statistics regarding the number of these injuries in each EU-country, is to include the cost of all injuries when estimating effects on fatal injuries. For 1995, the total cost of injuries was estimated at about 113 billion Euro, that of all injuries, per fatality, was thus 113,000/45,000 = 2.512 million.

Seat belts are somewhat less effective in preventing serious or slight injuries than in preventing fatal injuries. A reasonable estimate of the total benefit to society of preventing one fatal injury by means of a seat belt is about 2 million Euro in 1995-prices. Adjusted for price inflation, this becomes 2.29 million Euro in 2000-prices[4].

It is assumed that seat belt reminders will be installed in new cars from a certain date. In the European Union about 15 million new cars are sold per year whilst, according to the IRTAD database, the total number of cars in the EU lies in the region of 177 million. Hence, the sale of new cars each year is slightly less than 10% of the total number of cars. However, both the total number of cars and the annual sale of new cars are growing. To account for this, it will be assumed that 20 million new cars are sold annually. It will further be assumed that after a period of ten years, seat belt reminders will have penetrated the whole car fleet.

There are no statistics showing the proportion of killed front seat car occupants by car model year. New cars are likely to be more crashworthy than old ones. On the other hand, new cars tend to be driven longer distances. It will be assumed that 10% of killed front seat occupants in cars are occupants of new cars, that is, of cars sold as new during the same year as the fatal accident.

Hence, the first year after its introduction, a mandatory seat belt reminder for the front seats will have an effect on 10% of front seat car occupant fatalities. This means that it will prevent 10% of the maximum number of preventable deaths estimated above, which corresponds to 483 fatalities. It will be assumed that a car is used for 12 years before it is scrapped. Future costs and benefits are discounted at a rate of 5% per year. The benefits of requiring seat belt reminders for the front seats of all new cars in the European Union in the first year after the introduction of such a requirement then become:

483 * 2.29 * 8.853 = 9,792 million Euro

483 is the number of fatalities prevented the first year; 2.29 is the benefit to society, in million Euro, of preventing a fatal injury as well as a number of serious and slight injuries;

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4 The 2.29 million figure is the total benefit of preventing a fatality, including serious injuries and slight injuries. This figure is different from the assumption made for DRL (paragraph 1.2.5) because DRL has been assumed to have the same percentage effect irrespective of injury severity, and because the figure used for DRL includes an effect on property-damage-only accidents as well.

8.853 is the present value of benefits during twelve years discounted at an annual rate of 5%. The costs during the first year will be 20,000,000 * 60 = 1,200 million Euro.

By repeating these estimates for twelve subsequent years, each year discounting future costs and benefits by 5%, it is found that the present value of the benefits of requiring audible seat belt reminders for the front seats of cars in the European Union amounts to 66,043 million Euro. The present value of the costs amounts to 11,146 million Euro, giving a cost benefit ratio of 1:6.

The benefits of audible seat belt reminders for front seats thus clearly exceed the costs.

1.5 USE OF EURONCAP AS AN INCENTIVE FOR DEVELOPING SAFER CARS

The European New Car Assessment Programme (EuroNCAP) tests the crashworthiness of new cars with respect to front and side impacts and pedestrian accidents. Results are stated in terms of stars: five stars represent the best performance (four stars in the case of pedestrian ratings), zero stars the worst.

The EuroNCAP programme is intended to influence road safety through a number of causal pathways. The most important of these include:

- By providing car manufacturers with an incentive to develop safer cars: EuroNCAP compares cars by crash test performance, and performing better than competing makes and models can be used for marketing purposes.
- By encouraging more cars to be tested in the programme: currently, not all makes and models of passenger cars are tested within EuroNCAP.
- By encouraging more countries to join EuroNCAP: joining the programme will give member countries an enhanced basis for providing consumer information.

However, tracing the final outcome of these potential effects of EuroNCAP in terms of fewer people killed or seriously injured is difficult.

Research by Anders Lie and Claes Tingvall (2001) has found that cars performing well according to EuroNCAP protect occupants better from fatal or serious injuries in real life crashes than badly performing ones and cars not rated at all. Based on this research, the following relationship between EuroNCAP performance and the relative risk of fatal or serious injury can be derived:

Number of stars	**Relative risk of getting killed or seriously injured as a car occupant**
0 or 1 or not stated	1.00
2	0.88
3	0.77
4	0.71
5	0.61

Table 7: Relationship between EuroNCAP performance and the relative risk of fatal or serious injury.

If all cars in a country score 0 or 1 star, or have not been rated in EuroNCAP, the relative number of fatal or serious injuries will be 100 * 1.00 = 100. If all cars in a country score 5 stars, the relative number of fatal or serious injuries will be 100 * 0.61 = 61. The maximum potential for improving safety by changing the composition of the car fleet in a country according to EuroNCAP performance is thus a 39% reduction of the number of killed or seriously injured car occupants.

According to sales statistics for nineteen countries, obtained by Anders Lie, 73% of all new cars sold have a EuroNCAP rating. The distribution of the sale of new cars by EuroNCAP rating in nineteen European countries during the first eight months of 2002 was:

Rating	Proportion of sales
Five stars	4%
Four stars	54%
Three stars	13%
Two stars	4%
Not rated in EuroNCAP	27%

Table 8: Distribution of the sale of new cars by EuroNCAP rating in nineteen European countries during the first eight months of 2002.

In the years since EuroNCAP was started, some car makes and models have been tested more than once. Table 9 gives the results for some of the car models where this has been the case.

Make and model	Year	Impact rating	Pedestrian rating	Price (NOK)	Change
Fiat Punto	1996	2	1	117,990	
	1999	4	2	123,900	5,910
Nissan Micra	1996	2	2	119,800	
	2000	2	2	136,600	16,800
Renault Clio	1996	2	1	139,000	
	2000	4	2	135,500	-3,500
Volkswagen Polo	1996	3	1	118,060	
	2002	4	1	138,170	20,110
Honda Civic	1998	3	2	199,000	
	2001	4	3	180,500	-18,500
Audi A4	1997	3	2	254,000	
	2001	4	1	271,900	17,900
Ford Mondeo	1997	3	2	226,900	
	2002	4	2	244,200	17,300
Peugeot 406	1997	2	2	239,900	
	2001	3	2	236,900	-3,000
Volkswagen Passat	1997	3	2	222,820	
	2001	4	2	233,920	11,100

Table 9: Results of repeated tests in EuroNCAP for selected car makes and models. Extracted from EuroNCAP website.

A total of nine car makes and models are included in table 9. Most of these improved their rating from the first to the second test. The selling price of these cars in Norway (cheapest version) in the respective years is also stated. While most cars became more expensive, this was by no means universal. On average, the nine models included in table 9 improved their impact rating from 2.56 stars in the first test to 3.67 stars in the second. The mean pedestrian impact rating improved from 1.67 to 1.89. The improvement of the mean star rating for the impact test corresponds to a reduction of the risk of fatal and serious injury of about 12%. The mean selling price increased by NOK 7,124, corresponding to about Euro 1,000. The price differential in most European countries would be substantially smaller than in Norway since, in the latter, cars are generally quite expensive.

This evidence suggests that car manufacturers do monitor EuroNCAP test results closely and seek to improve models that do not perform well. Its beneficial effects are accentuated by the fact that models with an improved crash test performance are not necessarily priced much higher than earlier ones and that EuroNCAP has relatively low operating costs (slightly more than 1 million Euro per year).

Nevertheless, the long-term impact of EuroNCAP in improving the crashworthiness of cars is more difficult to assess. As noted above, there were 23,781 car occupant fatalities in Europe in 2000, with about 177 million cars in circulation. The mean fatality rate per car per year was therefore 0.0001344. A 12% reduction of this rate corresponds to a cost saving (present value for 10 years) of 157 Euro per car. To this should be added savings resulting from reductions in serious injuries, which are more difficult to assess, but are likely to be of the same magnitude as the saving resulting from a lower fatality rate.

While a precise analysis is difficult, the evidence quoted above does indicate that EuroNCAP is contributing to an improvement in vehicle crashworthiness, likely providing benefits significantly greater than the cost to society of achieving these improvements. It should be noted, however, that EuroNCAP is just one of many forces that are driving car manufacturers towards producing safer cars.

1.6 ROAD SAFETY ENGINEERING: BEST PRACTICE GUIDELINES

The term best practice guidelines for road safety engineering refers to guidelines intended to help highway agencies implement effective safety management of the road system for which they are responsible. Aspects of this complex topic have been the subject of previous ETSC reviews (ETSC 1996b, 1997a), dealing with low cost road and traffic engineering measures and with road safety audits and safety impact assessment. This report is based on the previous ETSC reports, but adds some new material.

The essential elements of a systematic approach to road safety engineering are outlined in Box 1.

Step 1: Define suitable elements of the road system
Examples of elements of the road system suitable for safety analysis include: road sections of a given length, junctions, driveways, horizontal curves, highway-railroad grade crossings, bridges, tunnels.
Step 2: Analyse distribution of accidents for each type of element
For each set of elements defined, the distribution of accidents should be analysed with respect to the mean number of accidents and the variance.
Step 3: Identify the safety performance function in each set of elements
A safety performance function is an equation that describes the sources of systematic variation in accidents, fitted by means of appropriate multivariate techniques of analysis.
Step 4: Estimate safety for each element using the empirical Bayes method
The empirical Bayes method combines information from two clues to safety, and can be used to estimate the expected number of accidents for each element.
Step 5: Define hazardous road locations and identify them statistically
A hazardous road location is any study unit for which the expected number of accidents is abnormally high.

Box 1: Essential elements of a systematic approach to road safety engineering.

As a first step it is necessary to define the elements of the road system that are suitable for safety analysis. These elements may include road sections of various types of roads, junctions, curves, bridges or tunnels. It is important that the elements of the road system are identically defined and can be counted.

Once a typology of elements of the road system has been developed, the distribution of accidents has to be analysed for a suitable period of time for each set of elements. In a city, for example, there will typically be a few hundred, or perhaps a few thousand junctions. Some of these will be quite safe, others less so. One should obtain information regarding the distribution of junctions by the number of accidents, using data for several years. The objective of studying the distribution of accidents is to determine if it contains systematic variation in the number of accidents. If the distribution of accidents across, for example, junctions, is purely random, the subsequent steps of analysis outlined in Box 1 become superfluous. If, as is nearly always the case, there is systematic variation in the number of accidents, the next task is to identify sources of that variation. This is best done by fitting a so-called safety performance function, which is a multivariate equation describing the effects of sources of systematic variation in the number of accidents. When fitting the safety performance function, it is cardinal to specify this function correctly, in particular with respect to the residual terms of the function. Residual terms describe that part of the variation in accidents which is not explained by the safety performance function. For further details, the reader can consult the book by Gaudry and Lassarre (2000).

A safety performance function will typically not include the effects of all sources of systematic variation in the number of accidents. Some of the omitted sources of systematic variation will be factors that are more or less specific to particular locations of the road system. The effects of these factors can be modelled by means of the empirical Bayes method (Hauer 1997). This method has been extensively applied in road safety evaluation research in recent years and is regarded as theoretically superior by virtually every leading road safety researcher. It combines two sources of information about the safety of a specific element of the road system: (1) the normal number of accidents for such an element, estimated by means of a safety performance function, and (2) the recorded number of accidents for the element.

Any difference between the normal number of accidents expected for a roadway element with certain characteristics (specified in the safety performance function) and its recorded number of accidents is decomposed into the contribution of two factors: (A) pure randomness, and (B) effects of factors not included in the safety performance function. The effects of pure randomness, often referred to as regression-to-the-mean, are eliminated, producing an estimate of safety that captures the joint contribution of factors included in the safety performance function and factors not included in that function.

Having estimated the expected number of accidents for each element of the road system, the logical next step is to define hazardous road locations. These locations would typically be locations that have a high expected number of accidents, in particular locations where there is reason to believe that a high expected number of accidents is attributable to factors whose effects are not included in the safety performance function. It is essential to define hazardous road locations in terms of the expected number of accidents, not the recorded number of accidents. By doing so, the problems of regression-to-the-mean are eliminated.

It is beyond the scope of the general guidelines offered here to describe in detail how to perform road safety audits or how to analyse accidents at hazardous road locations. Once hazardous road locations have been identified, the next steps would often imply conducting a road safety audit or a detailed analysis of accidents. Both these techniques have been developed for the purpose of identifying site-specific features contributing to accidents and to propose safety measures to remedy these site-specific features.

At many hazardous road locations, low cost measures will solve the problem, though a few may need more expensive solutions. The term low cost measure refers to any measure that can be carried out within the existing roadway area; that is without having to acquire new land or draft new land use plans. Moreover, low cost measures would typically not cost more than – at most – a few hundred thousand Euro. Table 10 gives an example of low cost treatments that have been introduced in Norway in recent years. The table gives the mean cost per location, the benefit-cost ratio and the mean annual average daily traffic (AADT) at the locations where the measures were introduced. It is important to bear in mind that the table is an example only; the actual figures will differ greatly from one country to another. By concentrating measures on hazardous road locations, the benefits will be maximised.

Treatment	Mean cost (NOK)	Mean AADT	Cost-benefit ratio
Pedestrian bridge or underpass	5,990,000	8,765	1:2.5
Converting 3-leg junction to roundabout	5,790,000	9,094	1:1.6
Converting 4-leg junction to roundabout	4,160,000	10,432	1:2.2
Removal of roadside obstacles	310,000	20,133	1:19.3
Minor improvements (miscellaneous)	5,640,000	3,269	1:1.5
Guard rail along roadside	860,000	10,947	1:10.4
Median guard rail	1,880,000	42,753	1:10.3
Signing of hazardous curves	60,000	1,169	1:3.5
Road lighting	650,000	8,179	1:10.7
Upgrading marked pedestrian crossings	390,000	10,484	1:14.0

1 NOK = 0.138 Euro (December 2002)

Table 10: Some examples of low cost road safety treatments in Norway. Source: Elvik and Rydningen 2002.

The cost-benefit ratios are impressive, exceeding one to ten for many of the safety treatments. Bearing in mind that Norway is a high-cost country that has a comparatively good road safety record, there is little reason to doubt that very favourable cost-benefit ratios can be achieved by systematically applying similar road safety measures in other European countries.

2 COST EFFECTIVE EU RAIL SAFETY MEASURES

This Chapter contains a review of some possible rail safety measures. However, this review is tentative and should only be taken as an indication of which measures might be cost-beneficial. It has not been possible to conduct a full cost-benefit analysis of the listed measures due to reasons given in section 2.1.1.

2.1 INTRODUCTION

The selection of measures is based on different information sources. These are:

- Actual accident outcomes as reported in accident databases
- The references listed at the end of the Review
- Safety measures suggested by professionals at the Safety Department of a train operating company and from the Rail Administration.

Accident statistics on European level have not been available to the author since there currently are no databases in service with an adequate amount of detail, for example on accident causes, for identifying problems and recurring accidents.

Level crossings constitute a well known problem in all countries and one of the proposed safety measures foresees installing barriers on level crossings with only flashlight and bell signals. Statistics on level crossing accidents are presented separately below. Apart from this, few measures with an obvious safety improving potential can be identified as a result of railways generally being a very safe mode of transport. Not many accidents occur and, furthermore, there has been a constant decrease in the number of fatal accidents over the years. Risks of multiple fatality accidents still exist, but the work of identifying possible measures that prevent them is a delicate task that involves looking at precursors of accidents and the barriers that prevent incidents from turning into accidents.

The data presented below is taken from BOR [5], a database on accidents involving passenger trains on the Swedish network from 1960 to the present. It contains information from four official databases that are administrated by the National Rail Administration, the Railway Inspectorate (two databases) and the former state-owned operator SJ respectively. It brings together all registered collisions, derailments and fires for passenger trains from 1985 to 1999. Furthermore, it also contains a time-series of fatal train accidents from 1960 to the present. It is therefore the best source of information on passenger train accidents available to date in Sweden. The drawback is that it does not cover accidents involving cargo trains, nor those on level crossings.

Swedish accident statistics show that driver errors, objects on the tracks, axle failures and faults on switches and crossings are the most common causes of passenger train derailments, together accounting for around 57% of all such incidents. Though the pattern is not as clear for passenger train collisions, a not unsubstantial 41% of all such incidents occurs between passenger trains and maintenance vehicles. Various causes can be

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5 The BOR database is presented in a Doctoral Thesis: Bäckman, 2002b. There is also a separate technical report Bäckman, 2002a.

identified for this, such as miscommunication of information, maintenance carried out at the wrong place, etc.

Hence, based on Swedish accident statistics, the references listed at the end, and discussions held with operators and the Swedish infrastructure manager Banverket, six measures are proposed in this paper.

2.1.1 Problems of finding information

Unfortunately it was not possible to find enough information to conduct a full cost-benefit analysis of the proposed measures. The problems of finding information are so numerous that they deserve this separate section to outline some of the reasons.

1. It is not possible to access reports produced by consultants commissioned by operators.

There is a strong reluctance to share information among operators and consultants. The author of this paper is aware of several reports on different safety measures that contain economic evaluations of the measures listed here. However, unwillingness to share information has prevented a review of the costs and benefits.

2. Reports and reliable estimates are seldom produced.

Far too often, there are no deeper analyses of the effects and costs of various possible safety measures. Decisions are based on expert judgements and calculations are limited to one hand-written paper. Written reports are lacking rendering it impossible to judge whether investments are cost-beneficial or not.

3. It is difficult to find information on the costs of installing equipment such as barriers on unprotected level crossing.

In Sweden, the number of barriers installed yearly is substantial. However, the costs of different projects are recorded in the accounting system from which it is difficult to extract information. It is therefore not possible to estimate the average cost or variation of costs of installing barriers on a nationwide level. The same holds for the UK where the costs vary significantly but no systems allowing their systematic analysis for different measures exist.

4. It is not possible to find reliable estimates of the safety effects of such measures as installing barriers on level crossings.

Accident statistics only procure a broad picture and an indication that the work of upgrading standards and removing dangerous crossings improve safety. Detailed information, however, is missing.

5. It is not possible to group level crossings by train speeds allowed.

The speed of trains strongly affects both the probabilities of level crossing accidents occurring and their consequences. Speed is therefore a necessary variable when estimating the effects of installing barriers. However, it has not been possible to find information on the number of different types of level crossings that allow low, normal or high speeds.

These are examples of problems that have prevented an analysis of the economic effects the proposed measures could have. It is for this reason that the list is tentative and should only be taken as an indication of potentially cost-effective measures. However, since some information on level crossings was found an analysis of this safety improving measure is provided in Appendix 3.

2.2 RAILWAY SAFETY MEASURES

2.2.1 Improvement of level crossing standards

Level crossing safety is a traditional area of interest with a lot of work having been put into developing models to support decisions on where best to invest in safety improvements. A number of different factors contributing to the risks at level crossings can be identified. Various models in different countries use different versions or interpretations of these risk contributors. Appendix 3 gives an outline of the Swedish model 6. It is relatively general and simple, the initial idea having been to use the model to analyse European accident data and to describe the effect of installing barriers on unprotected crossings. The analysis, however, identifies some problems with this model, as a result of which it is revised and given a new structure.

The analysis brings to a cost benefit ratio of 1 : 1.4, which implies that the safety benefit outweighs the investment costs by 40%. However, due to differences in costs for specific objects, as well as differences in other conditions, the calculations and profitabilities for specific objects might differ significantly from the results presented here. The model can be used to calculate the profitability for specific objects and as a management tool for decisions on where to spend resources on safety.

2.2.2 On-board detectors of heated bearings and axle failures

The traditional method for detecting heated bearings is by using detectors installed along the lines. Detectors are placed in regular intervals along the railway line that, when detecting heated bearings, sends signals through line side cables to a CTC which can stop the train. This technique is infrastructure bound and has limitations. When a bearing starts to wear off, the process can be relatively fast and it is possible to have a complete axle failure within just 3 km of driving.

On-board detectors would detect problems immediately and inform the driver who could then stop the train. Such a system would not be dependent on infrastructure or CTC. The Swedish operator SJ has commissioned a study on the possible benefits and costs of different versions of on-board detectors. It shows that heated bearings detectors are cost-beneficial if fitted to new rolling stock or rolling stock with the latest standards. The exact requirements for the vehicles are specified in the SJ report, to which the author of this paper has not been given access.

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6 Banverket, 2001, section 2.14. The model is based on the research report ”Olyckor i plankorsningar mellan väg och järnväg (Accidents in level crossings between road and rail)”, Transportforskningsdelegationen, 1981.

2.2.3 Fencing at stations to prevent passengers from taking short-cuts between platforms.

This idea is taken from a risk analysis of the Finnish rail system 7. In Gothenburg, Sweden, the tramway company has mounted fences between the platforms in order to prevent passengers from taking short-cuts and risking being hit by an approaching tram. It has reduced accident risks. No estimates of the effects have been available to the author. Note that tram systems and the Finnish stations have very low platforms and therefore do not provide “natural barriers” for people taking short-cuts.

2.2.4 Door improvements to prevent passengers from falling out of moving trains

This is a common problem but since these risks are often self-inflicted they are slightly more difficult to handle. On a large proportion of the European fleet of loco-hauled passenger trains, the doors are automatically closed when the trains start rolling. However, the speed controlled door-interlocking has its flaws as a result of there being a small time interval between trains starting to move and the door locking allowing passengers to jump on and off the train. During the period 1990-1999 five persons were killed in Sweden when jumping off a train in motion.

This can be prevented by installing driver operated door interlocking. The effects and costs of this have been studied by SJ, in Sweden. The cost of retrofitting the equipment into a standard train with traction unit and three passenger cars would amount to approximately € 9,000. The total cost of installing this equipment on the whole Swedish fleet of 130 traction units and around 400 passenger coaches would therefore amount to no more than € 1.1 million. The Swedish value for preventing a fatality is currently €1.6 million. It therefore appears to be a cost-beneficial measure 8. This does not hold for multiple-unit trains as they normally have other technology.

2.2.5 Measures to prevent trains from colliding with maintenance vehicles

In a deregulated market new risks are emerging when maintenance is being carried out. There are now many organisations acting on the market, and there is often a long chain of actors from the CTC via the infrastructure holder, the train operating companies, the infrastructure maintenance company, and the companies projecting and leading the maintenance to subcontractors doing parts of the work. Handling information and safety critical operations in this new situation requires new tools to ensure a safe maintenance situation. Some work currently being carried out can be studied further:

1. The Swedish National Rail Administration is currently working on upgrading the instructions for safety planning of track maintenance. There are currently no cost or effect estimates for this available.
2. In a report the Swedish Railway Inspectorate has pointed to the problems of responsibility for maintaining maintenance vehicles. These are often on a one-year

7 Kallberg, Ruuhilehto, et al., 2002.

8 Information given in telephone interview with Gary Hörneaus, SJ, 06-03-2003.

lease and the responsibility for maintenance of brakes, etc. is not clearly laid out. This might be a specific Swedish problem but can serve as an example of safety critical activities that fall between the responsibilities of different bodies and are thus "forgotten".

3. Regarding working procedures, Sweden is now trying to follow the example of the UK which minimises work on tracks during train traffic. Work is only allowed without any trains on the track section, the section being blocked until work is finished. More and more work is carried out during night time.
4. Technical aids protecting working scenes could also help increasing safety. A Swedish company "Track Warning" has developed a train-warning device to be used by track workers. The device is now certified in the UK. It uses sensors that warn track workers through radio signals about approaching trains. The issue has also been studied by the Swedish Railway Inspectorate 9.

2.2.6 Breaking the electric tension over parked railcars

During the last ten years Sweden has had 25 fatalities caused by the electric tension in the catenary. Most of the victims were boys, climbing parked freight cars. Such accidents can be avoided by making it possible to cut off the tension over parked rail vehicles. A simple driver operated device would suffice and have the potential of being a very cost-effective solution 10.

9 Lundström, 1997.

10 Proposed by the National Rail Administration, Per Sillén, in telephone interview 14-03-2003.

3 COST EFFECTIVE EU MARITIME SAFETY MEASURES

3.1 INTRODUCTION

The improvement of maritime safety is a complex problem involving many actors. Both the maritime authorities of coastal regions and the flag states have to shoulder certain responsibilities to enforce measures taken to reduce the risk of maritime shipping. Coastal states have the right to intervene when it is clear that a stricken vessel is threatening their coast. The intervention instruments are given by the United Nation Convention on the Law of the Sea (UNCLOS) and are made more specific in International Maritime Organisation (IMO) conventions such as the Intervention Convention and the Oil Pollution Preparedness, Response and Co-operation Convention (OPRC). Although the IMO, as a special UN agency, deals with all issues regarding vessels, the European Union has the right to devise special measures to protect the European coastline. However, these measures should not conflict with the internationally adopted conventions. Individual EU member states, then, may take action if there is sufficient proof that the very action is justified, for example when there is evidence that an oil tanker is spilling oil.

This complex distribution of competences between global, European and national authorities, of course, has implications for carrying out cost benefit analyses in the maritime sector. Due to the uncertainties that evolve from such a structure, a CBA does not necessarily qualify as the arch instrument of decision making within maritime safety policy. Consequently, this chapter merely seeks to outline some of the principles which underpin CBAs in the maritime sector. It does so by briefly looking at three measures: a monitoring network based on an Automated Identification System (AIS) along the European coast, the reporting of dangerous goods as well as an Emergency Towing Vessel (ETV).

3.2 AIS MONITORING NETWORK ALONG EUROPEAN COAST

3.2.1 Description of measure

The mounting of an Automated Identification System (AIS) is mandatory since 2002. It is a terrestrial VHF device that sends the identification and position of the vessel at regular intervals and receives the same information from ships within VHF coverage. The first application to be introduced was a ship-to-ship device assisting in resolving problems when two vessels were in an encounter situation. More recent applications, such as an onshore, passive (i. e. non-sending) AIS can still overhear the reports of ships within the VHF coverage. First trials held in Sweden were successful and the EU monitoring directive now requires member states to install an AIS network along their coasts and monitor vessels that are plying along their coasts. From a commercial perspective the information received by a passive system on shore can be provided to the adjacent ports and, when properly used, can improve the planning of resources such as pilots, tugs and berths.

In order to carry out a C/B analysis on AIS one should define a reference situation against which to assess the new system. This would be a situation without the AIS systems in place.

3.2.2 Costs of the measure

The measure foresees that each passive shore station should be part of a network and it is estimated that each station will cost about € 200,000 for each 30 miles of coast length. The coastline should be measured according to the UNCLOS measurements that pertain to the determination of the territorial sea. The Dutch coast, as an example, would have 8 to 10 shore stations. On top of this, the network and the set-up of consoles with software need to be catered for. It is estimated that the costs will amount to some € 3,000,000 for each centre.

3.2.3 Benefits of the measure

The benefits are twofold: there are safety as well as commercial benefits.

- *Safety Benefits:* when a vessel is in distress Safe And Rescue (SAR) may be alerted in an early phase of the accident. This is an important aspect of AIS because rescue resources, such as lifeboats and helicopters, have a certain response time. (Frequently, vessels may also change course to the location of distress – a movement that is as well monitored by the AIS. It is then up to the SAR operator to decide which other vessels is nearest to the derelict vessel and request them to help the vessel in distress). With the reduction of response times, crew and passengers have a better chance to be rescued.

  When a vessel is drifting, often due to an engine failure, a monitoring network can assist, because it enables to predict the path of a vessel. The enormous costs of the cleanup of the Amoco Cadiz and the Prestige are still vividly in the mind of the public, not to mention the structural environmental damage that was inflicted to coastal regions (biologists speak about a recovery time of about 100 years after such a catastrophe). Here, AIS reduces the risk of water and coastal pollution.

- *Commercial benefits:* for some busy ports, planning on the basis of a precise Estimated Time of Arrival (ETA) may have two types of benefits: a more efficient use of pilots and tugs as well as a reduction in waiting times for ships.

3.2.4 Calculation method

While the *costs* for mounting a monitoring system can be fairly well calculated, the *safety and commercial benefits* are more difficult to estimate:

- For any estimate of the *safety benefits* it is necessary to know how many SAR actions were initiated and what their outcome was. It is important to look at the time of the first report as well as the time at which the first committed resources have attained the stricken vessel. For this, the following data is required:
    - the number of passengers saved and dead in the SAR files of the different member states;

- the response times between the moment when help was required and the time when the SAR authority was alerted;
- the response times of the present resources;
- the minimised response times when the SAR operator decides to send a suitable vessel nearby using AIS;
- general information about sinking times of vessels.

Additional data on the number of vessels drifting in EU waters can be drawn from three different sources:

- a traffic database consisting of routes along the member states' coastlines populated with voyage records;
- an accident database including the relevant type of accidents;
- a database on the reliability of the main propulsion of a vessel and the steering engine.

In order to get an impression of the accuracy of the databases (and the models associated with them) the number of ships in distress must be calculated and compared with the number of reported incidents. From this data, then, an estimation of the reduction of vessels stranding on the coasts becomes feasible.

- The *commercial benefits* can be calculated as follows: large ports can improve efficiency and productivity by providing ships with a Requested Time of Arrival (RTA). It is said that a large tug operator in the port of Rotterdam can reduce its fleet by 10% when accurate ETAs are available and ship operators are prepared to accept RTAs. The RTA also allows reducing the speed of the vessel and hence its fuel consumption, with the consequence that some commercial benefits will be reaped by the vessel. Finally, the shippers and forwarders may also benefit from reduced transport costs and a more accurate delivery.

3.3 DANGEROUS GOODS REPORTING

3.3.1 Description of measure

For EU waters, the HAZMAT Directive (93/75) regulates that information on dangerous goods should be made available to the commander on scene 15 minutes after a request had been made.

3.3.2 Costs of measure

The costs of the measures under the HAZMAT directive are determined by the time and effort needed to assemble information on all parts of the cargo to be transported as well as the establishment of a web-based service ensuring the accessibility of the information.

3.3.3 Benefits of measure

The benefit of reporting dangerous goods transport is given by the minimisation of response times for calamity abatement actions.

3.3.4 Calculation method

The calculation method is based on the total number of reports filed, the number of accidents and incidents that require dangerous goods information and the consequences of dangerous goods accidents as a function of the response time.

3.4 EMERGENCY TOWING VESSEL (ETV)

3.4.1 Description of measure

An Emergency Towing Vessel (ETV) is sent to a vessel that is drifting around by the authorities. Intervention of such a vessel is allowed when it poses a threat to the coast of a member state. The threat needs to be substantiated by facts. In other words: some member states only permit intervention if the vessel threatens to hit a platform, will ground or loses oil or chemicals that are visible. The standard situation for assessment is the situation where no ETV is used.

3.4.2 Costs of measure

Annual operating costs for a medium sized tug will be in the order of M€ 8. Most member states were of the opinion not to use such a vessel. Still the UK, the Netherlands, Germany and Ireland are among the member states that have decided to utilise such a vessel.

3.4.3 Benefits of measure

The benefits of an ETV result from accident prevention. Their calculation is based on the number of expected accidents requiring the intervention of a tug. For any estimated benefits response-times are an important issue. They in turn depend on a) the weather conditions and b) the location of the ETV.

3.4.4 Calculation method

The calculation of the effectiveness considers the risk of spill of dangerous goods when the vessel is in distress. It is based on traffic and accident models in connection with spill models. Given a number of different stations the calculation seeks to maximise the number of vessels that can be reached in time, i.e. before they hit a platform, the coast or any other obstacle.

3.5 CONCLUSION

The above examples illustrate that any cost benefit analysis in the maritime safety sector faces a series of problems, mostly due to the complexity of involved parties. But they also show that CBAs are indeed possible and can quite often provide a fair estimate of the effectiveness of a particular measure. Past experience has shown that global, European and national authorities have reached decisions partly based on the results of CBAs. However, many governments have also passed legislation on measures that were considered “not cost-effective”. This practice shows that CBAs are often just one out of many instruments providing the basis for sound safety policy making.

Still, also within maritime safety, CBAs are a crucially important part of Formal Safety Assessments (FSA) as adopted by the IMO. In order to ensure the use of appropriate data and make possible the consideration of all costs and benefits of a particular measure, maritime authorities have to provide easily accessible databases as well as the resources necessary to conduct a sound analysis.

4 COST EFFECTIVE EU AIR SAFETY MEASURES

In aviation, increasingly broad consensus exists on the need to improve safety, expressed in the number of accidents per million flights or flight hours, such that the absolute number of accidents per year does not increase. To achieve this objective, safety must be improved at the same pace as traffic growth, which is about 5% per year. This ambition level is considered necessary to prevent that increasing numbers of accidents lead to a perception of deteriorating safety and a subsequent decline in demand for air travel. As a consequence, current thinking about safety improvement measures is not necessarily about identifying safety measures with an individual positive return on investment and implementing those, but about identifying the set of safety measures that will together deliver sufficient safety improvement to compensate for traffic growth. If more safety improvement is expected from the identified set of safety measures than is needed to compensate for traffic growth, safety measures are prioritised based on cost benefit considerations. Thus, while the costs of accidents, which are increasing strongly, do play a role in the considerations around safety improvement programmes, these costs do not constitute the main driving force behind the industry wide safety improvement initiatives. As a matter of fact, it is a common tendency in aviation to identify the main accident categories and to concentrate on measures to reduce these rather than to check whether the same safety improvement could be achieved at less cost, through a larger set of other safety measures. Many ‘priority lists’ in aviation safety programmes are thus in order of their pay-off in terms of accident risk reduction rather than the ratio between the costs of the safety measure and the expected return on that investment in terms of prevented accident costs.

This is not to say that cost-benefit considerations are irrelevant in this sector. A number of important initiatives have been developed in the recent Framework Programmes[11] to develop methods and tools to support cost benefit analyses for aviation safety. The results of these programmes are, however, not yet applied widely. Other important developments (quantitatively) relating the costs of safety measures to the expected benefits in terms of accident prevention are ongoing in the US Commercial Aviation Safety Team (CAST). Their so-called JIMDAT12 approach is probably state-of-the-art in this regard. The European counterpart of CAST is the Joint Safety Strategy Initiative (JSSI) led by the JAA. JSSI is the most important safety programme in Europe today, because it does bring together the safety initiatives of all the important players in European air safety. Many European and global organisations such as Eurocontrol, IATA, AECMA, ACI and others bring their safety agendas to the JSSI program. The CAST programme and JSSI work together and share results, among which are those of JIMDAT. The top 10 safety enhancement priorities of CAST are thus coordinated with - and effectively adopted by JSSI. Of course there are important differences between the aviation sector in Europe and that in the US, which is why JSSI has its own list of most important safety improvement measures and associated action plans that, while being largely in accordance with CAST priorities, reflect the specific European concerns and context.

11 Such as the DESIRE and ASTER programs in the fourth and first Framework Programs.

12 JIMDAT stands for “Joint Implementation Measurement Data Analysis Team”.

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APPENDIX

APPENDIX 1
TRANSPORT ACCIDENT COSTS AND THE VALUE OF SAFETY

An update of ETSC cost estimates from 1995 to 2000

This short note contains an update of ETSC's estimates of the costs of transport accidents and the value of safety from 1995-prices to 2000-prices. The Eurostat yearbook 2002, chapter 3, economy and finance, has been used as the source for updating the cost estimates.

The value of preventing road accident injuries as stated in 1995-prices was (ETSC 1997b):

Injury severity	Value of prevention (Euro 1995)
1 fatal injury	1,116,700
1 serious injury	114,700
1 slight injury	2,400
1 case of property damage	1,000

Updating these estimates by the growth of the gross domestic product in fixed prices and by the consumer price index gives slightly different results. It is reasonable to assume that the valuation of transport safety is more closely related to growth in income than to growth in the prices of consumer products. A mean of the two estimates has been estimated, by giving 90% weight to the update based on the gross domestic product and 10% weight to the update based on consumer prices. This weighted estimate has then been rounded. The rounded estimates in 2000-prices are shown below:

Injury severity	Value of prevention (Euro 2000)
1 fatal injury	1,265,000
1 serious injury	125,000
1 slight injury	2,720
1 case of property damage	1,130

In the ETSC report, values that are 38% higher than those stated above are used to value the prevention of injuries for railways, air travel and maritime travel. Recent research by Michael Jones-Lee (2001) suggests that the basis for such a differentiation in the value of life saving and injury prevention is tenuous. It is therefore proposed to use the values given above for all modes of transport.

APPENDIX 2
ESTIMATING THE PROPORTION OF FATALLY INJURED CAR OCCUPANTS WEARING A SEAT BELT

The proportion of fatally injured front seat car occupants who wear seat belts can be estimated as follows:

	Number who wear seat belts	**Number who do not wear seat belts**
EU-average on the road	76	24
Relative accident involvement rate	1.0	1.5
Numbers involved in potentially fatal accidents	76	36
Protective effect of seat belts	0.5	1.0
Numbers killed	38	36
Numbers converted to percentages and rounded	50%	50%

On the road, 76 out of 100 front seat occupants wear a seat belt, 24 do not. Those who do not wear a seat belt are involved in potentially fatal accidents at a 50% higher rate than those who wear a seat belt. Hence, the number involved in accidents will be

76 * 1 = 76

for those who wear seat belts, and

24 *1.5 = 36

for those who do not wear seat belts. Wearing a seat belt reduces the chance of getting killed by 50%. Hence, among those killed,

76 * 0.5 = 38

will wear a seat belt, and

36 * 1 = 36

will not wear a seat belt. Converting these numbers to percentages and rounding them gives an estimate that 50% of killed front seat car occupants in the European Union wore a seat belt, 50% did not.

APPENDIX 3
IMPROVEMENT OF LEVEL CROSSING STANDARDS

A.3.1 The Swedish model

The Swedish model for allocating resources to level crossing safety measures calculates the relative risk for a specific crossing measured as the expected number of accidents per year. It is based on the traffic product of both rail and road at the intersection, the average traffic product at the specific level crossing type, the average accident frequency of the specific crossing type, the average cost of a level crossing accident, etc. The calculations also cover the costs of the road users such as increased fuel consumption, increased vehicle wear and tear and the induced delay from the lowering of the gates. We will here only look at safety benefits and investment costs.

The model has been developed and continuously revised since the beginning of the eighties. The formula used today to calculate the expected number of accidents per year for a given level crossing reads as follows:

$$R = O_{mf} * f(Sth) * (Q_t * Q_r) / TFP_{average}$$

Where

R= Relative risk (Number of accidents per year)
O_{mf} = average accident frequency for the actual level crossing type
f(Sth) = correction factor; is a function of train speed and level crossing type
Qt = daily train traffic flow
Qr= daily road traffic flow
$TFP_{average}$ = Average traffic flow product for the actual level crossing type.

The first part of the formula states that the expected number of accidents on a level crossing is determined by the average accident frequency of the crossing type and a correction factor for train speed. The second considers that if the traffic flow product is higher than the average, the expected number of collisions increases.

According to the model, the average accident frequency (O_{mf}) and the average traffic flow product ($TFP_{average}$) is to be taken from the following table 13:

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13 It is apparent from table 11 that it is not possible to use the average accident frequencies to estimate the effect of installing barriers on a level crossing with flashlight and bell or without any protection. The average accident frequency is clearly lower for crossings with barriers. The traffic product being much higher direct comparisons are not possible. With all conditions equal, the accident frequency would be many times higher for level crossings with only light and sound than for crossings with barriers. The figures above are estimated from the actual outcome. However, the existence of level crossings with barriers is not random since they can be found where the traffic flow product is high. The low average accident frequency should thus be interpreted as “low in spite of high traffic product”.

Protection type	O_{mf}	$TFP_{average}$
Barriers	0.0033	9,000
Barriers with detectors	0.0055	60,000
Half barriers	0.0076	12,000
Light and sound	0.0156	1,400
St Andrew's cross	0.0080	300
No protection	0.0008	-

Table 11: Average accident frequency O_{mf} and average traffic flow product $TFP_{average}$.

Note that the O_{mf} value for barriers with detectors is hypothetical because so far accidents on level crossings with this type of protection have not occurred. In order to calculate the effect of installing barriers, we will also need to use the correction factor f(Sth) for protection type and train speed. It is given in the following table:

	Level crossing type / Protection type	
Speed	**Barriers or light / sound**	**Unprotected**
0-50	0.5	0.5
50-100	0.5+0.01*(train speed – 50)	0.5+0.01*(train speed – 50)
100-140		$1.02784^{(\text{train speed} - 100)}$
100-200	$1.01622^{(\text{train speed} - 100)}$	

Table12: Formulae for correction factor f(Sth).

Economic evaluation in the Swedish model

In the Swedish model, consequences are accounted for in a single figure, composed of the average costs for:

1. Rail administration costs of repair, administration, etc
2. Operator-costs of repair, traffic control, etc
3. Costs for police and rescuing services, etc
4. Costs of delay to passengers and cargo customers.

The costs were estimated at € 25,000, price level 1999-01 14. Furthermore, based on accident statistics, the weighted average consequences (AVC) have been calculated for collisions between cars and trains (see table below).

Consequence	AVC
Killed	0.23
Major injury	0.13 [15]
Minor injury	0.27
Accident without killed/injured	0.38

Table 13: Weighted average consequence of level crossing accidents.

14 Prices in euros calculated with the conversion rate 9.2 SEK = 1 Euro.
15 This figure is incorrectly given as 0.12 in the Swedish handbook. This is corrected here and in the following tables and calculations.

The material accident costs and risk valuations used by the Swedish National Road Administration in the standard appraisal of road projects is given in the following table:

	Material costs	Risk valuation (WTP)	Total
Killed	141,300	1,413,000	1,554,300
Major injury	65,200	217,400	282,600
Minor injury	6,500	9,800	16,300
Accident without killed/injured	1,400	-	1,400

Table 14: Costs of road accidents, Euros.

The average accident cost for a level crossing accident is thereby calculated as

Killed	(1,554,300+25,000)*0,23 = 363,200
Major injury	(282,600+25,000)*0,13 = 40,000
Minor injury	(16,300+25,000)*0,27 = 11,200
Accident without killed/injured	1,400+25,000*0,37 = 9,800
Total average accident cost	**424,200**

Table 15: Average accident costs including costs for infrastructure manager and operators.

Comments on the Swedish model

It is now time to take a step back and consider the model itself. It is possible to calculate the expected number of accidents for each crossing type simply by multiplying the average accident frequencies given in the Rail Administration Handbook and estimated for the period 1994-1998, with the number of crossings of each type during the same period.

	O_{mf}	No of crossings	No of accidents
Barriers	0.0033	1,316	4.3
Barriers with detectors	0.0055	80	0.4
Half barriers	0.0076	698	5.3
Light and sound	0.0156	703	11.0
St Andrew's cross	0.008	1,104	8.8
No Protection	0,0008	5,203	4,2
		Total	**34,0**

Table 16: Expected number of accidents per crossing type and year.

Table 16 shows that this would lead to a result of 34 accidents per year. In reality, however, the average number for the period was 41. Looking at the average accident frequencies leads to an underestimation of the risk. In addition to this, the model has not been updated and the given figures for average accident frequencies are not valid anymore. There are thus good reasons to revise it and use other estimates of the average accident frequencies.

The model calculates the expected number of accidents from the actual traffic flow product, the average traffic flow product for the crossing type, the train speed and the average accident frequency. Regarding the speed of trains, the problem is that even though it is conceivable that it affects the probability, this does not constitute the reason why it was included. At the time when this model was conceived (around 20 years ago) it was not possible to let speed affect the consequences, something that would have been more accurate. Instead of changing the calculated consequence depending on the line speed, the model constructor had to include speed on the probability side of the model.

Furthermore, the consequences are given as a bundle of economic costs and values for life per se, estimated using the willingness to pay method. The straightforward way of determining the consequences would be to let speed affect the expected number of fatalities, injuries, etc. and then apply the risk value. We will change this here and let speed affect the consequences before the economic evaluation is conducted.

A.3.2 A new model

A small model for calculating the effect of installing barriers on crossings with flashlight and bell is outlined and applied to European data.

The expected number of accidents will be calculated from the following formula:

$$R = O_{mf} * (Q_t * Q_r) / TFP_{average}$$

where
R= Relative risk (Number of accidents per year)
O_{mf} = average accident frequency for the actual level crossing type
Qt = daily train traffic flow
Qr= daily road traffic flow
$TFP_{average}$ = Average traffic flow product for the actual level crossing type.

This will produce an estimate of the expected number of accidents per year and level crossing. The weighted average consequences, AVC, for collisions between cars and trains are given in Table 13 above.

We will let speed affect the consequences. It is assumed that the average line speed for crossings with flashlight and bell or barriers is 100 km/hour. The severity of consequences decreases if the line speed is below 100 km/hour and increases if it is above this figure. This is taken into account by letting the share of accidents with fatalities and major injuries increase by the factor f(Sth) and the share of accidents with minor injuries or without killed/injuries decrease by a corresponding amount. f(Sth) is calculated with the formula

$$f(Sth) = 0.01 * Speed$$

The expected consequences, EXC, for accidents with fatalities or major injuries are then calculated as

$$EXC_{killed} = AVC_{killed} * f(Sth)$$

and correspondingly for major injuries. On the other hand, the share of minor injuries is determined using the following formula:

$EXC_{minor} = AVC_{minor} + (AVC_{killed} – EXC_{killed} + AVC_{major} – EXC_{major}) * 0.5$

and correspondingly for accidents without fatalities or injuries. In other words, for crossings with a line speed below 100 km/hour (average line speed) the reduced share of accidents with fatalities and major injuries is evenly distributed to accidents with minor injuries or without consequences for human health. This is very rudimentary but allows the inclusion of line speed in a more credible way than has been done previously.

The table below outlines the consequences of level crossing accidents at three different line-speeds: the middle column gives the average consequences (AVC), the corresponding side columns outline values for line-speeds of 50 and 130 km/hour:

Speed	**50**	**100**	**130**
f(Sth)	**0.5**	**1**	**1.3**
Consequence	**EXC**	**AVC**	**EXC**
Killed	0.115	0.23	0.299
Major injury	0.065	0.13	0.169
Minor injury	0.36	0.27	0.216
Accident without killed/injured	0.46	0.37	0.316
Totals	1	1	1

Table 17: Consequences of level crossing accidents at three different line-speeds.

To illustrate the formula above, EXC_{minor} is calculated as

$EXC_{minor} = 0.27 + (0.23 - 0.115 + 0.13 - 0.065) * 0.5 = 0.36$

Based on these figures we are now ready to apply the model to European data.

Analysis of European data

In a European study financed by the European Commission, accident data for level crossings in nine different countries have been examined[16], revealing large differences. Philippe Lejeune chaired the working group dealing with this issue, at the Centre d’Etudes Technique de l’Equipment du Sud-Ouest, C.E.T.E, in France. Its aim was to exchange information on accident and risk exposure variables, regulation of level crossings, road signing and equipment of level crossings.

Over a period of one year, between 1998 and 1999, the working group collected information through questionnaires on three parameters for seven identified level crossing types. The parameters were:

1. Number of level crossings

16 C.E.T.E Working group, 2000.

2. Number of vehicle collisions
3. Number of fatalities

In addition, it also collected general information on road network length, rail network length and the number of inhabitants. From this information risk levels, severity levels and other intensities were calculated.

The results showed a variation from 32.38 for Austria to 0.28 for the UK and 0.9 in Norway in the number of collisions per million inhabitants, with a median of 4.37. The number of fatalities per accident was on the other hand very low for Austria (0.1) and rather high for Norway (1.5). These figures work in opposite directions when the risks are analysed, and care needs to be taken as the figures are for one year only.

In this analysis, the average figures for the nine countries will be used. Though it would be preferable to make use of information on accidents for several years, it has unfortunately not been possible to find such figures, the problem also being that relatively detailed information on the number of accidents for each level crossing type would be needed. Official statistics do not include such data because the number of reported level crossing accidents is normally aggregated for all level crossing types. With some assumptions, we will be able to make general calculations on the effectiveness of upgrading level crossings with no protection or only sound and/or light warnings to automatic level crossings equipped with light, sound and barriers, based on the data provided in the C.E.T.E. report and the Swedish model. The report contains data for nine countries given in the table below. Crossing types A1 and A2 are both barrier crossings whilst B1 and B2 are both unprotected.

Level crossing type	***Number of Level crossings***									
	A	**B**	**D**	**F**	**L**	**N**	**P**	**UK**	**Total**	**Aggregated**
A1	555	22	4643	2032	9	0	211	884	8356	
A2	803	1299	5048	11114	81	302	139	503	19289	27645
B1	488	411	1762	61	9	9	291	142	3173	
B2	2987	293	13714	4307	7	101	0	60	21469	24642
Level crossing type	***Number of Collisions***									
	A	**B**	**D**	**F**	**L**	**N**	**P**	**UK**	**Total**	**Aggregated**
A1	16	0	19	4	0	0	2	3	44	
A2	17	38	98	133	1	3	3	7	300	344
B1	21	26	110	0	0	1	8	6	172	
B2	204	3	256	34	0	0	0	1	498	670
	Number of fatalities									
A1	2	0	2	1	0	0	0	1	6	
A2	3	15	23	41	1	6	1	1	91	97
B1	8	3	34	0	0	0	4	0	49	
B2	13	0	42	8	0	0	0	0	63	112

Table 18: Accident data from 9 different European countries, 1998-1999.

It is possible to calculate the expected number of accidents per level crossing from the data above. By using the aggregated figures in the last column we find for example that the average number of collisions per barrier level crossing and year is 344 / 27,645 = 0.012443 and that the corresponding figure for crossings with sound/light is 670 / 24,642 = 0.02718. The difference is 0.014746. However, the average traffic flow product is different in the two samples, rendering it necessary to adjust for this. In Sweden, the traffic flow product for crossings with barriers is on average about six times higher than for crossings with only flashlight and bell.

According to the model, the effect of the traffic flow is calculated from the formula

$F = (Q_t * Q_r) / TFP_{average}$

where $TFP_{average}$ is substituted by TFP_{S+L} for crossings with flashlight and bell and TFP_B for crossings with barriers, which are the average TFPs for respective crossing types. Now let the average traffic flow product TFP_{S+L} for crossings with flashlight and bell be x and let the average traffic flow product for a crossing with barriers be yx. We then get

$TFP/x = 1$ and $TFP/yx = 1/y$

By assigning different values to y we can study the effect on the difference in the expected accident frequency for crossings that are upgraded from flashlight and bell to barriers.

Y	1	2	4	6	8	10	20
Barriers	0.012443	0.0062217	0.003111	0.002074	0.001555	0.001244	0.000622
Flashlight and bell	0.027189	0.0271894	0.027189	0.027189	0.027189	0.027189	0.027189
Difference	0.014746	0.0209676	0.024078	0.025115	0.025634	0.025945	0.026567

Table 19: Accident frequencies for given differences in traffic flow product, difference set as y.

The effect of installing barriers is within this range. It is reasonable to assume that the average traffic flow product of crossings with barriers is at least 4 and the maximum 20 times higher than the value for crossings with flashlight and bell. The difference in accident frequency then ranges from 0.024 to 0.027.

Using the model

It is now possible to calculate the effect of installing barriers on level crossings with light and sound.

If we look at average figures and do not take the traffic flow product into account we can determine the effect of installing barriers by subtracting the accident frequency for barrier crossings from that of light/sound crossings. As shown in the previous section this was found to be a reduction in the number of accidents between 0.024 and 0.027 per year and crossing. For an average crossing with an average line speed, the expected reduction in number of persons killed per crossing and year would then be:

$0.024 * 0.23 = 0.006$

However, these figures only hold as averages and are not very helpful for deciding where to install barriers. We will thus have to look at the traffic flow product. First, the traffic flow factor needs to be calculated using the formula

$(Q_t * Q_r) / TFP_{average}$

which is the last part of the model. To do this we need information on the average traffic flow products for crossings with flashlight and bell and crossings with barriers. Swedish figures will be used for lack of availability of European data. As stated in Table 11, the average traffic flow product for crossings with flashlight and bell is 1,400. Lacking other information, this figure is used as a starting point in the model. As clarified in the previous section, we assume that the average traffic flow product for crossings with barriers is 4 times higher, that is 5,600. For a crossing with a traffic flow product of 1,400 we will thus have the following impact of the TFP:

	TFP ($Q_t * Q_r$)	**1,400**
	$TFP_{average}$	TFP factor
Barriers	5,600	0.25
Light and sound	1,400	1

Table 20: TFP factors.

By multiplying the frequencies given in column 4 in Table 19, with the TFP factors given above, we will get the following:

	TFP		1,400	
	O_{mf}	$TFP_{average}$	TFP factor	R
Barriers	0.003111	5,600	0.25	0.00078
Light and sound	0.027189	1,400	1	0.02719
			Difference:	0.02641

Table 21: Accident frequencies for crossings with light/sound or barriers with traffic flow product of 1,400.

We can now turn to calculating the consequences for the three cases given above in Table 17. This will give us the expected safety benefit for level crossings with a traffic flow product of 1,400 for three different line speeds:

Speed	50	100	130
Consequence	EXC(TFP=1,400)	EXC(TFP=1,400)	EXC(TFP=1,400)
Killed	0,003037	0,006075	0,007897
Major injury	0,001717	0,003433	0,004464
Minor injury	0,009508	0,007131	0,005705
Accident without killed/injured	0,012149	0,009772	0,008346

Table 22: Expected consequences for a level crossing with TFP = 1,400, events per year.

We can now turn to the economic evaluation.

Economic evaluation

Safety effects
For the economic evaluation, the risk values given in Appendix 1 are used. The values are:

Consequence	**Total**
Killed	1,265,000
Major injury	125,000
Minor injury	2,720
Accident without killed/injured	1,130

Table 23: Value of accident prevention, in Euro. For an explanation, see Appendix 1.

By multiplying these values with the expected consequences illustrated in table 22 and adding them together we get the safety benefit per year for the three cases:

Line speed (km/hour)	50	100	130
Killed	3,842	7,684	9,990
Major injury	215	429	558
Minor injury	26	19	16
Accident without killed/injured	14	11	9
Total safety benefit €/year	**4,096**	**8,144**	**10,573**

Table 24: Total benefit in Euro for the three cases of line speed 50, 100 or 130 km/hour.

Other effects
It is conceivable that installing barriers will increase time delays, fuel consumption and vehicle wear and tear for road users. However, it has not been possible within this work to make any estimates of this. It is assumed that this effect is relatively insignificant since barriers will be installed on crossings with a small traffic flow product, hence only leading to minor delays. These effects are therefore not included in the economic evaluation here.

Cost
The investment cost is set to be € 170,000, based on a review of 7 different projects in Sweden where barriers have been installed. This sum is a conservative estimate for normal crossings since for installations in cities, or close to stations, the costs can be considerably higher.

C/B analysis
We can now put together costs and effects of installing barriers in an economic evaluation. This has been done in the table below for a traffic flow product of 1,400, the time horizon being 40 years with a discount rate of 5%.

Line speed (km/hour)	50	100	130
Safety benefit per year and crossing	€ 4,096	€ 8,144	€ 10,573
Present value	€ 70,290	€ 139,743	€ 181,415
Cost of installing barriers	€ 170,000	€ 170,000	€ 170,000
Net benefit	€ -99,710	€-30,257	€ 11,415
Cost : Benefit Ratio	**1 : 0.41**	**1 : 0.82**	**1 : 1.07**

Table 25: Economic evaluation of installing barriers at level crossings with TFP=1,400.

It can be seen that with a traffic flow product of 1,400, installation of barriers only gets profitable on level crossings with an allowed train speed of 130 km/hour or more. For crossings with a lower line-speed, the investment is not profitable, assuming the same TFP.

This model has been used to determine the necessary traffic flow product for the installation of barriers having safety benefits that equal the investment costs for lines with a permitted speed of 100 km/hour and 50 km/hour respectively. The result showed that a TFP above 1,700 would be required for lines with permitted train speed of 100 km/hour and a TFP over 3,390 for lines with 50 km/hour.

A.3.3 Conclusions

A conservative policy would require a cost benefit ratio of 1 : 1.4, which implies that the safety benefit outweighs the investment costs by 40%. Based on the model outlined above, the required traffic flow products is calculated for level crossings with the following allowed train speeds:

Allowed train speed	Required TFP	Cost Benefit Ratio
50	4,740	1 : 1.4
100	2,400	1 : 1.4
130	1,840	1 : 1.4

Table 26: Traffic flow product required for profitable installation of barriers at different line speeds.

Due to differences in costs for specific objects, as well as differences in other conditions, the calculations and profitabilities for specific objects might differ significantly from the results presented here. The model can be used to calculate the profitability for specific objects and as a management tool for decisions on where to spend resources on safety.