Economic evaluation of road traffic safety measures

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1. Introduction

The number of road traffic accidents is still very high although the number of fatalities in Germany and many other European countries is declining. In road traffic accidents with personal injuries, economic resources are destroyed and with that, the efficiency of the economy is impaired. The costs by traffic accidents represent the most important part in the sum of the economical costs of traffic. The knowledge of the effects of road accidents on the economy is essential; therefore measures to reduce road traffic accidents should be identified and introduced. Once an economic assessment of road safety measures has been made, work on improving safety in accordance with economic criteria can be organized as efficiently as possible. Therefore, it is necessary to select measures, which promise a high degree of success to avoid accidents. The effects of these measures have to be quantified and evaluated. The objective is to use available resources in such a way that the greatest possible benefit for society can be achieved. Even with a favorable trend in the incidence of road accidents, there is still a need for measures to increase road safety. Such measures can be introduced at different starting points of the accident (Figure 1).

Planning road safety measures is a complex task, because a wide range of technical and non-technical measures is available to improve road traffic safety:

- The potential of technical measures to improve road safety is not yet exhausted. In the past technical innovations increased road safety (e.g. airbag, strengthened passenger compartment, plastic fuel tank). However, active and passive safety can be improved still further by technical measures (e.g. telematics applications).

- Active safety can be improved by investments into the human factor. Education and training programs for road users can help to reduce individual traffic failures.

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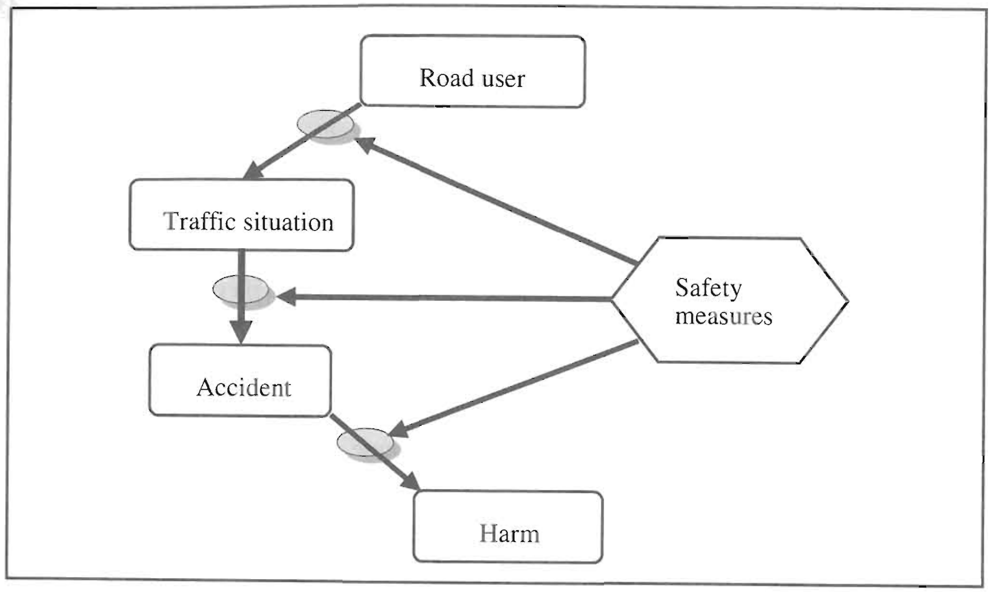
- Even in the context of the economic framework conditions, there still exist possibilities for increasing road safety. For example, changes in insurance tariffs can provide incentives for careful behavior on the roads.

Figure 1: Starting points of road traffic safety measures



Source: own diagram.

2. Evaluation methods – A critical review

A controversy exists over the choice of the correct way of evaluating road safety measures. The following distinguishes between cost-benefit analysis and alternative methodological approaches.

2.1 State of the art

The cost-benefit analysis is regarded as a sophisticated, objective evaluation instrument. The economic cost-benefit analysis goes back to the welfare theory. The increase of the overall economic production potential is used as a standard for evaluating a measure. The costs of the regarded measure are confronted with this overall economic effect. The benefits are defined as the savings of productive resources ("cost savings approach"). The result of the evaluation is obtained by comparing costs with benefits (difference or quotient rule). A measure is macro-economically profitable, if the difference between benefits and costs is greater than zero or the benefit-cost ratio is greater than one.

Economic evaluation of road safety measures using cost-benefit analysis is based on the costs incurred as a result of road accidents. Avoiding such costs represents the economic benefit of road safety measures. If the scale of these benefits is to be ascertained, the costs of road accidents must be worked out. The costs of safety measures cover implementation and maintenance costs. The benefit-cost ratio represents the economic advantage of the safety measures:

$$\text{Cost} - \text{benefit ratio} = \frac{\text{benefits}}{\text{costs}} = \frac{\text{reduction of accident costs}}{\text{costs of measures}}$$

According to a more widely held interpretation, the benefits of the measure encompass other reductions in costs, such as those resulting from emissions, noise, or losses of time. It should be borne in mind that road safety measures can also produce higher costs, which reduce then the overall benefits (e.g. losses of time due to speed limits).

In addition to cost-benefit analysis, other methods are used to evaluate road safety measures:

- In **cost-effectiveness analyses** the costs of a measure are confronted with its effects. The effects of the measure are not expressed in monetary terms.

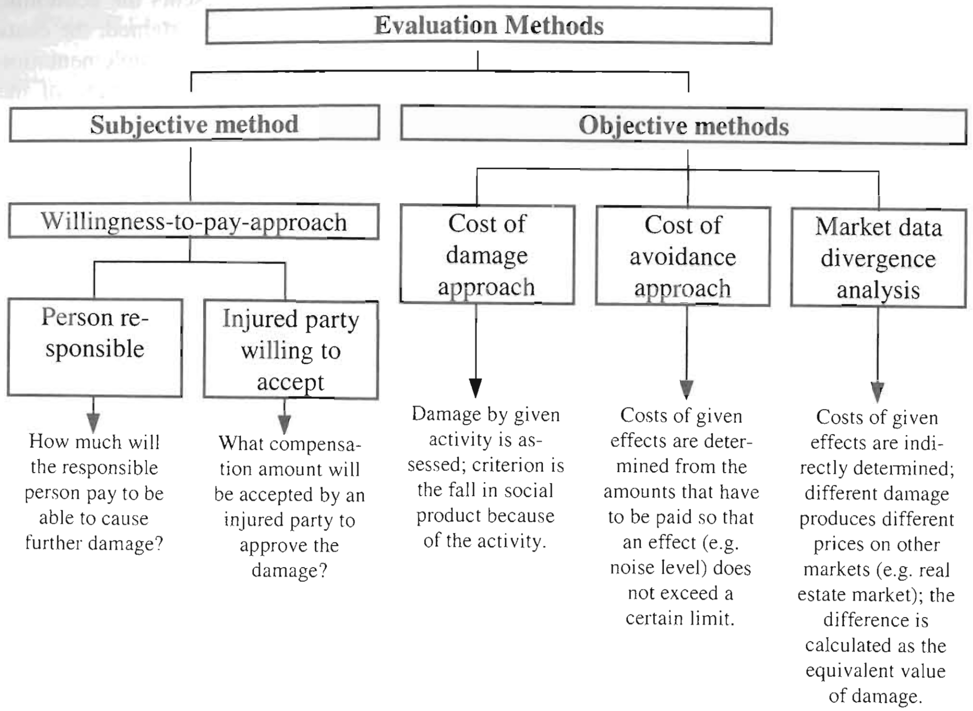
- **Multi-criteria processes** are "open" methods of evaluation. They have the lowest request in terms of data. The evaluation is based on (policy-orientated) goal-functions, which have to be established before the evaluation. It measures the extent to which objectives are met, and this is evaluated by using a point system.

With evaluation processes, which do not consider all relevant monetary values, the synthesis of the results is a serious problem. However, because they can be used more generally and their scope of application is broader, they are often preferred to cost-benefit analysis.

2.2 A true evaluation - mission impossible?

In the evaluation of road traffic accidents a dilemma exists because of the fact that different appraisal procedures supply different statements and estimated values. Moreover, the concentrated efforts of research toward the accident costs in the past did not lead to a comprehensively accepted level of knowledge. Estimates of the costs of accidents display considerable diversity. Different results are obtained depending on the method chosen for quantifying them. The question arises, which method of evaluation should be used. To determine the economic cost of road traffic accidents it is of prime importance to establish an appropriate value framework. For this a variety of concepts can be used (Figure 2).

Figure 2: Methods for calculating the cost of accidents



Source: own diagram.

The "cost of damage" method determines costs through direct assessment of the damage caused by accidents. By determining the actual damage this approach attempts to make an objective evaluation of the costs, based on economic factors. The "cost of damage" method has been used hitherto to calculate the cost of accidents, in Germany and the USA amongst other countries. Several objections have been made to this approach (INFRAS, IWW, 1995):

- It is argued that the "cost of damage" method, which is based on lost output, would send out the wrong signal with respect to welfare. Although a greater number of accidents leads to an increase in reproduction costs (e.g. repair of property damages, net product from hospital treatment, etc.), the social product will turn out to be higher, the greater the number of accidents. Against this argument, it can be objected that accidents cause a reduction in the productive factors of labor and real capital, which, according to the production function used, leads to a fall in social product. Losses of resources through road traffic accidents are accordingly reflected in a reduction and not an increase in social product. The argument that it causes an increase in social product could therefore apply at most to the reproduction services, which are included in the statistical records of the national economy's net product. However, it must also be noted that the factors of production used in reproduction services would have been used in other applications if no accident had occurred. The increase in the social product does not stem specifically from reproduction work following accidents but from the production potential of available resources.

- The "cost of damage" method does not cover all damage, but only such as represents a reduction in economic net product. This point seems reasonable, but then that is the whole purpose of the evaluation procedure. It is supposed to determine costs incurred through accidents, and these costs are derived from an economic assessment of accidents. Any damage that is not relevant to the market can also be taken into account in the assessment.

- The "cost of damage" method can lead to ethical problems in that injury may be assessed differently, depending on the individual injured and his/her contribution to production. For example, the value of a human life would be assessed differently depending on whether the victim of the accident was a full-time or part-time worker. It is possible to avoid the kind of value distinction that depends on working arrangements by establishing the individual's potential productive value, i.e. what could be achieved with normal use of the factors of production.

Sometimes accidents costs need to be reassessed based on "willingness to pay", so that a more accurate indication of the losses to the national economy resulting from road accidents may be obtained. The "willingness to pay" method is also used internationally for evaluating accidents costs, in Great Britain for example.

- The "willingness to pay" approach determines the extra financial burden a person is prepared to accept to refrain from harmful practice or the amount a person suffering the effects of such practice is prepared to pay to prevent it.

- The "willingness to accept" approach establishes the payments that must be made to induce a person responsible for harmful practice to stop or an injured party to tolerate such practice.

The following objections have been made to the "willingness to pay" approach (Baum, Esser, Höhnscheid, 1997):

- Willingness-to-pay analyses are conducted using surveys ("stated preference approach"). The results depend on the way the survey is designed and conducted. The extent to which the methods of evaluation are comparable in different cases is therefore questionable.

- In establishing their "willingness to pay", false estimates may be made by the respondents. Expressing a willingness to pay is one thing, actually having to pay is another. Even on the question of human health, it is necessary to be aware of the danger that hypothetical and actual willingness-to-pay are at variance.
- The "willingness to pay" concept sets out to determine the cost of accidents in terms of the market price the road user would be prepared to pay to prevent accidents. In the "willingness to pay" analyses, however, only the evaluation of the demander is considered and there is no assessment of the price at which the supplier would provide certain services. If, however, the "willingness to pay" expressed in the survey is used as a basis for calculating costs; the costs in structural terms are overestimated. The "willingness to pay" approach goes further than the market price level approach as it includes an assessment of consumers' incomes.

In this respect, even the "willingness to pay" approach to evaluating the cost of accidents is fraught with problems and disadvantages. The cost of accidents should be calculated by means of a completely objective process, geared to actual economic loss. The "cost of damage" approach best fulfils the claim to providing the most objective representation of costs. Investigations involving more subjective survey methods provide additional information, which increases what we already know of the complexity of calculating the costs of accidents. However, their disadvantages make them less suitable for planning purposes.

2.3 Are accident costs external or internal?

The economic costs of traffic can be subdivided into internal and external costs. This also applies to costs resulting from accidents, though in some calculations of traffic costs, all costs due to accidents are classified as external costs. The classification of the different costs due to accidents as internal and external is not uniform, however. Very often, the cost of loss of resources is classified as an external cost and the cost of reproduction as an internal cost. In order to get clear definitions; it is necessary to establish whether particular heads are to be included under external or internal costs. To discuss the externality of costs arising from accidents, those involved in the accident should be divided into those who cause and those who are victims of accidents. According to the definition of externality, costs arising from accidents are external when one person causes harm to another person involved in an accident, or to a third party, without providing appropriate compensation. Compensation for the harm suffered may be provided by the person who caused the accident or by an insurance company. The payment compensates the victim of the accident and requires the person responsible to pay the corresponding costs. They replace the price mechanism that is lacking in the case of externalities and are therefore an effective means of reallocation.

- The costs of reproduction where the victim was not the cause of the accident are borne through a "knock-for-knock" process by the person who caused the accident himself or by his vehicle- or third-party insurance. The third-party insurance system and the law on liability therefore internalize them. An exception is made in the case of accidents incurring costs more than the limit of liability laid down in the insurance policy.
- The cost of loss of resources to victims of accidents who were not responsible for them, are also borne by the third-party insurance of the person responsible or by that person himself. It is worked out based on the average income of the victim in the months preceding the accident.
- The costs of reproduction and loss of resources to the person responsible for the accident, which the latter bears himself, e.g. through loss of income, are internal costs.
- The reproduction costs of the person responsible for the accident, which are met by various types of insurance (e.g. health insurance), are borne by a group of insured parties, which does not fully correspond to the group of road users or the group covered by third party insurance. The costs of reproduction are external in that extra costs in the form of higher insurance premiums are incurred by those who do not use road transport.
- The human costs to victims who are not responsible for accidents and to their families are internalized by the payment of damages.
- Costs incurred outside the market (losses in the shadow economy and housework) to victims who are not responsible for accidents are not internalized through insurance and are therefore external.

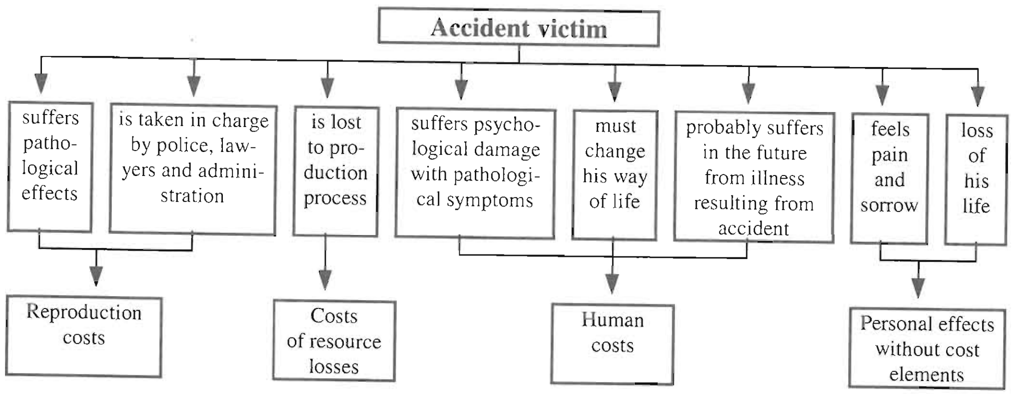
These examples show that accident costs cannot generally be classified as internal or external, but that they need to be viewed with discernment. The separating of such costs into internal and external components from one country to another depends on the way their national insurance systems and laws on liability operate. However, in an evaluation of road safety measures, the total economic cost of road accidents involving casualties would normally be ascertained. The division into internal and external costs is therefore not usually relevant.

2.4 Additional heads: human and extra-market costs

Some consequences of accidents are not accounted for, or only partly, by the costs of reproduction and resource losses. These include, for example, the pain and suffering of the victim, psychological considerations, a diminished capacity to endure stress, and a fall in the quality of life. These consequences are described as human. These human costs are gaining increasing importance in the evaluation of accident costs. They mainly cover damages paid for physical and psychological harm to the victim and his family, lower educational and professional opportunities, and loss of independence, amongst other things. An assessment is required of whether the human consequences can actually be quantified in monetary terms or whether they represent a payment that should not be taken into account for accounting purposes. The calculation of accident costs in some countries (e.g. Great Britain) involves an assessment of the human costs, which are added to the overall costs arising from an accident.

The human consequences of accidents may amount to the loss of productive human resources or a decline in their performance. It is therefore justified to regard human costs as a component part of the overall costs arising from accidents. Human consequences that do not lead to a loss of resources and entail no costs are not to be taken into account in the calculation of costs arising from accidents. Figure 3 shows the distinction.

Figure 3: Distinguishing consequences of accidents and assigning costs

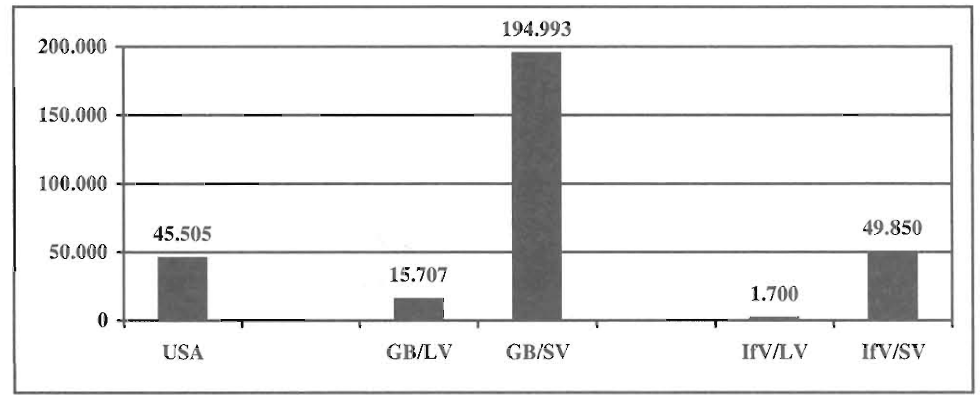


Source: own diagram.

An attempt is sometimes made in the literature to replace the "resources" approach with the "value of life" (*pretium vivendi*) approach (INFRAS, IWW, 1995). A comprehensive evaluation of human life (the "human" as well as the economic aspects) is thereby made. Such an attempt goes beyond establishing the contribution to economic output of the accident victim. It may be an appropriate way of highlighting the personal consequences of accidents, but it does not reveal the economic loss, which is the basis of the cost concept here. The "value of human life" concept should not therefore be pursued as a means of establishing the human cost.

An international comparison (Fig. 4) reveals very diverse findings with respect to human costs. The main causes of this diversity are the different assessment methods ("willingness to pay" approach, "cost of damage" approach) used in different investigations. The results obtained from the "costs" approach used in Germany, based on the cost of damage approach, are the lowest (Baum, Höhnscheid, 1999). The American and British calculations use the "willingness to pay" method. The value for the USA was calculated as the average of the costs for individual injuries of different severity, weighted by the frequency of accidents.

Figure 4: International comparison of human costs (DM)



LV = Minor injury, SV = serious injury, IfV = costs for Germany.
Sources: NHTSA, 1994; Department of Transport, 1996; own calculation.

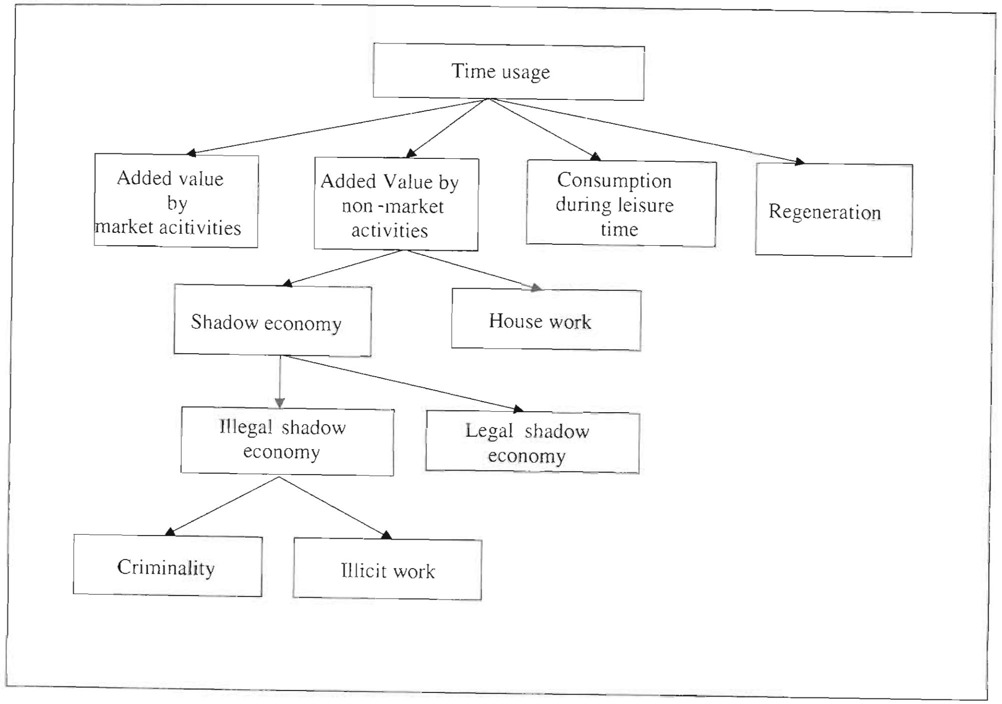
Most calculations of accident costs include only the loss of net product in the markets resulting from accidents. In a national economy, over and above the net product from the market, this appears in the social product, other goods and services are produced outside the market, which do not contribute to the social product. Such extra-market costs must also be factored into the costs of road accidents. Extra-market economic activity is of increasing importance; the shadow economy alone accounts for the equivalent of 10 to 27% of the social product. In determining costs arising from accidents, the corresponding reduction in this part of the net product should also be taken into account. The extra-market activities of private economic players extend to the following areas:

- Housework is carried out in the individual's own household and involves such activities as bringing up children or cleaning.

- The shadow economy covers all services (except housework) that ought to be, but are not included in the calculation of the official social product. The shadow economy may be legal or illegal.

Time is also spent in leisure activities, i.e. use of time that yields no net product (e.g. sporting activity). In determining costs arising from accidents, the legal shadow economy and leisure activities should not be taken into consideration. This is because of lack of information and practical considerations.

Figure 5: Added-value activities of private persons by their time usage



Source: own diagram.

On behalf of the Bundesanstalt für Straßenwesen, the Institute for Transport Economics at the University of Cologne is supplementing the evaluation of accident costs in Germany by factoring in human costs and extra-market net product losses (Baum, Höhnscheid, 1999). The results of the calculation are presented in Chapter 3.

2.5 Macroeconomic basis for the evaluation of accident costs

The economic costs of resource losses are based on the loss of net product by the accident victim. The overall national calculation provides different parameters from which the net product can be determined. As regards the evaluation of road traffic victims this gives rise to three questions:

1) What is the appropriate measurement of the overall contribution to output? Above all it must be decided whether gross or net output is to provide a basis for the evaluation of accident victims.

2) Should the assessment be made based on actual or potential output? Hitherto, road accidents costs have been calculated based on actual output values. Since the end of the sixties production potential has been used in macroeconomic analysis as an indicator of macroeconomic capacity. It is necessary to determine whether a corresponding use of production potential should also be used in evaluating road accidents.

3) To what extent should macroeconomic output performance be attributed to the factor labor or the factor capital? Until now overall productive performance has been ascribed to the factor labor and road accidents have been evaluated accordingly. If a production function is used, it is possible to take account of the different contributions to output of labor and capital.

2.5.1 Overall economic account indicators

The overall economic account determines several characteristic variables, which can be used as indicators of overall economic output:

- Gross net product corresponds to the sum of the output values of all economic sectors (= turnovers) minus their outlay;
- Gross domestic product at the market price is obtained from the gross net product, in that non-deductible turnover tax and import duties are added;
- Net domestic product at the market price is obtained by subtracting depreciation costs from gross domestic product;
- Net domestic product at factor cost (= national income) is obtained by taking net domestic product at market prices, subtracting indirect taxes and adding subsidies.

The production potential itself is not an element in the overall economic account, but is determined by special calculations. The production potential shows the production rate that can be achieved in a national economy with normal utilization of the factors labor and capital. The fact that it only indicates potential distinguishes it from actual output performance variables. In the evaluation of lost output due to road accidents it is necessary to decide which net product indicator should be used as a basis, since it will have a significant effect on the level of costs arising from loss of resources.

2.5.2 Actual output or output potential?

Since the end of the sixties, potential output (= production potential) rather than actual output has been used in some countries to measure the economic efficiency of an economy in quantitative terms. Thus, the European Commission and the OECD, for example, use production potential to indicate economic capacity.

The argument for production potential is based on the view that actual output depends on a variety of various circumstances, e.g. the influence of monetary or financial policy. In order to identify the actual production potential of an economy, it is necessary to consider its supply side. This depends on the availability of both factors labor and capital. The amount and the productivity of the factors determine what an economy can produce in terms of goods and services in a given period with normal utilization of resources, unaffected by economic policy measures. If actual output were a basic factor in the evaluation of road accidents, economic losses would vary depending on whether the economic climate was good or bad.

2.5.3 Evaluation of losses of labor and capital

The factor labor (i.e. the performance of the workforce) is often held fully responsible for down-times in terms of production. In fact, the social product is determined both by labor and by capital. It is therefore necessary to split the economic net product to reflect the different contributions of both factors labor and capital. The consequence of this correction would be a decrease of the resource loss costs. Leaving the factor capital out of consideration would to some extent prove that the accumulation of capital depends on the factor labor. Recent developments in growth theory, however, have emphasized the autonomy of the factor capital, so that a division of the output yield corresponding to both factors seems reasonable.

3. New evidence in accident costs

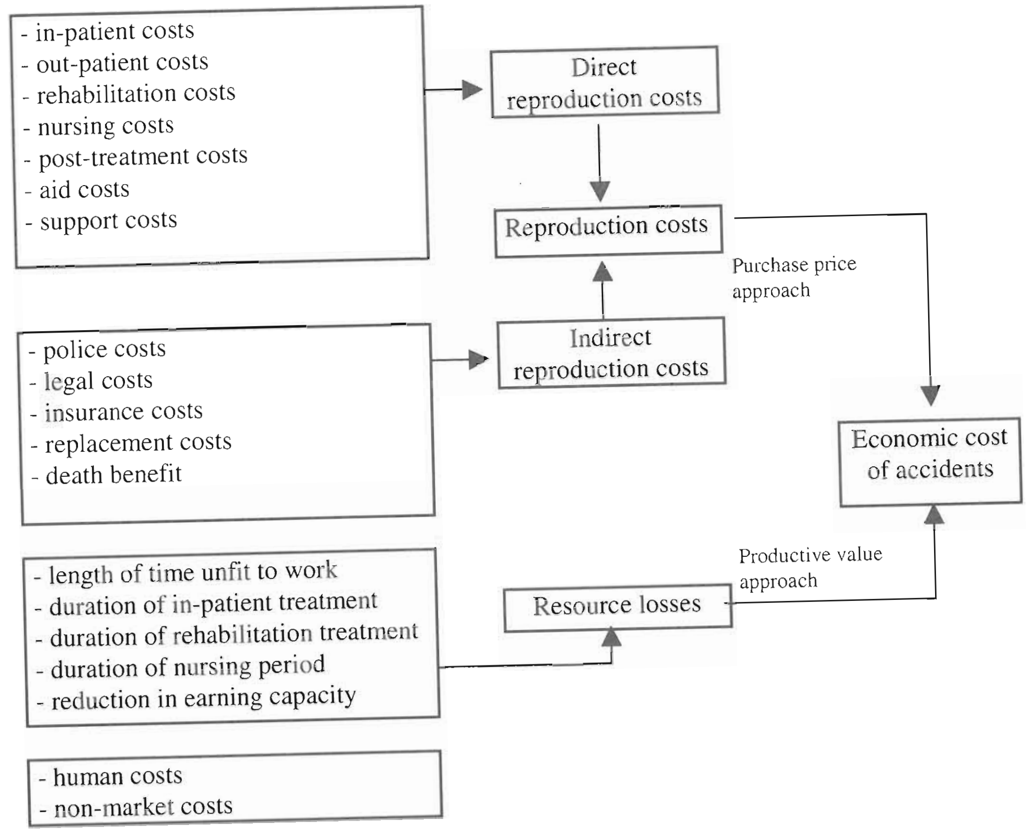
There is new research work, which is concerned with updating and developing the calculation of accident costs and which produces quantitative results. Figure 6 below shows the elements that make up an accident cost analysis and gives the results of the current analysis for Germany.

3.1 Elements of accident cost analysis

In economic analyses of road safety measures, it is important to assess costs arising from accidents – like investment costs. The calculation of the economic costs of road accidents take into account all the consequences of an accident that lead to a loss of net product. The

elements of accident cost analysis are presented in Figure 6. A comparable breakdown can be made for property damages.

Figure 6: Elements of accident cost analysis



Source: own diagram.

1. **Reproduction costs are incurred** where a situation equivalent to the one before the accident is brought about through recourse to medical, handicraft, legal, administrative and other measures.

   – Direct reproduction costs arise from the medical and professional rehabilitation of the accident victim. Medical rehabilitation comprises in-patient or out-patient treatment of the victim, provision of transport and after-care treatment. Professional rehabilitation consists of measures that enable the accident victim to resume his professional activity.

- Indirect reproduction costs arise from the attempt to settle legal matters (police costs, legal costs, and insurance claims).

2. The **costs arising from loss of resources** cover the reduction in economic net product resulting from the fact that persons injured or killed in an accident are no longer able to take part in the production process. The consequence of the death or injury of a person is thus to reduce social product in the future. Moreover, vehicles are damaged or destroyed in road accidents. These vehicles represent real capital. As a result of the damage caused by road accidents this real capital is available to the production process for a reduced period or is permanently disabled.

   Furthermore, road accidents lead to losses other than the loss of net product in the markets. Loss of net product from housework and work in the shadow economy are not reflected in the official social product. Any calculation of the economic cost of accidents must ensure that these losses of net product are also included.

3. At least, do accidents have **human consequences** that lead to a loss of resources:

   - An accident is an experience that can have harmful psychological effects on those involved and their families, for which no pathological symptoms can be identified. This may so limit their capacity to endure stress as to make them unfit for work, and this entails a loss in net product.

   - Many accident victims have to change their way of life because of their experience. This leads to a reduction in productivity.

   - Moreover, when assessing human costs it is necessary to consider the possibility of further unpredictable consequences. These include costs associated with the higher probability of future illness.

Where there is no loss of resources, the human consequences of accidents should not be taken into account in calculating the costs arising from accidents. These mental problems will only be factored in when costs are incurred. The emotional state caused by the experience of an accident (e.g. bereavement) cannot be evaluated in monetary terms.

The human costs are the basis for actual decisions to award damages. The most suitable approach to determining human costs is therefore based on the payment of damages to the accident victim.

3.2 Results of accident cost analysis – The case of Germany

Table 1 shows the actual cost unit rates for personal injuries and property damages for Germany, established annually by the Bundesanstalt für Straßenwesen. By linking costs arising from accidents, grouped according to degree of severity, with the frequency with which they occur in the survey year, the cost to the economy of personal injuries sustained in road accidents can be worked out. The Bundesanstalt für Straßenwesen's computation model is used to determine accident costs, which are broken down according to the severity of the injury (fatal, severe, and slight). Persons killed in road accidents in 1998 accounted for the highest cost: more than 2.3 million DM, of which the costs arising from loss of resources – more than 1.5 million DM – represented the highest proportion. A basic factor in calculating the costs arising from property damages in road accidents is the police estimate of the repair costs. The following table shows the costs arising from personal injury in 1998, according to degree of severity, and from property damages according to the type of accident.

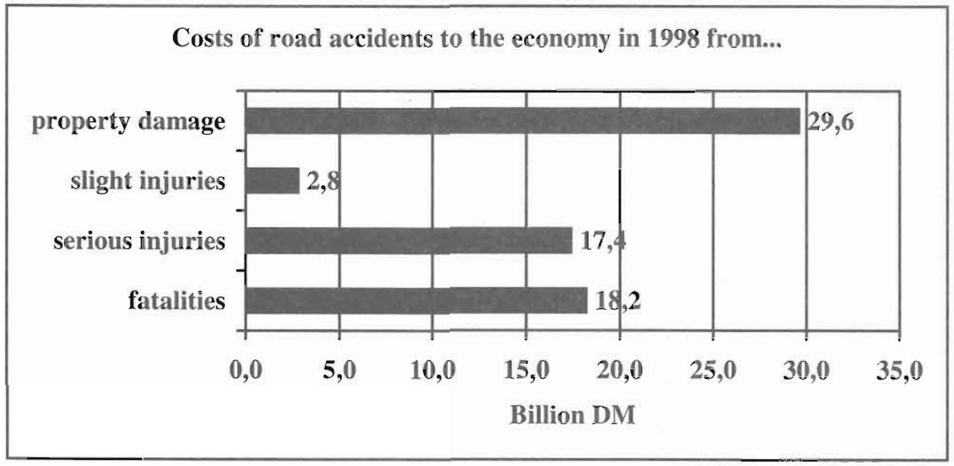
Table 1: Cost unit rates for personal injuries and property damages of road accidents 1998

	Cost unit rates (DM)
Personal injuries	
Fatal	2.333.989
Severe	159.856
Slight	7.139
Property damages	
Accidents with fatalities	49.575
Accidents with severe injuries	24.343
Accidents with slight injuries	17.970
Serious accidents only with damages	24.481
Other accidents with damages	10.981
Other alcohol accidents	8.546

Source: Höhnscheid, 1999; Baum, Höhnscheid, Höhnscheid, Schott, 2000.

The total cost of road accidents to the German economy in 1998 amounted to 68 billion DM (Figure 7).

Figure 7: Cost of road accidents to the German economy in 1998 (in billions of DM)



Source: Baum, Höhnscheid, 1999; Baum, Höhnscheid, Höhnscheid, Schott, 2000.

Personal injuries accounted for 56 per cent of the total costs in 1998 and property damages for 44 %. Total costs arising from personal injuries were more than 38 billion DM, the highest proportion of which were the costs arising from loss of resources, amounting to 26.84 billion DM (Table 2).

Table 2: Accident costs from personal injuries in 1998

	Costs (billion DM)
Reproduction costs	4,67
Resource losses with:	26,84
Direct resource losses	17,89
Shadow economy	2,09
Housework	6,86
Human costs	6,85
Personal injury costs (total)	**38,37**

Source: Baum, Höhnscheid, 1999; Baum, Höhnscheid, Höhnscheid, Schott, 2000.

As to the different categories, fatal injuries cost the economy over 18 billion DM. The overall costs arising from property damages are determined by adding the reproduction costs to the costs resulting from resource losses, as well as the loss of net product from extra-market activity. In 1998, they amounted to over 29.5 billion DM. Other accidents causing property damages accounted for 19,3 billion DM, the highest amount for any individual category.

The results of the analysis of costs arising from road accidents in Germany in 1998 are shown in Table 3.

Table 3: Accident costs by personal injuries and property damages in 1998 (in billions of DM)

Costs by personal injuries	**Costs in billion DM**
Fatal	18,19
Severe	17,41
Slight	2,77
Costs by property damages	
Accidents with fatalities	0,342
Accidents with severe injuries	2,158
Accidents with slight injuries	4,920
Serious accidents only with property damages	2,609
Other accidents with property damages	19,297
Other alcohol accidents	0,227

Source: Baum, Höhnscheid, 1999; Baum, Höhnscheid, Höhnscheid, Schott, 2000.

4. Empirical evaluation of road safety measures

The results of selected investigations into the effect on accidents of traffic measures are presented below. They cover a number of individual measures.

4.1 Identifying the causes of accidents

Road safety is affected by three factors: man, vehicle and infrastructure. The following table shows the most common causes of accidents involving personal injuries. It emerges that human error is a far more frequent cause than technical failure or the condition of the infrastructure.

Table 4: Causes of accidents with personal injuries in Germany (1997)

		Share (%)	
Driver errors		85,4	
of which:	*Driving too fast*		*16,0*
	Right of way, traffic regulations		*11,8*
	Turning, driving on/off, turning around		*11,8*
	Driving too close		*9,3*
	Driving under the influence of alcohol		*5,4*
	Using the wrong lane		*6,1*
	Overtaking, passing		*5,1*
	Disregarding pedestrians		*3,7*
	Other causes		*16,3*
Vehicle failures		0,9	
Pedestrian's failures		5,1	
Road conditions		6,4	
Other		2,1	
Total		100,0	

Source: Bundesministerium für Verkehr (Hrsg.), Verkehr in Zahlen 1998, Bonn 1998, S.173ff.

4.2 Case studies

4.2.1 Active and passive safety measures

The TÜV Rheinland has produced estimates of the potential of safety measures to reduce traffic accidents (Rompe, 1998). They are based on studies of the international literature, expert opinions, and test results. The estimates of the potential for reducing accidents relate to the European Union. This potential is not expressed in monetary terms.

Other possible ways of reducing accidents, which have yet to be quantified, include:

- Improving facilities in vehicles (e.g. driver-support systems, optimized headrests);
- Introduction of underrun protection systems at the sides and rear of trucks;
- Developing vehicle surveillance;
- Improving safety of buses and tanker lorries;
- Improving procedures in case of an accident (e.g. automatic distress call).

Table 5: Potential of vehicle safety measure to reduce road accidents

	Measures	**Potential for reducing accidents**
Active safety	Reduction of average speed on all roads (by 5 km/h)	25%
	Checking blood-alcohol level	8-16%
	Day-time running lights for passenger cars	2-7%
	ABS systems for all passenger cars	3-5%
	Day-time running lights for motorcycles	1%
	Reflective edges for trucks	1%
Passive safety	Crash evaluation program	15-25%
	Higher degree of seat belt-using	15%
	Driver and front seat passenger airbag	5-10%
	Side airbag	3-5%
	Front underrun protection for trucks	3%
	100% usage of protective helmets	3%
	Better protection for pedestrians	2-7%
	Higher usage of child support systems	1%

Source: Rompe, 1998.

4.2.2 Measures for transferring and reducing traffic under established economic framework conditions

Pischinger, Sammer, Schneider *et al.* have checked the effects on the environment of various measures. Their effect on the incidence of accidents was also evaluated. The potential for reduction applies to those injured and those killed. The investigation conducted in 1997 concerned Austria (Pischinger, *et al.*, 1997).

Table 6: Potentials for reducing accidents by 2005

Measures	**Cost-benefit-difference* (in million Sch)**	**Injured**	**Killed**
Speed surveillance	663	-5,2 %	-5,0 %
Speed limit	28.211	-21,3 %	-20,8 %
Parking space management	-906	-0,1 %	-0,1 %
Increasing fuel prices	149.183	-16 %	-16 %
Eco-bonus	144.887	-16 %	-15 %
Road pricing	118.789	-20 %	-19 %
Vehicle access restrictions, Pedestrian zones	-4.363	+0,1 %	+0,1 %

Table 6 (continued)

Measures	Cost-benefit-difference* (in million Sch)	Injured	Killed
Use of cycles ("cycle-friendly city")	42.111	+11,3 %	0 %
Extension of multi-modal transport	-22.071	-0,1 %	-0,1 %
Extension of rail passenger transport	-31.900	-1,8 %	-1,6 %
Extension of public transport	-17.122	-2,7 %	-1,7 %
Logistics	44.953	-0,3 %	-0,5 %
Road guidance systems	-15.307	-1,3 %	-1,2 %
Campaigns to increase awareness	11.208	-5,0 %	-5,0 %

* without CO_2-assessment

Source: Pischinger, et al., 1997.

4.2.3 Accident prevention measures

For Switzerland, the **Beratungsstelle für Unfallverhütung (bfu)** has made national assessments of 22 different safety measures (Eckhardt, Seitz, 1998). Of the 22 measures investigated, 12 have relevance for traffic:

- Two-phase model: three-year probationary period with further training for new drivers, additional instruction for those who fail probationary period;
- Random breath tests for alcohol level: police may carry out breath tests where driver shows no sign of drunkenness;
- Accident data recorder: fitted to all newly registered private cars and motor cycles;
- Speed warning device: fitted to all newly registered private cars.
- Distance warning device: fitted to all newly registered private cars;
- Design of local passages: reducing speed and increasing attentiveness through arrangements to ease traffic on main city center (roundabouts, traffic islands with shrubbery, center islands, etc.);
- Mandatory child support systems: tested restraint systems ensuring the safety of children up to 7 years old;
- Higher control degree: level of police control increased by 50 %;
- ADMAS point system: penalty points for certain traffic offences and temporary confiscation of license when a minimum number of points has been exceeded;

- Cycle and moped training courses: compulsory courses for young persons;
- Higher share of public transport: requirement that 10% of individual motorized transport is transferred to public transport;
- Obligation for cycling helmets: children obliged to wear cycling helmets.

Table 7 shows cost-benefit ratios and cost-benefit differences for the various traffic safety measures.

Table 7: Cost-benefit results of traffic safety measures

No.	Measure	Benefits (in million Fr./year)	Costs (in million Fr./year)	Cost-benefit ratio	Cost-benefit difference (in mill. Fr./year)
1	Two-phase model	109	66	1,6	43
2a	Random breathalyzer tests for alcohol level without blood-alcohol test	227	12	19	215
2b	Random breathalyzer tests for alcohol level with blood-alcohol test	227	14	17	213
3	Accident data recorder	49	83	0,6	-34
4	Speed warning devices	187	162	1,2	25
5	Distance warning devices	113	157	0,7	-44
6	Design of local passages	27	25	1,1	2
7	Mandatory child support systems	5	5	1,1	0,5
8	Higher control degree	26	5	5,5	22
9	ADMAS point system	524	26	20	498
10	Cycle and moped training courses	5	4	1,1	0,5
11	Higher share of public transport	1.122	61	18	1.061
12	Obligation for cycling helmets	40	9	4,7	32

Source: Eckhardt, Seitz, 1998.

4.2.4 Comprehensive traffic safety programs

For the USA, the current results of cost-effectiveness analyses of more than 550 different safety measures are available from Tengs, Adams, Pliskin and others (Tengs, *et al.,* 1995). Table 8 shows the range of costs for different categories of measures required to save one year of a person's life.

Table 8: Cost-effectiveness analyses for different groups of measures

	cost/life-year
Automobile design improvements	≤ $ 0 – 450.000
Automobile occupant restraint systems	≤ $ 0 – 360.000
Helmet promotion	≤ $ 0 – 44.000
Highway improvement	$ 29.000 – 420.000
Light truck design improvements	$ 13.000 – 10.000.000
Light truck occupant restraint systems	$ 14.000 – 67.000
School bus safety	$ 150.000 – 4.900.000
Speed limit	$ 6.600 – 510.000
Traffic safety education	≤ $ 0 – 720.000
Vehicle inspections	$ 1.500 – 1.300.000

Source: Tengs, et al., 1995

The following measures are particularly cost-effective; each of them amounting to less than $100 for each year of life saved:

- Fitting windscreens using adhesive substance rather than rubber seal;
- Automatic rather than manual driver safety belt;
- Compulsory wearing of seat belts;
- Compulsory use of child restraint systems;
- Compulsory wearing of motor cycle helmets;
- Further training for incompetent drivers (rather than withdrawal of their licenses);
- Ban on the sale of three-wheel cross-country vehicles.

4.2.5 Telematics

The Institute of Transport Economics at the University of Cologne has analyzed the effect on safety of the use of telematics (Baum *et al.*, 1994). The results apply to Germany. The evaluation was made using a traffic simulation model.

Table 9: Road safety effects of telematic applications

	Cost-benefit ratio	Accident costs (in mill. DM)
Road guidance systems - Companion	1,1	-12,07
Road guidance - Integrated telematics system	1,6	-361,95
Driver assistance systems for coupling trucks electronically	4,37	-13,42

Source: Baum, et al., 1994.

4.2.6 Measures regarding infrastructure and organization

The Institute of Transport Economics at the University of Cologne has investigated the impact on road traffic safety of measures to improve infrastructure and organization in the context of various research projects (Baum *et al.*, 1994). These assessments were also made using a traffic simulation model.

Table 10: Effects of measures to improve safety on the road

	Cost-benefit ratio	Cost of accidents (in mill. DM)
Integration measures		
Combined transport (BVWP 92)	1,1	-46,73
Freight transport centers	1,9	-9,88
Park and Ride	2,5	-167,21
Organizational measures		
Replacement of own-account transport	8,6	-98,91
Increasing payload	6,4	-103,70
Cooperation (Alternative 1)	3,3	-23,30
Planning trips	1,9	-23,49
Satellite radio	2,6	-4,41
Transport exchange	3,7	-0,55
JIT avoidance	0,3 – 3,2	-50,03
Carpooling (Alternative 2)	1,7	-22,83
Road infrastructure		
Closing gaps	2,2	-88,80
By-pass (dual carriageway)	3,9 – 5,1	-209,49
Continuos building sites	3,4	-0,80
Daytime building sites	0,3	-9,47
Third lane on motorway	5,2	0
Hard-shoulders	0,5	-3,37

Source: Baum, et al., 1994.

4.2.7 Insurance incentives

The possibility of improving road safety by providing financial incentives through insurance systems has not so far been sufficiently exploited. If we consider the insurance systems that are currently found worldwide, two basic types can be identified (Table 11).

Table 11: Characteristics of third-party and no-fault insurance systems

	Third-party insurance	No-Fault insurance
Liability	Person responsible for the accident	No liability
Benefits	Parties injured by policy holder	Victim of accident (= Policyholder)

Source: Baum, Kling, 1997.

The existing motor insurance systems in Europe are based on several charging criteria, such as type of vehicle, licensing authority, and individual claims record (no-claims or bonus-malus system). It is generally agreed that road safety is promoted by the bonus-malus system, which punishes those responsible for accidents with higher premiums and rewards those who are not with lower ones.

A fundamentally different system applies in certain states in the USA and Canada. There, accident victims are compensated by private or public motor insurance institutions, whether or not they were responsible for the accident ("no fault"). At present, no-fault systems exist in 23 states in the USA. Under the system, the injured party loses his legal third party claims upon the person responsible for the accident. It appears that this limitation of liability on the part of the person who caused the accident tends to lead to a rise in the frequency of accidents. Studies that have attempted to identify the effect of the no-fault rule on the incidence of accidents, have concluded that the number of accidents and accident victims has risen (Sloan *et al.,* 1995, p. 72 ff.); furthermore, the number of fatal accidents has increased (Cummins, Weiss, 1991, p. 22).

To be able to estimate the effects of insurance schemes, a standardized expert survey was conducted as part of a study carried out by the Institute of Transport Economics at the University of Cologne. The respondents had to name the five instruments that in their opinion had the greatest effect on traffic safety. The answers to this question were very much in line with the assessments of the individual measures. The respondents as a whole ranked the instruments as follows (see Table 12).

All those surveyed felt that taking account of the points record when assessing tariffs had the most significant effect. After that came two instruments intended to achieve a more distinct, more individual liability, namely the closer identification of the driver of the vehicle and the excess motor insurance. At the lower levels were the different arrangements geared to kilometer performance and the general rise in premium levels.

Table 12: Ranking of safety measures in order of effectiveness

Ranking	Measures
1.	Taking points record into consideration
2.	Closer identification of the driver of the vehicle
3.	Self-participation in the insurance system
4.	Reimbursement of payment
5.	Money gratuities and special gifts for driving without accidents
6.	Savings scheme models
7.	Refusal to pay in cases of roughly negligent behavior
8.	Promotion of safety technologies
9.	Greater spread of the bonus-malus system
10.	Extension of possibility of compensation
11.	Greater differentiation of premiums
12.	Contracts based on annual vehicle-kilometers
13.	Variable insurance premiums
14.	General rise in premium levels

Source: Baum, Kling, 1997.

4.2.8 Local incentive schemes

In 1981, **France** set out to reduce the fatality rate by a third, from 45 to 30 deaths per billion vehicle-km, within five years. To this end, responsibility for road safety was to be largely transferred to those able to exert influence on the incidence of accidents at local level (Brühning, 1985, p. 30 ff.). Accordingly, two programs were initiated in 1982-83:

- "REAGIR" (Réagir par des Enquètes sur les Accidents Graves et par des Initiatives pour y Remédier) provides for the investigation of every serious accident by a multidisciplinary commission. The concluding report, drawn up jointly, is supposed to reconstruct the accident as far as possible and offer suggestions in the light of presumed causes of the accident;

- With the program "MINUS 10%", the number of accidents involving personal injury was expected to fall by 10% per year. The state entered into agreements with larger municipalities (populations more than 50.000) and Departments, under which the latter undertook to improve road safety. The state provided the following grants for this purpose:

- a one-off payment corresponding to 1 FF per inhabitant, regardless of success, amounting to at least 100.000 FF, and at most 500.000 FF;

- in the event of the -10% target being reached within a year, an award for each accident avoided of 20.000 FF in rural areas and small villages (competence of the gendarmerie) or 10.000 FF in other municipalities (competence of the police).

In the period 1983 to 1988, around 372 million FF were set aside, of which 12% was to pay participants and 88% to reward success. Table. 13 shows that MINUS 10% proved to be a success.

Table 13: Success rates of "MINUS 10%" program in France

Year	Status	Administrative areas: Departments	Cities	Other	Total
1	Participating	90	79	23	192
	Target reached (1x)	71	74	21	166
	Success rate	79%	94%	91%	86%
2	Participating	70	74	21	165
	Target reached (2x)	20	45	10	75
	Success rate	29%	61%	48%	45%
3	Participating	19	41	9	69
	Target reached (3x)	2	19	4	25
	Success rate	11%	46%	44%	36%
4	Participating	1	15	3	19
	Target reached (4x)	0	3	1	4
	Success rate	-	20%	33%	27%

Source: Schlabbach, 1991.

Of the departments and local authorities taking part, one of them (Soissons) actually managed to achieve the 10% reduction level five times. The figures nevertheless show that longer-term programs – lasting several years – and substantial financial resources are required for significant improvements in road safety. It also emerges that the potential for improvement diminishes after the scheme has been in progress several years and "natural" limits to accident prevention seem to become apparent (Schlabbach, 1991, p. 146 ff.). In mid-1989 the MINUS 10% was abandoned and replaced with an information and training scheme.

Austria followed the French example and implemented a similar program (*Aktion Minus-10-Prozent weniger Verkehrsunfälle*), in which the district authorities were to participate. The Austrians, however, took the view that the commitment of those involved should not be bought with financial benefits and instead success was repaid with honors and distinctions, and with benefits in kind. The object was to reduce the number of accidents (from the average number for 1984 and 1985) by 10% per year. All 121 district authorities took part (Schlabbach, 1991). The results of the scheme are by no means clear. Although the number of accidents fell by 4.1% in the first six months of the scheme (second half of 1986), the influence of "Minus 10%" could not be demonstrated. In the second year of the scheme, however, the number of accidents increased by 3.6% and fatalities by 13.1%.

4.2.9 Assessing the problems of dealing with organs

Since 1997, a new law on transplants, regulating the removal and transplanting of organs, has been in force in Germany. Amongst other things, this law forbids trade in organs. It is not certain how organ transplants and the law on transplants affect costs arising from accidents or whether the incidence of accidents has any effect on the cost of transplants (Baum, Höhnscheid, 1999). In road accidents causing serious personal injury the effects are twofold:

- Injuries may be sustained that can only be treated by means of a transplant. In that case, accidents victims are demanders of organs; the corresponding costs must be considered as reproduction costs when the costs arising from the accident are calculated;

- In road accidents with fatal consequences, accident victims may end up as organ donors. Organ donations can save lives and the survival of the recipient can lead to a reduction in the costs due to loss of resources. Researchers need to determine whether this reduction of costs is to be regarded as a possible economic benefit of road accidents.

With the development of medical science, the transplantation of certain organs has now become a normal part of medical care. Organ transplants have different effects on costs resulting from accidents:

- There is considerable excess demand for organ transplants; i.e. the demand for replacement organs cannot be fully satisfied, or only after a long delay. This often results in higher treatment costs; regular dialysis is required, for example, until a replacement kidney becomes available (Table 14).

Table 14: Costs of dialysis and kidney transplants

	Costs
Dialysis, annual	45.000 - 90.000 DM
Kidney transplant, one time	50.000 DM
After-care costs, annual	15.000 - 20.000 DM

Source: Arbeitskreis Organspende, 1995.

- The effect of organ transplantation on the economic cost of accidents is relatively low. The injuries most often sustained in road accidents cannot be treated by means of a transplant. Table 15 shows the injuries from accidents that entail the highest economic costs.

Table 15: The most cost-intensive injuries (in mill. DM)

	Economic cost (mill. DM)
Closed fracture of the femur	214
Contusio cerebri	158
Closed fracture of the tibia	145
Fracture of the vertebrae	120
Closed fracture of the foot	89
Closed fracture of the shoulder joint/head of humerus	84
Open fracture of the tibia	84
Closed fracture of the elbow, forearm bones	64
Commotio cerebri	58
Torn knee	35

Source: Mattern, et al., 1988.

Transplants are not shown as a separate item on the list of reproduction costs owing to their minor significance in accident costs. They are accounted for under medical treatment costs.

Anybody killed in an accident is a potential organ donor. The organs from fatal accident victims represent an increase in supply, which could have the effect of lowering costs.

- With the greater supply of donated organs, there is an increase in the number of persons having organ transplants, who are thus able to survive. As a result, there is a fall in costs due to loss of human resources, i.e. of persons who would not have survived without the donated organs;

- An organ transplant may well entail lower reproduction costs than a protracted alternative treatment (e.g. dialysis);

- Today many organ transplants still present challenges to medical science. With the increase in the number of operations, made possible by accidents, staff carrying out operations and those conducting research are able to learn more.

The beneficial effects of accidents are, however, subject to various limitations:

- Not all those killed in accidents are potential organ donors. Only a certain number of accident victims may legally be used as organ donors. Of this number a further proportion of the fatally injured have to be ruled out, since their body parts have been so badly damaged in the accident that there can be no question of using them for transplantation purposes. It must nevertheless be recognized that even a small number of fatally injured persons with organs suitable for transplantation represent a significant increase in the organ supply, given the number of transplant operations carried out in Germany every year. Moreover, an accident victim might serve as a donor of different organs;

- Hitherto, certain types of organ transplantation have only guaranteed the short-term survival of the recipient. There is no certainty that he will become fit to work again. If the organ recipient remains unfit for work, the donation of organs does not lead to a fall in the costs arising from lack of resources;

- As regards the cost of treatment, it is not clear whether organ transplants lead to cost savings. The costs of after-care treatment of organ recipients have to be seen in relation to the cost of the very short courses of treatment that patients who have not received a new organ are often given throughout their lives.

Furthermore, there are serious ethical objections to interpreting the loss of a human life as a "benefit". The protection of human life is recognized as the highest ethical goal by society. Calculation of costs arising from accidents is not done for its own sake. Rather, these costs provide a source of information on which to base traffic policy, whose most important concern in the field of road safety is the protection of human life. To interpret death as beneficial therefore offends not only the common values of society, but also discredits the trend in research into accidents costs as the economic basis of road safety measures.

4.3 Comparability of road safety measures

The results of these case studies on the effectiveness of road safety measures cannot always be easily compared:

- Studies of the costs arising from road accidents reveal considerable differences in scope and composition. For example, property damages is often not taken into account in the calculation of accident costs, although they account for a considerable proportion – over 40% – of overall costs;

- Differences in accident cost levels also result from the fact that the cost components and evaluation procedures used in the calculations are not always the same. Assessments based on willingness-to-pay surveys normally lead to substantially higher valuations of casualties than other methods;

- The origin of data is not always clear from studies, which makes comparison and judgement difficult. The information available for assessing the measures is sometimes incomplete. The functional connections between traffic parameters (e.g. kilometer performance, speed) and the frequency and seriousness of accidents are not always apparent. These are, however, important factors in assessing the validity of the results;

- The studies and the results concern different countries. The extent to which the results obtained can be applied to other countries is open to question. In this connection, the comparability of situations should be checked and, where appropriate, weighting should be introduced to offset any differences. Examples of differences between countries are to be found *inter alia* in legal regulations (requirement to wear seat belt, helmet) or financial incentives in insurance arrangements.

The reductions shown in the studies should be understood as potential reductions, while the actual results of the reduction in accident numbers should be empirically investigated. Furthermore, the overall assessment of road safety measures must include effects that cannot be measured in terms of allocations (costs or benefits). These include in particular the distributive and social effects of road safety measures.

4.4 Conclusion

The many and varied international assessments show that the implementation of certain road safety measures could develop the potential for safety even further. This potential is associated with technological and legal measures, as well as those that address behavior:

- The introduction of a points register has produced one of the best cost-benefit results. This regulation is already being successfully applied in Germany. Moreover, further improvements can be expected from a link between the points record and insurance premium levels;

- As regards legal measures, the requirement to wear seat belts and helmets is proving to have a significant effect on road safety while also being more cost-effective;

- A further tightening of blood-alcohol tests is also regarded by many experts as an effective way of improving road safety;

- Various measures that increase the share in the modal split of less hazardous means of transport also show promise. These are mainly public transport systems. The problem lies in ensuring that that the increase in safety is not offset by a fall in quality;

- If the accident reduction target alone is considered, we might expect speed restrictions to have a significant effect on road safety. Unfortunately, the available data on the cost-effectiveness of speed restrictions are insufficient. Investigations carried out in the USA – the broader relevance of which is by no means certain – suggest that such a measure would lead to higher costs, resulting mainly from loss of time;

- Technological innovations also promise further improvements in road safety. This involves measures taken both inside and outside the vehicle. The critical point is that technological improvements are often associated with significant costs, which mean unsatisfactory cost-benefit ratios;

- Studies of the cost-effectiveness of measures that affect behavior are comparatively rare. Nevertheless, some studies of campaigns to increase awareness reveal positive results, showing a fall in the number of casualties as well as good cost-effectiveness. Particular stress is placed on the effectiveness of the special training given to incompetent drivers.

5. Prospects for further evaluation procedure

A modernized evaluation procedure has to meet different demands and address outstanding questions:

1) In all calculations of accident costs and economic assessments of road safety measures, it is essential that data should be highly transparent. Every stage in the calculation and assessment process must be comprehensible, so that, for example results from different countries can be compared.

2) Establishing a quantitative framework for reviewing accidents can still present serious problems. It is not always possible to quantify the connection between the effect of safety measures and the incidence of accidents. This is true inter alia of measures designed to influence behavior, whose effects on the incidence of accidents can seldom be isolated. However, these very measures are of increasing importance in the field of traffic policy. In particular, it is difficult to establish a clear relationship between the causes of accidents, the effects of accidents and the effects of road safety measures, because the incidence of accidents is due to a wide range of factors.

3) A further problem arises from the fact that the numbers of cases, whether those involving casualties or property damages, are often simply estimated. Therefore, the costs themselves are underestimated. False estimations may result from problems of definition or recording. In calculating the cost of accidents, an attempt should be made to keep the number of estimated figures as small as possible.

4) A great variety of cost accounting methods and assessment procedures are used across the world to provide answers to questions that arise in the context road safety. A greater

convergence and harmonization of the different procedures is definitely needed. This presupposes an international economic consensus on the most effective approaches.

5) The question of the extent to which human suffering should be taken into account in the economic evaluation meets with a different response in different countries. Whereas Germany consistently gears its evaluations to the question of resources, other countries also take account of the human consequences of accidents that are unrelated to any loss of resources.

6) In the case of resource losses caused by road accidents, a problem arises from the fact that casualties fall into different employment categories (full-time or part-time workers, unemployed persons and housewives). In face of the constant change in employment arrangements (e.g. part-time employment) or chronic unemployment, an assessment should be made of the extent to which the costs of accidents affect the situation in the labor market. A distinction should be made here between short-term, economic developments (e.g. short-time work, short-term part-time work, cyclical unemployment) and structural changes to the labor market (e.g. a rise in natural or structural unemployment, or a permanent increase in part-time work at the expense of full-time work).

7) An assessment of the resource losses is necessary when children and young people are the casualties. In some calculations they are included in the costs of upbringing and education. This means that the costs are underestimated. The evaluation must take into account the overall contribution of children and young people to net product if they had not been involved in accidents. The socio-demographic structure of casualties must be, however, reflected in the evaluation. An evaluation that ignores the age distribution of the accident victims leads to false signals for the transport policy.

8) Individuals cost items require constant updating and extrapolation. Costs should take into account the current state of relevant factors. If, for example, a long-term care insurance policy creates a new market for nursing services, which would presumably be accompanied by a greater demand for services, this would have to be considered in the reproduction costs. Other changes in reproduction costs result, for example, from measures to reduce costs in the health sector.

9) Environmental and congestion costs resulting from road accidents have not been considered so far. Congestion costs as element of the time costs, which arise for the other road users because of an accident, have to be calculated. Environmental costs arise, for example, where an accident involving vehicles with dangerous goods pollutes surface and ground water or damages flora and soil. Environmental costs also arise as a result of the extra emission when traffic is congested as a result of an accident. Time losses and damages of the environment because of accidents should also be considered in the assessment of road safety measures.

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Verkehr und/oder Telekommunikation? – Eine Untersuchung zu physischen und virtuellen Raumüberwindungsprozessen

VON DIRK VALLEE, STUTTGART UND STEFAN KÖHLER, RAVENSBURG

1. Einleitung

Die Entwicklung und zunehmende Verbreitung moderner Kommunikationsmedien übt einen immer stärkeren Effekt auf das aktionsräumliche Verhalten von Individuen aus. Damit wird es für die Verkehrswissenschaft und die Raumforschung zunehmend zur Aufgabe, die physischen und virtuellen Raumüberwindungsprozesse der Menschen zu untersuchen und erfassen, um sie dann nachvollziehen und abbilden zu können. In der Verkehrswissenschaft lagen anfangs die Schwerpunkte stärker auf Fragen des Schienenverkehrs und der Automobilität, später wurden dann der ÖPNV und letztlich dann auch der Fahrrad- und Fußgängerverkehr in wissenschaftliche Fragestellungen mit einbezogen. Jede dieser Forschungen hat das Verständnis der Entwicklungsprozesse im Mobilitätsverhalten von Individuen verbessert.

Mit der inzwischen fast flächendeckenden Verbreitung und zunehmend auch privaten Nutzung der Kommunikationsmedien, insbesondere Internet, e-mail, Telefax, Mobiltelefon, ist die Verkehrswissenschaft aufgefordert, diese Kommunikationsprozesse neben dem physischen Verkehr als virtuellen Verkehr mit einzubeziehen (vgl. Abb. 1).

Die in dieser Abhandlung vorgestellten Untersuchungsergebnisse sind Resultate eines Forschungsprojektes der Autoren zusammen mit dem Institut für Verkehrswesen der Universität Karlsruhe (Prof. Dr.-Ing. Dirk Zumkeller) im Auftrag der Landesarbeitsgemeinschaft Baden-Württemberg der Akademie für Raumforschung und Landesplanung /1/.

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