
# THE HANDBOOK OF ROAD SAFETY MEASURES

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# PART II

# GENERAL-PURPOSE POLICY INSTRUMENTS

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# O.0 INTRODUCTION AND OVERVIEW OF 14 MEASURES

This section of the book deals with general purpose policy instruments affecting road safety. A distinction is made between 14 types of measures

O.1 Organisational measures
O.2 Information for decision makers
O.3 Quantified road safety targets and targeted road safety programmes
O.4 Safe community programmes
O.5 Exposure control
O.6 Land use plans (urban and regional planning)
O.7 Road plans and road construction
O.8 Road safety audits
O.9 Motor vehicle taxation
O.10 Road pricing
O.11 Changes in the modal split of travel
O.12 Road traffic legislation
O.13 Regulating commercial transport
O.14 Provision of medical services

In this introductory chapter, the main points in current knowledge of how these policy instruments affect traffic safety are summarised.

## Characteristics of general purpose policy instruments

The term general-purpose policy instruments, refers to policy instruments that are applied in many areas of public policy. An important characteristic of such measures is that the objectives are very complex. Improving road safety is not the only objective, and in many cases, it is not the most important objective of these measures. For example, some of the objectives in controlling land use in society through urban and regional planning include protecting areas of unspoilt nature and valuable landscape areas, encouraging business development in the municipality, reducing energy consumption and air pollution and improving road safety. These objectives are sometimes conflicting. It is rarely possible to accomplish all of them fully in a single land use plan.

Partly as a result of these complex objectives, the measures are also somewhat complex. They come in different forms and in different varieties. Using land use plans as an example there is a range from general master plans to more detailed plans of various types, which designate land use for large or small areas, and for short or long periods of time. Thus, referring to "land use plans" as a single measure is somewhat misleading. In reality it comprises a range of measures.

The complex character of the general-purpose policy instruments makes it difficult to generalise about their effects. The effects depend on the way in which these measures are designed and used. From a road safety perspective, general-purpose measures differ from other road safety measures by trying to influence traffic volume, the modal split of transport, or both.

Some of these measures are concerned with the design of the institutional framework for road safety policy. Such measures are intended to affect the objectives which government sets for road safety or the amount of resources allocated to road safety measures and the type of information used to make decisions about road safety measures. It is obvious that the causal relationship between institutional measures and the number of accidents and injuries is extremely complex and consists of many steps. This does not mean that institutional measures are unimportant and do not affect road safety. However, it does mean that it is very difficult, and perhaps not particularly meaningful, to quantify the effects of such measures on accidents and injuries.

Nonetheless, for some measures it is meaningful to quantify the effects on the number of accidents and injuries. In the following section, the main features of current knowledge about the effects of these measures on the numbers of accidents and injuries are summarised.

## Amount and quality of research evaluating the effects of general purpose policy instruments

The amount and quality of research, which has evaluated the effects of general-purpose policy instruments on the number of accidents and injuries varies considerably. The most comprehensive research refers to land use plans, road plans and regulating commercial transport. Comprehensive research has also evaluated the relationship between traffic volume and the number of accidents. The relationship between the modal split of transport, and the number of accidents has been less well studied.

Meta-analysis has been used to summarise knowledge of the effects of the measures for quantified road safety targets and road safety programmes, safe community programmes, exposure control, land use plans, road plans, changes in the modal split of transport, road traffic legislation, regulating commercial transport and the provision of medical services. There is no basis for using meta-analysis for the remaining general-purpose policy instruments. Table O.0.1

shows the amount of research, which has evaluated the effects of general-purpose policy instruments on road safety.

*Table O.0.1: Overview of the number of studies, number of results and statistical weights for studies of the effects of general purpose policy instruments on traffic safety.*

| Measure | Number of studies | Number of results | Statistical weights |
|---|---|---|---|
| O.1 Organisational measures | 7 | 7 | 0 |
| O.2 Information for decision makers | 11 | 11 | 0 |
| O.3 Quantified road safety targets and targeted road safety programmes | 1 | 35 | 71,716 |
| O.4 Safe community programmes | 7 | 20 | 28,119 |
| O.5 Exposure control | 11 | 76 | 700,800 |
| O.6 Urban and regional planning | 12 | 50 | 1,680 |
| O.7 Road plans and road construction | 10 | 16 | 0 |
| O.8 Road safety audits | 4 | 4 | 0 |
| O.9 Motor vehicle taxation | 3 | 24 | 0 |
| O.10 Road pricing | 9 | 9 | 0 |
| O.11 Changes in the modal split of travel | 7 | 66 | 85,183 |
| O.12 Road traffic legislation | 1 | 9 | 8,711 |
| O.13 Regulating commercial transport | 6 | 18 | 186,468 |
| O.14 Provision of medical services | 31 | 70 | 813 |

All the studies, which have evaluated the effects on road safety of general-purpose policy instruments are non-experimental and are not always of a particularly good methodological quality. This means that the knowledge of these effects is somewhat uncertain. It may seem somewhat surprising that the effects of general-purpose policy instruments are not better known. These measures are potentially amongst the most drastic that can be taken to affect the number of accidents. However, as mentioned above, these measures are highly complex and sometimes affect the number of accidents or injuries only indirectly. Furthermore, they do not lend themselves very easily to randomised controlled trials. This means that it is more difficult to evaluate the effects of general-purpose policy instruments than it is to evaluate the effects of smaller, simpler measures.

## Main elements in effects on accidents

General-purpose policy instruments have varying effects on accidents. As far as organisational measures and information for decision makers are concerned, the effect on accidents is unknown. The relationship between these measures and the number of accidents is too indirect to be meaningfully measured.

Quantified road safety targets and targeted road safety programmes have been found to be associated with a small improvement in road safety performance. This results is, however, very uncertain and it has been difficult to evaluate the effects of quantified road safety targets and targeted road safety programmes in a sufficiently rigorous manner to get credible results.

Local community safety programmes have been found to reduce the number of accidents in these communities significantly. However, not all local community safety programmes are successful. To succeed, a community needs good local accident statistics, a capability to identify the most important local accident problems and ways of creating a strong motivation for improving safety. These conditions do not always exist.

Traffic volume is the single most important factor affecting the number of accidents. Studies indicate that the number of injury accidents will increase by around 80% when traffic increases by 100%. The number of fatal accidents will increase by around 25% when traffic increases by 100%.

Land use plans and the pattern of land use in an area can affect the number of accidents by influencing traffic volume, the modal split of traffic, how traffic is distributed between various roads and the accident rate for each road or each mode of transport. An international comparison indicates that the development pattern in Norwegian towns and cities is relatively demanding in terms of transport. Traffic separation in residential areas has been found to reduce the accident rate. Designing access roads so that speed is kept low also contributes to reducing the number of accidents.

Road plans and road construction can also affect the number of accidents by influencing traffic volume, the distribution of traffic on the road network and the accident rate of each road. Increasing road capacity in areas with capacity problems on the road network can generate more traffic. New roads are usually safer than old roads. The net effect of road construction on the number of accidents thus depends on which partial effect is strongest: increased traffic or reduced accident rate per km driven.

Road safety audits are systematic checks to ensure that road and traffic facilities are designed in such a way that they do not create unnecessary hazards to traffic or contain defects, which can easily be corrected. Experiences with road safety audits in Denmark and Great Britain are very favourable.

Taxes on the purchase, ownership and use of motor vehicles affect the numbers of vehicles and the use of each vehicle. The more expensive it is to own or use a vehicle, the lower the usage. In this way, motor vehicle taxation affects both traffic volume and its composition. If there were no vehicle taxes in Norway, the number of kilometres driven per vehicle would increase by around 30 - 40%.

The costs to society of using motor vehicles vary considerably in time and space. For example, the costs of driving in a queue are considerably higher than when each driver can choose his speed. Motor vehicle taxation does not fully reflect these variations in costs. Road pricing is payment for the use of a specific road. Road pricing systems can be designed to take into account variations in costs between types of roads and over the 24 hours period for a given road. For the time being, experiences with road pricing are limited. The effect on road safety of road pricing would depend on how the system is designed. In Norwegian cities where toll rings or local fuel taxes have been introduced (Oslo, Bergen, Trondheim, Tromsø) both traffic volume and the number of accidents went down when such taxes were introduced.

The risk of injury varies considerably between different means of transport. High risks are associated with walking, cycling or riding mopeds or motorcycles. Passengers using public transport have a low risk. Drivers and passengers of private cars also have a relatively low risk. Comparing the risk between different forms of transport is difficult due to the different levels of under-reporting of accidents in official statistics. A transition from individual to public transport in large cities may reduce the number of injury accidents. Model simulations based on Norwegian estimates of injury risk also indicate that a reduction in the number of police reported injury accidents is likely when a higher proportion of journeys made by public transport, but that there may be an increase in the number of unreported falls amongst pedestrians. Pedestrian falls are not counted as a road traffic accident in official accident statistics. Major changes in the number of accidents as a result of a change in the modal split of transport are nonetheless difficult to imagine, because it is difficult to achieve major changes in the modal split of transport.

Road traffic legislation includes a number of acts and regulations. The effects of such legislation on the number of accidents depend on (1) the risk represented by the actions or risk factors subject to legal regulation, and (2) the level of compliance with the legislation. It has been estimated that number of injured persons in traffic in Norway could be around 27% (± 18%) lower if perfect compliance with current legislation was realised. The number of road accident fatalities in Norway could be 48% (± 30%) lower assuming 100% compliance with road traffic legislation.

Commercial transport has to a large extent been deregulated in the last 15 - 20 years. Studies from a number of countries do not indicate that the deregulation of commercial transport has significantly affected the number of road accidents.

Provision of medical services has improved over the last 20 - 30 years. Studies of ambulance services indicate that improvements, such as shorter response times, increase the probability of surviving an accident.

### Main elements in effects on mobility

Improving accessibility and mobility is an important objective of many of the general-purpose policy instruments, including land use plans, road plans, road pricing and legislation of road traffic. When road capacity increases, or when a new road with a better design than the existing road is built, mobility is improved. Road pricing which leads to less, or more evenly distributed, traffic improves mobility for remaining traffic. An increase in the number of people who use public transport will also improve mobility, at least to the extent that it reduces the amount of car traffic. The existence of speed limits probably means that the speed level is lower than it otherwise would have been. Vehicle taxation and road traffic legislation reduce travel demand, in that they increase road users' generalised travel costs (i.e. the sum of direct expenses of travel and all other sacrifices or disadvantages of travel).

### Main elements in effects on the environment

Measures curbing travel demand contribute to reducing all the environmental impacts of traffic that are proportional to the amount of road traffic. This is true of the bulk of environmental problems attributable to road traffic, including noise, barrier effects, air pollution, fuel consumption and land use. Measures reducing traffic congestion also reduce environmental problems, primarily air pollution. Limiting traffic volume in residential areas is a highly valued environmental benefit, which not only contributes to less noise and pollution, but also to increased safety and a more pleasant environment in a wide sense. The actual environmental effects of the general-purpose policy instruments are not very well documented.

### Main elements in costs

The costs of the general-purpose policy instruments are difficult to estimate. One of the problems is that these measures have complex goals. The costs therefore ought to be allocated between the different goals, according to their importance. There is too little information available to make such an allocation possible. In table O.0.2 the total costs of the general-purpose policy instruments are shown, to the extent that they are known. The table shows that the costs of these measures are substantial.

A distinction is made between three types of costs of general-purpose policy instruments: (1) administrative costs, including the cost of developing land use plans and road plans and for collecting vehicle taxes; (2) implementation costs, which includes the costs of implementing land use plans, road plans or other measures and (3) financial transfers, which includes the payment of vehicle taxation and toll fees. The cost figures in table O.0.2 are taken from easily accessible sources and are not an adequate estimate of the social opportunity costs of the measures (i.e. the value of the resources consumed).

*Table O.0.2: Cost of organisational measures, Norway. Million NOK 1995.*

| Measure | Amount in mill NOK 1995 | | |
|---|---|---|---|
| | Administrative costs | Implementation costs | Transfers |
| O.1 Organisational measures (1) | 5 | | |
| O.2 Information for decision makers | | 20 | |
| O.3 Quantified road safety targets and road safety programmes (2) | | 189 | |
| O.4 Safe community programmes (1) | | 5 | |
| O.5 Exposure control (3) | | | |
| O.6 Urban and regional planning (4) | 324 | 3, 316 | |
| O.7 Road plans and road construction (5) | 330 | 4,256 | |
| O.8 Road safety audits (1) | 10 | 50 | |
| O.9 Motor vehicle taxation | 653 | | 29,581 |
| O.10 Road pricing | 128 | | 1,037 |
| O.11 Changes in the modal split of transport (6) | | | 4,478 |
| O.12 Road traffic legislation | | 659 | |
| O.13 Regulation of commercial transport | 85 | | |
| O.14 Provision of medical services | | 235 | |

(1) Approximate calculation of the order of magnitude of the costs

(2) The figure refers to costs of special traffic safety measures in the Norwegian road and road traffic plan 1994-97

(3) The costs are entered under other measures, including land use plans, road plans, vehicle taxation and road pricing

(4) Implementation costs are the municipalities' spending on transport and communications

(5) Implementation costs are grants for national highway investments, special road safety measures excepted.

(6) National and county council subsidies for the operation of public transport.

The costs of legislation include the costs of enforcement and sanctions. The costs shown for medical services include the costs of the national air ambulance service.

## Main elements in cost-benefit analyses

It is not feasible to carry out meaningful cost benefit analyses of general-purpose policy instruments on the basis of current knowledge. Firstly, the effects of these measures are quite uncertain, as has already been stated. Secondly, the costs are not really known. Thirdly, the effects of the measures on other policy objectives than improving road safety are only partly known. The cost benefit analyses, which can be made can be summarised as follows.

Quantified road safety targets and targeted road safety programmes have a high benefit cost ratio, provided the road safety programmes contain long-term measures that are known to reduce the number of accidents. The same applies to local community safety programmes.

The costs and benefits of land use plans and road plans depend on the content. Road construction is usually most cost-effective when there is a high traffic volume and severe problems connected with traffic (high risks, congestion and environmental problems).

A Danish study calculated the benefits in the first year of 13 road safety audits to be DKR 19.9 million. The costs were estimated to be DKR 13.6 million.

The cost-effectiveness of vehicle taxation and road pricing depend on the size of the external effects of road traffic. External effects refer to the disadvantages of road traffic in terms of accidents, congestion and environmental problems. When these external effects are severe, it is cost-effective to curb traffic demand or to distribute traffic more evenly in time to reduce these effects. According to an analysis carried out by Statistics Norway, current Norwegian vehicle taxation is cost-effective, i.e. the benefits of a reduction of accidents and environmental problems, attributable to this taxation, are greater than the loss of benefits from suppressed traffic demand. Introducing road pricing in Oslo, Norway, would also be cost-effective.

Similar points of view apply with regard to road traffic legislation. If having no legislation encourages dangerous behaviour or behaviour that damages the environment, it is cost-effective to try to reduce the incidence of such behaviour by means of legislation. A number of elements of road traffic legislation are cost-effective. The costs and benefits to society of regulating commercial transport depend not only on how such legislation affects the external effects of transport, but also on how it affects transport prices. In practice, the regulation of commercial transport can easily turn into protection for producers at the expense of consumers. One effect of such regulation may be that prices are higher than they otherwise would have been. Analyses indicate that that the deregulation of the transport market, which has taken place in a number of countries in the last 15 to 20 years, has been cost-effective.

Subsidising public transport is normally cost-effective in city areas where roads are congested and the external effects of transport are large.

Cost benefit analyses indicate that the provision of ambulance services is cost-effective.

## O.1 ORGANISATIONAL MEASURES

### Problem and objective

The responsibility for developing and implementing road safety measures is usually divided among a number of governmental agencies at the national, regional and local level. An extensive division of responsibility can make it difficult to implement road safety measures in the most cost-effective way.

The objective of organisational measures are to ensure that adequate resources are available for road safety purposes based on the targets and priorities set by the authorities, and to ensure the most effective utilisation of these resources, through an appropriate division of work and responsibility. Organisational measures should also ensure that road safety measures are not unintentionally given low priority due to a lack of clarity in the distribution of tasks between the public agencies, inadequate organisation of the work or poorly-defined responsibility for traffic safety.

### Description of the measure

Organisational measures are defined as all measures which: (1) affect the power that governmental agencies have to introduce road safety measures, (2) alter systems for the allocation of resources for road safety purposes or (3) alter the division of tasks and responsibilities between governmental agencies. Organisational measures can include setting up or closing down certain agencies (offices, departments etc), allocating new tasks to certain agencies, changing the method of planning of measures and changing financial responsibility. The following measures are included:

1. Empowering public agencies to introduce road safety measures
2. Systems for resource allocation for safety purposes, including incentive systems for local authorities.
3. Formalising responsibility for introducing road safety measures and detailed planning of measures
4. Defining the extent of legal responsibility for the design and maintenance of public roads

Experience from Norway and from other countries will be included, since a number of significant problems in these areas have much in common with other countries.

## Effect on accidents

***Empowering public agencies.*** Power can be defined as the product of interest in a decision and control of the outcome of the decision (Hernes 1975). Interest refers to the difference in utility of different possible outcomes of a decision. Control refers to the ability to increase the probability that the most desirable outcome will occur (Elvik 1993E; 1993G). Does any single governmental agency have both interest in and control over road accidents?

A problem pointed out by a number of researchers (Trinca et al 1988; Køltzow 1990; 1993; Elvik, 1993A; 1993B), is that the public bodies have only a relatively small direct financial interest in improving road safety. The financial benefit of fewer road accidents accrues primarily to road users. The benefit does not show up in the road budget. However, the road budget contains the largest public expenses for road safety measures. This point of view is developed in table O.1.1, which shows the distribution of accident costs and costs of road safety measures are between sectors of society in Norway (Hagen 1994; Elvik 1993C; 1994; 1995; Statistisk sentralbyrå 1993). The costs of road accidents include injury accidents only. The cost figures include both direct expenditures and the valuation of loss of quality of life. The loss of quality of life is treated as an internal cost to road users. The figures in the table should not be treated as exact. They are rough estimates of the size of the costs and their approximate distribution across the administrative levels and sectors. The figures show annual costs.

*Table O.1.1: Distribution of accident costs and costs of road safety measures amongst sectors of society in Norway. Amounts in million NOK. 1993-prices. Injury accidents only.*

| | | Amount in million NOK 1993 | |
|---|---|---|---|
| Administrative level | Sector | Accident costs | Cost of measures |
| State | Health sector | 160 | |
| | Social security | 1,160 | |
| | Road sector | | 2,180 |
| | Justice and police | 170 | 350 |
| | Other sectors | 570 | 30 |
| County councils | Health sector | 330 | |
| | Road sector | | 320 |
| | Other sectors | 210 | 10 |
| Municipality | Health sector | 90 | |
| | Road sector | | 280 |
| | Other sector | 410 | 10 |
| Road users | Road users | 13,400 | 5,520 |
| Total | | 16,500 | 8,700 |

The table shows that the greatest costs to the public sector of road accidents are not incurred by the same agencies as those who pay the costs of the road safety measures. There is, in other words, a weak relationship between the interest in road safety (the prospect of a financial gain) and the control of road safety measures. The accident costs to the public consist of costs for health services, social security payments and loss of income through loss of taxes (as a result of sick leave etc). Most of the costs of road safety measures refer to road construction and maintenance.

The current system of public budgets in Norway does not encourage the use of cost-benefit analysis or other efficiency assessment tools. The effects of this on the priority given to road safety in public budgets are not known.

***Systems for the allocation of resources in the public sector - incentive systems.*** Are public budgets prepared in a way that ensures that the maximum benefit of measures funded by these budgets, are reaped? In Norway, this question has been discussed in relation to how public funds for national highways investments are allocated between the counties. The pattern of allocation, which was laid down in the Norwegian Road Plan in the 1960s has later proved to be highly stable (Bjørnland 1989; Elvik 1993A, 1995C). However, the current allocation is not based on cost-benefit analyses (Killi and Ryntveit 1996). Increasing use of cost-benefit analyses for road planning appears to have had little impact on the distribution of investment funding between counties, or on the priority given to different investment projects in each county. The question is therefore whether the allocation between counties of state funds for national road investments can be explained in another way.

This question has been studied by Elvik (1995C), who compared three models for the distribution of public funds for national road investments between counties: (1) An economic benefit model, where the allocation was assumed to be the result of cost-benefit analyses, (2) A game theoretic model where it was assumed that the counties formed informal coalitions to ensure an allocation which was advantageous for the majority of counties, (3) An engineering standards model where the investment funds are distributed according to technical criteria, based on the objective of achieving a certain minimum standard of roads in all counties.

Analyses of the allocation of national highway funding between counties in the periods 1990-93 and 1994-97 supported both the game theory model and the engineering standards model. The economic benefit model received little support. (Elvik 1995C).

One problem experienced by many countries is that local authorities do not always implement mandates from central government regarding road safety measures. In the United States, the federal government has tried to solve this problem by threatening non-compliant states with the withdrawal of road funding if they do not comply with federal guidelines (Campbell 1991). Experiences with such threats are mixed. Around 1970, the federal government succeeded in forcing the states to adopt of motorcycle helmet wearing laws. However, strong opposition to this measure forced the federal government to abandon this policy in 1976. The result was that about half the states repealed the motorcycle helmet wearing laws. The national speed limit of 55 mph (88 km/hr), which was introduced in the United States in early 1974 to save fuel, met a similar fate. Federal government threatened states, which did not enforce the speed limit with the withdrawal of 10% of the road funding. When matters came to a head in 1987, the federal government lost and the speed limit was initially raised to 65 miles/hr. Later the national speed limit was repealed altogether.

In other cases, however, the federal government in the United States has been successful in bringing pressure to bear on the states (Campbell 1991). For example, the states were forced to raise the minimum drinking age from 18 to 21 years, which all the states, (some rather unwillingly), have done. The federal government has also been successful in forcing the states to pass seat belt laws.

Rewards are usually more effective in influencing behaviour than punishment. In the Netherlands, the central government introduced a reward system for municipalities that succeeded in improving road safety. (Wegman, Van Selm and Herweijer 1991). Each municipality, or coalition of municipalities with more than 20,000 inhabitants, could apply for a public subsidy for road safety measures. Municipalities which applied for the subsidy agreed to try to reduce the number of traffic injuries by 5% between 1986 and 1987, 10% between 1986 and 1988 and 15% between 1986 and 1989. If this reduction was achieved, the municipality received a reward of 5,000 guilders per traffic injury prevented. The first year the system was in use, 98% of municipalities signed up for the system. The effects of the system on the number of persons injured in traffic have not been evaluated.

In Austria, the municipalities were encouraged to implement road safety measures with the objective of reducing the number of injury accidents by 10% in the period 1.6.1986-31.5.1987, compared with the annual average for 1984 and 1985 (Risser, Michalik and Stratil 1987). No public financial subsidies were offered to the municipalities. Nonetheless, 100% of the municipalities in Austria were willing to participate in "Action minus 10%". A study of accident trends in the first four months of the campaign found a decrease of around 5% in the number of injury accidents (Risser, Michalik and Stratil 1987). The total number of injury accidents reported to the police in Austria went down from an average of 47,211 in 1984-85 to 44,570 in 1986-87. This is a decrease of 5.6%. A similar programme has been implemented in France.

***Responsibility for initiatives for new measures - special road safety agencies.*** In Norway, no single public agency has legal responsibility for proposing or developing new road safety measures.

The fact that responsibility for road safety is spread across a number of administrative levels and authorities creates problems of co-ordination, which could be solved by setting up a special road safety authority (Køltzow 1990, 1993). A number of motorised countries including the United States, New Zealand and Sweden have or have had such agencies (National Highway Traffic Safety Administration in USA, established in 1966; Trafiksäkerhetsverket in Sweden, established in 1967, abolished in 1993; Land Transport Safety Authority in New Zealand, start date unknown).

Table O.1.2 compares the relative number of road accident fatalities in five countries in the periods 1966-70 and 1986-90 (Elvik 1993B). Two of the countries had a national traffic safety agency in this period, while three of them did not.

*Table O.1.2: Relative number of road accident fatalities in five countries 1966-70 and 1986-90. Source: Elvik 1993B*

| | | Relative figures. 1966-70 = 100 | |
|---|---|---|---|
| Traffic safety agency | Country | Killed 1966-70 | Killed 1986-90 |
| Yes | USA | 100 | 84 |
| | Sweden | 100 | 66 |
| No | Denmark | 100 | 62 |
| | Finland | 100 | 64 |
| | Norway | 100 | 79 |

Countries with traffic safety agencies have not accomplished a greater reduction in the number of road accident fatalities than countries without traffic safety agencies.

***Legal responsibility for the design of roads.*** The Norwegian Road Traffic Act places the legal responsibility for preventing accidents primarily on the road user, by stating that everyone is required to travel considerately and carefully, in a way not causing damage or creating a hazard (Road Traffic Act § 3). In many other countries, including the United States, government - primarily the road authorities- are legally responsible for keeping roads in a safe condition. In Norway, road authorities can only be held legally responsible for injuries to road users when evidence of gross negligence on the part of road authorities can be produced in court.

The American rules imply that the road authorities can be held responsible for injuries resulting from poor road design or road maintenance (Baldwin 1980). An example of this is as follows: The road design standards contain rules governing the height of guardrails. If the road is paved without adequately removing the old road surface, guardrails that were originally correctly installed, can become too low. In an accident where it can be proven that the guardrail was too low, the road authority, according to American law, can be held responsible for injuries, which occurred or were made worse for this reason.

Liability for compensation gives the road authorities a financial incentive to maintain the roads in a safe condition (Baldwin 1980). However, this may also have adverse impacts. In the United States, the legal responsibility of highway agencies has become so extensive that even minor upgrading of a road, can be interpreted as an indirect admission that the road was not previously safe for traffic (Baldwin 1980). In turn this can make highway agencies abstain from improving a road. This can also lead to safety assessment of a road being based on purely formal criteria, for example whether or not it is in line with the road design standards, and not according to the actual accident rate (Hauer 1993).

### Effect on mobility

The effects on mobility of the organisational measures described above have not been evaluated.

### Effect on the environment

The effects on the environment of the organisational measures described above have not been evaluated.

### Costs

The direct costs associated with the organisational measures are largely unknown.

Introducing a system where highway agencies are held responsible for deficiencies in road design and maintenance will increase their payments for accidents. It is not possible say how much such payments would increase

### Cost-benefit analysis

It is extremely difficult to judge the costs and benefits of organisational measures. If the measures lead to more effective use of road safety measures, the benefit-cost ratio may be very high. If the measures do not have this effect, however, the risk is that they will only incur costs, which would otherwise have been avoided. At present, the benefit-cost ratio of organisational measures is not known.

## O.2 INFORMATION FOR DECISION MAKERS

### Problem and objective

Decisions concerning the use of road safety measures need to be based on information about the number of accidents, when and where accidents occur, the road user groups which are involved, the factors which contribute to accidents and the measures which can be taken to reduce the number of accidents or injury severity.

The objective of information for decision makers is to give the decision makers the best possible knowledge about the number of road accidents, types of accidents and the effects of road safety measures, including the costs of the measures, in order to avoid ineffective priority setting.

### Description of the measure

Information for decision makers is taken to mean generally available information for government and people working with road safety, including information concerning these topics:

1. The number of accidents and types of accidents
2. Road safety measures and their effects, including the results of road safety research
3. Technical standards for different measures
4. Costs of the measures
5. Formal methods for priority setting of measures
6. The attitudes of the general public to various measures

Information for decision makers concerning road safety is currently found in a number of different sources. This chapter will review some of the most important sources.

### Effect on accidents

There is no simple relationship between the supply of professional information and the number of accidents. Better information makes it possible to make better decisions. This chapter evaluates the following items:

1. Access to and quality of accident data

2. The knowledge of road safety and desired priorities for measures among decision makers at different levels
3. The relationship between knowledge of effects of measures and the attitudes towards the use of the measures
4. The understanding among decision makers of the attitudes of the general public towards road safety measures
5. The use of formal methods for priority setting among decision makers

***Access to and quality of accident data.*** The most frequently used source of data on accidents in planning road safety measures is the official accident record. It is a well-known fact that far from all reportable accidents involving injuries are in fact reported (Borger, Fosser, Ingebrigtsen and Sætermo 1995). The actual numbers of injured persons in traffic accidents can be estimated on the basis of hospital records and can be compared with the official records. For 1991, this comparison shows for Norway (Hvoslef 1996):

| | Number of persons injured | | | |
|---|---|---|---|---|
| Road user group | Official statistics | Hospital records | Level of reporting (%) | Inflation factor |
| *Reportable accidents in which motor vehicles are involved* | | | | |
| Pedestrians | 1,149 | 2,521 | 45.6 | 2.2 |
| Cyclists | 847 | 2,000 | 42.4 | 2.4 |
| Moped riders | 768 | 2,316 | 33.2 | 3.0 |
| Motorcyclists | 468 | 1,234 | 37.9 | 2.6 |
| Car occupants | 8,568 | 16,276 | 52.6 | 1.9 |
| Other motor vehicles | 64 | 589 | 10.9 | 9.2 |
| Total | 11,864 | 24,936 | 47.6 | 2.1 |
| *Reportable accidents in which motor vehicles are not involved* | | | | |
| Pedestrians hit by bicycles | 39 | 382 | 10.2 | 9.8 |
| Cyclists hit by pedestrians | 0 | 39 | 0.0 | Undefined |
| Collisions between bicycles | 37 | 1,490 | 2.5 | 40.3 |
| Single-vehicle accident involving bicycle | 65 | 9,272 | 0.7 | 142.9 |
| Road user group not stated | 29 | 68 | 42.6 | 2.3 |
| Total | 170 | 11,183 | 1.5 | 65.8 |
| All reportable accidents | 12,034 | 36,119 | 33.3 | 3.0 |
| *Other accidents on public traffic areas (not defined as traffic accidents)* | | | | |
| Pedestrian falls | 1 | 21,067 | 0.0 | Undefined |

An injury is defined as reportable if the injured person has to go to hospital or an accident and emergency department for treatment following the accident. For all reportable accidents combined, the estimated level of reporting is 33%. However, there is a significant difference between accidents where motor vehicles are involved and accidents where motor vehicles are not involved. For accidents where motor vehicles are involved, the level of reporting is close to 50%. For accidents where motor vehicles are not involved, the level of reporting is only 2%.

In addition to reportable traffic accidents a large number of accidents involve pedestrians who fall and get injured. These accidents are not defined as traffic accidents and are as a result not included in the official accident record.

***Knowledge of road safety and desired priorities among decision makers.*** A number of studies have evaluated the amount of knowledge which decision makers at different levels have regarding road safety, and which types of measures these decision-makers want to prioritise..

An interview survey among 30 leading decision makers (Køltzow 1990, 1993) elicited their priorities for road safety measures. When asked about the measures they would use if costs were not to be considered, the following main groups of measures were mentioned, rank ordered according to the number of times they were mentioned (each person interviewed could mention more than one measure):

(1) Traffic engineering measures (84 times )
(2) Legislation and police enforcement (49 times),
(3) Changes in attitude, training and information (44 times),
(4) Increased public transport (6 times),
(5) Changes in the organisation of traffic safety agencies (twice)

When those interviewed were asked to take the costs of the measures into consideration, thus indicating the measures they felt to be the most cost-effective, the following main groups of measures were mentioned:

(1) Police enforcement (35 times),
(2) Traffic engineering measures (33 times)
(3) Changes in attitude, training and information (15 times).

The study concluded that those interviewed had good knowledge of the most effective road safety measures.

***The relationship between knowledge of effects of measures and attitudes to the use of the measures.*** Two American studies have evaluated the relationship between knowledge of the effects of a road safety measure and attitudes to the use of the measure. The measure studied was the mandatory use of seat belts in cars. Slovic, Fischhoff and Lichtenstein (1978) studied how two methods of presenting risk information influenced attitudes to the mandatory use of seat belts. One group was told that the probability of being killed per trip was 0.000000286 (1 per 3.5 million). In this group, 54% were in favour of the mandatory use of seat belts. A second group was told that the lifetime probability of being killed in traffic accidents is around 0.01 (1 per 100). In this group, 78% were in favour of mandatory use of seat belts.

In a second study (Runyan and Earp 1985) a sample of students were randomly divided into one group that was told about the effects of seat belts, and a second group that was not given this information. Both groups were asked about their attitudes to mandatory use of seat belts. 60% were in favour of such legislation in the group that had been told about the effect of seatbelts, as opposed to just 22% in the group that was not given this information. The study shows that the attitude to a particular traffic safety measure depends on the level of knowledge regarding the effects of the measure.

***Decision maker perception of popular attitudes to different measures.*** A study carried out on behalf of the Norske Transportbedrifters Landsforening (the Norwegian Association of Public Transport Companies) and Oslo Sporveier (the Oslo Tram Company) (Stangeby 1994) compared politicians' attitudes to traffic restrictions with the general public's attitudes to the same restrictions, and politicians' perception of the attitude which they thought the majority of the general public had to such traffic restrictions. With regard to measures designed to reduce traffic congestion in town centres, the proportion in favour of different measures was as follows:

| | Percentage in favour of various measures | | |
|---|---|---|---|
| Measure | Municipal politicians | What the politicians thought people wanted | The general public |
| Parking restrictions | 61 | 31 | 43 |
| Pedestrian streets | 68 | 38 | 53 |
| Limiting the amount of traffic in cities | 72 | 24 | 64 |

The politicians were largely in favour of the restrictive measures, but did not think the general public would be in favour of them. However, a higher proportion of the general public was in favour of such restrictive measures than politicians thought to be the case. To the extent that the politicians have an inaccurate perception of public attitude to different measures, this may prevent them from taking measures which they believe will not be supported by the public, but which would in fact be widely supported.

***Decision makers' use of formal methods for priority setting of measures.*** Cost benefit analyses are carried out routinely for all major investments on national roads in Norway.

A number of studies (Odeck 1991, 1996, Elvik 1993E, 1995C, Fridstrøm and Elvik 1995, Nyborg and Spangen 1996) show that actual priority setting for road investments in Norway is not based on cost-benefit analyses. Possible explanations of why so little weight is placed on the results of cost benefit analyses may be that many people do not think that the analyses include all the relevant impacts of road investments; scepticism regarding the economic valuation of a number of effects and institutional traditions which make it difficult to deviate from earlier decisions, even if those were not based on cost-benefit analyses. Interviews with members of the parliamentary committee for transport (in the 1990-93 election term) show that the attitude towards cost benefit analyses follows a Right-Left axis. The attitude to such analyses is most favourable among politicians who are to the Right (Nyborg and Spangen 1996).

**Effect on mobility**

No effects on mobility of information for decision makers have been documented.

**Effect on the environment**

No effects on the environment of information on road safety for decision makers have been documented.

**Costs**

Little information is available regarding the costs of information for decision makers. Costs are likely to be in the order of 20-50 million NOK per year.

**Cost-benefit analysis**

No cost-benefit analyses of information on road safety for decision makers have been reported. The costs of such information probably correspond to the costs to society of some 10-20 injury accidents each year. It is possible that the sensible use of such information could prevent a corresponding number of accidents each year.

## O.3 Quantified Road Safety Targets and Targeted Road Safety Programmes

### Problem and objective

The current number of road accidents and accident victims is regarded as unacceptably high by the governments of most countries. It has therefore become increasingly common in recent years to set quantified targets for improving road safety, in particular for reducing the number of road accident fatalities. Many countries in Europe, as well as Australia and New Zealand have set quantified road safety targets and developed targeted road safety programmes designed to realise these targets.

Before these targets were set and the associated safety programmes passed, most countries had only qualitative target formulations, such as "to continue to improve road safety". These target formulations did not state how much road safety was to be improved and how soon an improvement was to be realised. The idea underlying a quantified road safety target is to strengthen the commitment to improving road safety by stating in clear terms the improvement to be aimed for within a certain period. A quantified target will also make it easier to assess the need for introducing road safety measures in order to realise the target. This chapter reviews the effectiveness of quantified road safety targets in improving road safety performance.

### Description of the measure

Road safety targets can be formulated in many ways (Elvik 1993B, OECD 1994). In this chapter quantified targets only will be considered. A quantified road safety targets usually states the reduction aimed for in the number of road accidents or road accident victims within a certain period. Table O.3.1 gives an overview of current quantified road safety targets in a number of countries.

The targets listed in table O.3.1 all refer to road accident fatalities at the national level. As can be seen from table O.3.1, most of the road safety targets are quite ambitious, and aim for a reduction of the number of road accident fatalities of some 40 to 50% during a period varying from five years in France to 14 years in Denmark. These targets represent an ambition to reduce the number of road accident fatalities more quickly than prolonging past trends would imply.

In addition to the targets for fatalities, some countries have set targets for reducing the number of injured road users, in particular those seriously injured. These targets tend to be somewhat less ambitious than those set for fatalities.

Most countries belonging to the European Union have set quantified road safety targets. There are, however, still some countries that do not have quantified road safety targets at the national level. These include (but are not limited to) Belgium and Germany. In both Germany and Norway, reports prepared by executive agencies or technical experts on behalf of the Ministry of Transport proposed quantified road safety targets. These proposals did not get political support in these countries. On the whole, however, the trend is for more and more countries to endorse quantified road safety targets.

*Table O.3.1: Quantified road safety targets in Europe and some other countries*

| Country | Base-year for target | Year in which target is to be realised | Target for reduction of the number of road accident fatalities |
|---|---|---|---|
| Australia | 1997 | 2005 | -10% |
| Austria | 1998-2000 | 2010 | -50% |
| Canada | 1991-1996 | 2008-2010 | -30% |
| Denmark | 1998 | 2012 | -40% |
| European Union | 2000 | 2010 | -50% |
| Finland | 2000 | 2010 | -37% |
| Finland | 2000 | 2025 | -75% |
| France | 1997 | 2002 | -50% |
| Greece | 2000 | 2005 | -20% |
| Greece | 2000 | 2015 | -40% |
| Ireland | 1997 | 2002 | -20% |
| Italy | 1998-2000 | 2010 | -40% |
| Netherlands | 1998 | 2010 | -30% |
| New Zealand | 1999 | 2010 | -42% |
| Poland | 1997-1999 | 2010 | -43% |
| Sweden | 1996 | 2007 | -50% |
| United Kingdom | 1994-98 | 2010 | -40% |
| United States | 1996 | 2008 | -20% |

## Effect on accidents

***Problems of measuring the effects of quantified road safety targets.*** It is difficult to measure the effects of quantified road safety targets on road safety performance. The chief problem is that there are few units of observation (few countries that have set quantified targets), while there are very many factors affecting road safety for each unit of observation. This means that it is difficult to rule of out the effects of confounding factors when evaluating the effects of quantified road safety targets.

A study has been made in which the effects on road safety performance of 22 quantified targets set by national governments and 13 quantified targets set by regional or local governments were evaluated (Elvik 2001A). As far as targets set by national governments were concerned, the evaluation referred to fatalities only. The IRTAD database was used as a source. In this database, the count of road accident fatalities has been standardised to conform to the 30-day rule for a fatality.

***Effects of quantified road safety targets.*** The study (Elvik 2001A) concluded that it was not possible to evaluate the effects on road safety performance of quantified road safety targets in a sufficiently rigorous manner to conclude anything about their effects.

Despite this inconclusive finding, one may nevertheless take the tendencies present in the data as showing real effects, since there does not exist other, more rigorous evaluation studies, and since no study providing perfect control for confounding factors is possible. On this interpretation, the study shows that a quantified road safety target is associated with a slight improvement in road safety performance, amounting to a net reduction of the number of road accident fatalities of about 0.8% per year. The largest improvement in road safety performance is associated with ambitious, long-term targets set by national governments.

Unfortunately, the study does not describe the safety programmes that have been implemented as a result of the targets set. One reason why quantified road safety targets apparently do not influence road safety very much, may be that effective safety programmes have not been implemented, and that the targets have, in effect, served a symbolic function mainly.

### Effect on mobility

The effects of quantified road safety targets and targeted safety programmes on mobility depend on the safety measures included in such programmes. Reducing speed limits may be one of the measures considered. On the other hand, improving roads is often also part of a road safety programme. The net effect on mobility is difficult to predict.

### Effect on the environment

The impacts of road traffic on the environment are closely related to traffic volume. Only one national road safety plan is known to have included a target for curbing traffic growth. That was the Dutch national road safety plan for the period 1985 to 2010, which contained a target stating that kilometres of driving in the Netherlands should not increase by more than 35% from 1985 to 2010 (Ministry of transport, public works and water management, 1996). Traffic has already increased by more than this target value, but so far no drastic measures have been taken in the Netherlands to curb further growth in traffic.

In most cases, targeted road safety programmes take future growth in traffic for granted and do not seek to influence it. To a very large extent, these programmes also take modal split for granted. As a consequence, targeted road safety programmes do not normally contain measures that will have much of an effect on the environment.

### Costs

The costs of a targeted road safety programme depend on the measures it contains. Some examples of the costs estimated for a number of national road safety programmes are given below.

The annual total cost of all road safety measures (public as well as private) currently used in the Netherlands has been estimated to about 1.7 billion US dollars (Ministry of transport, public works and water management 1996). A corresponding estimate for Norway puts the cost at about 1 billion US dollars per year (Elvik 1999). For Sweden, the annual total cost of road safety programmes has been estimated to about 2.6 billion US dollars (Sund 2000). All these estimates refer to the total cost of all ongoing safety programmes in both the public and private sector.

The marginal cost of additional measures that are introduced as part of a targeted road safety programme is generally substantially less than the total cost of all safety programmes that are operated at any time. As an example, the annual cost of all road safety measures in Norway whose marginal benefits are greater than the marginal cost amounts to about 0.5 billion US dollars (Elvik 1999). In Denmark, the marginal cost of the road safety plan for the period 2001-2012 is estimated to about 0.13 billion US dollars per year (Færdselssikkerhedskommissionen 2000).

### Cost-benefit analysis

The costs and benefits of targeted road safety programmes are likely to vary substantially, making it difficult to provide typical figures.

Analyses of road safety policy in Norway (Elvik 1999) and Sweden (Elvik and Amundsen 2000; Elvik 2001B) indicate that it is in principle possible to achieve a reduction of the number of road accident fatalities of about 50% by introducing measures whose benefits are greater than the costs. The analyses also show that current road safety policies in Norway and Sweden are not fully realising the potential for reducing traffic fatalities by introducing cost-effective measures. To the extent that setting a quantified road safety target strengthens interest in applying cost-effective measures, it may result in more efficient priority setting for such measures.

## O.4 SAFE COMMUNITY PROGRAMMES

### Problem and objective

A common problem in accident and injury prevention work is lack of motivation. Common reasons why many people do not want to get involved in accident and injury prevention are that they do not regard accidents as a problem or they do not believe it is worth doing anything to prevent accidents (Hoff 1996). The success of accident prevention is therefore to some extent dependent showing by means of good examples that this type of work can succeed. Such examples can motivate others.

A necessary condition for success in preventing accidents is that people are aware of how many accidents that actually occur, know who the accidents affect and know the circumstances surrounding the accidents. Existing accident statistics often give an incomplete picture of the accident problem.

Responsibility for preventing accidents is divided between many bodies. No single agency has overall responsibility for preventing accidents. In order to demonstrate good examples of accident prevention at the local level, the World Health Organisation has launched the concept of Safe Communities (Hoff 1996). In order to be designated as a safe community, a local community must fulfil several requirements regarding accident prevention.

Local community safety programmes are designed to create a better basis for local accident prevention by giving examples of how such work can be organised and by reducing the number of injured persons in those societies where the programmes are implemented.

### Description of the measure

Safe community programmes are systematic accident prevention programmes that have the following characteristics:

1 The systematic recording of accidents in a local community over a given period of time. Normally, hospitals or other health institutions are responsible for the records.

2 On the basis of accident records, the dominant accident problems in the local community are identified. Information about these problems is published in the local community.
3 A steering group for accident prevention in the local community is set up, with participation from all parties which are presumably able to contribute to preventing accidents, usually including the municipality (administration and politicians), schools, the health service, the police, the fire service, representatives of trade and industry and voluntary organisations.
4 A quantified target for accident reduction during a given period, for example the next 2 or 3 years, is set. A set of measures designed to achieve this target is developed. It is assumed that the whole steering group for accident prevention will support both the targets and the programme of measures.
5 The safety programme is implemented. During the whole implementation period, changes in the number of accidents and injuries are monitored closely and information on new developments is given to all those participating in the programme.
6 When the safety programme has been implemented, its effects on the number of accidents in the local community are studied. The results are published and on the basis of these, changes may be made in the targets for accident reduction or in the safety programme.

Programmes containing these elements have been introduced in a number of local communities, both in Norway and in other countries. The programmes have been directed both towards traffic accidents and towards other types of accidents.

**Effect on accidents**

The results presented here are based on the following studies that have evaluated safe community programmes:

Tellnes 1984 (Værøy, Norway)
Schelp 1987 (Falköping, Sweden)
Guyer, Gallagher, Chang, Azzara, Cupples and Colton 1989 (cities in Massachusetts, USA)
Haugen et al 1991 (Bø i Telemark, Norway)
Davidson, Durkin, Kuhn, O'Connor, Barlow and Heagarty 1994 (Harlem, New York, USA)
Ytterstad and Wasmuth 1995 (Harstad, Norway)
Hingson, McGovern, Howland, Heeren, Winter and Zakocs 1996 (Massachusetts USA).

On the basis of these studies, best estimates of the effects of the programmes on the number of accidents are given in table O.4.1 (percentage change in the number of injury accidents per year).

Table O.4.1 shows that a decrease of around 30% in the number of traffic accidents has been achieved. This has been estimated on the basis of special accident records set up in local communities as part of the programmes. The number of accidents of other types has been reduced by around 20 %.

*Table O.4.1: Effects of local community safety programmes on the number of injury accidents*

| | Percentage change in the number of accidents | | |
|---|---|---|---|
| Source of accident data | Types of accidents affected | Best estimate | 95% confidence interval |
| Special records | Traffic accidents | -29 | (-35; -22) |
| Official accident record | Traffic accidents | +8 | (+6; +9) |
| Special records | Non-traffic accidents | -17 | (-22; -12) |

If only accidents included in the official accident record are considered, there appears to be an increase of around 5 - 10 %. The explanation for this is probably that the level of reporting of traffic accidents in the official record has increased in the communities where the safety programmes have been introduced. Stimulating interest in safety can make people more aware of their duty to report traffic accidents and lead them to do so more often than they did before.

### Effect on mobility

The effects on mobility of local community safety programmes depend on the types of measures included in such programmes. In Harstad, Norway, where a comprehensive programme was introduced in the period 1985 - 1992, the following measures were included (Ytterstad and Wasmuth 1995): information (in the form of brochures, lectures, guidance for parents etc), black spot treatment on the road network, a rental system for safety equipment for children in cars, free installation of high-mounted brake lights on cars, and police enforcement. Most of these measures do not affect mobility.

### Effect on the environment

No effects on the environment of local community safety programmes have been documented.

### Costs

None of the studies of local community safety programmes referred to in this chapter give any information about the total costs of the programmes. Thus it is difficult to provide cost figures.

### Cost-benefit analysis

No formal cost-benefit analyses of local community safety programmes are available.

## O.5 EXPOSURE CONTROL

### Problem and objective

The single most important factor influencing the number of road accidents is traffic volume. This applies in both the short term and the long term. The more traffic there is, the more traffic accidents can be expected to occur, all other conditions being equal. Studies in the Nordic countries (Fridstrøm et al 1993, 1995) indicate that variation in traffic volume, measured on the basis of fuel consumption, explain around 65 to 75% of the systematic variation in accident counts. The same studies have found that the number of injury accidents increases almost proportionally with the amount of traffic, given that everything else remains unchanged. The number of fatal accidents also increases as traffic volume increases, but not as much as the number of injury accidents.

Limiting the amount of traffic can thus affect the number of road accidents more than any other measure. A basic principle of transport policy (Samferdselsdepartementet, st.meld. 32, 1995-96), is that both the general public and trade and industry have the right to choose when, where, how and how much they will travel or transport goods. Direct regulation of road traffic is therefore not a feasible option. However, traffic volume can be influenced by means of other policy instruments that do not encroach on the freedom of choice with regard to modes of travel and amount of travel.

Regulating traffic volume measure is designed to limit or reduce the amount of traffic in order to reduce the number of road traffic accidents.

### Description of the measure

***Measures which affect the amount of traffic.*** The amount of road traffic can be influenced using a number of measures. The best means for this are:

1. Land use plans
2. Road plans and road construction
3. Motor vehicle taxation
4. Road pricing

5. Public transport (prices, frequency, choice of route etc)
6. Regulating commercial transport
7. Traffic control measures

These measures are described in greater detail in other chapters in this book. Only the main elements are described here. Land use plans establish both the main principles and the details of land use in a specific area. The development pattern in an area affects both the total volume of traffic and the modal split of travel (see Chapter O.6).

Road plans and road construction determine the supply of road capacity in an area and the standard of the roads. Both elements influence traffic volume and the quality of the traffic flow (see chapter O.7). Motor vehicle taxation affects the price of purchasing and using motor vehicles and thus influences the number of vehicles purchased and the extent to which these are used (see chapter O.9)

The costs to society of using motor vehicles vary considerably. Motor vehicle taxation does not fully reflect such variations. Road pricing, which is payment for the use of a given road at a given time, is intended to transfer all the costs of using motor vehicles to the road user. Road pricing can affect the total volume of traffic, the distribution of traffic over the 24-hour period and the modal split of traffic (see chapter O.10).

The number of vehicles in the traffic system can be reduced by changing from travelling individually to using public transport, This can limit traffic volume in towns and cities where the infrastructure for providing good public transport already exists (see chapter O.11).

In principle, regulating commercial transport makes it possible to regulate the amount of traffic by limiting the numbers of those allowed to operate commercial transport and regulating the areas where such transport can take place (see chapter O.13).

A number of traffic control measures can be used to limit the amount of traffic locally. Examples of such measures include traffic calming, parking regulations and dynamic route guidance (see chapter 3, traffic control).

**Effect on accidents**

***Causal relationship between exposure control and the number of accidents.*** The relationship between exposure control and the number of accidents is indirect. In order to quantify the effect on the number of accidents of measures affecting traffic volume, it is important to know both the effect of the measures on traffic volume and the relationship between traffic volume and the number of accidents. This is shown in figure O.5.1.

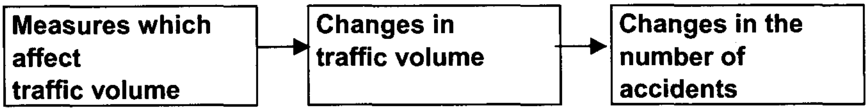


*Figure O.5.1: Casual chain from measures which affect the amount of traffic to the number of accidents*

***The relationship between traffic volume and the number of accidents.*** The relationship between traffic volume and the number of accidents has been evaluated in a number of studies. The results presented here are taken from the following studies:

Erlander, Gustavsson and Larusson 1969 (Sweden)
Krenk 1985 (Denmark)
Elvik 1991 (Norway)
Fridstrøm and Ingebrigtsen 1991 (Norway)
Brüde and Larsson 1992 (Sweden)
Bonneson and McCoy 1993 (USA)
Persaud and Dzbik 1993 (Canada)
Fridstrøm, Ifver, Ingebrigtsen, Kulmala and Krogsgård Thomsen 1995 (Nordic countries)
Kulmala 1995 (Finland)
Pajunen and Kulmala 1995 (Finland)
Mountain, Fawaz and Jarrett 1996 (Great Britain)
Summersgill and Layfield 1996 (Great Britain)

On the basis of these studies, the relationships between traffic volume and the number of fatal accidents and between traffic volume and the number of injury accidents are shown in figure O.5.2.

Traffic volume in figure O.5.2 refers to motor vehicles alone. The figure shows that when traffic volume, measured in the number of vehicle kilometres, increases from 1 to 100, the expected number of injury accidents, (including fatal accidents) increases from 1 to around 79 (77; 80). The expected number of fatal accidents increases from 1 to around 26 (24; 28) when traffic volume increases from 1 to 100. This relationship applies when all other conditions are equal, i.e. under given weather and driving conditions, with a given fleet of vehicles and driver population, and given that the road network (number of kilometres of road) is expanded in line with the number of kilometres driven.

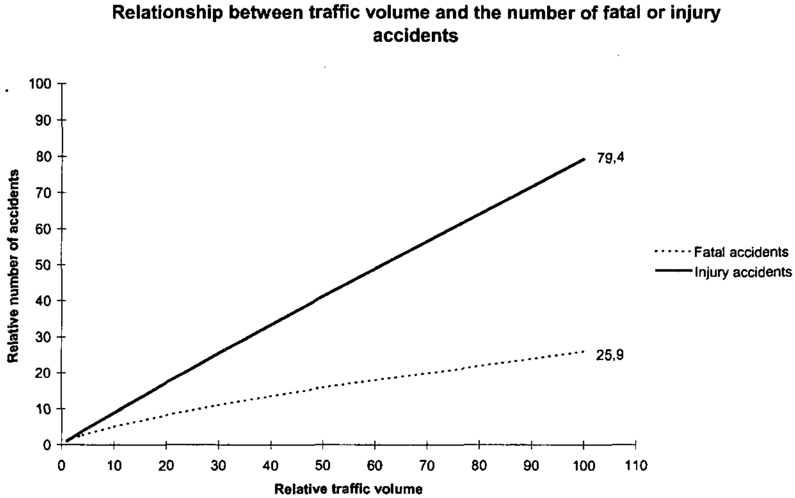


*Figure O.5.2: Relationship between changes in traffic volume and changes in the number of fatal accidents and the number of injury accidents*

The relationship between traffic volume and the number of property damage only accidents is less known than relationship between traffic volume and the number of injury accidents. A Finnish study (Pajunen and Kulmala 1995) of the relationship between hourly traffic and the risk of property damage only accidents on different types of roads in daylight produced the results shown in figure O.5.3.

Figure O.5.3 shows the relationship between hourly traffic in daytime and the risk of property damage only accidents (accidents per million vehicle km) for four types of road in Finland: two-lane roads, four lane roads, motorways class B (MvB) and motorways class A (MvA). If the number of property-damage-only accidents increases in proportion to traffic volume, the accident rate will be independent of traffic volume. The curves in figure O.5.3 should then be horizontal. The figure shows a somewhat untidy pattern. On some types of road, there is a tendency for the number of property damage only accidents to increase more than proportionally with traffic volume (increasing level of risk with increased hourly traffic). On other roads, there is a tendency in the opposite direction. Many of the risk estimates are based on a small number of accidents and are therefore highly uncertain.

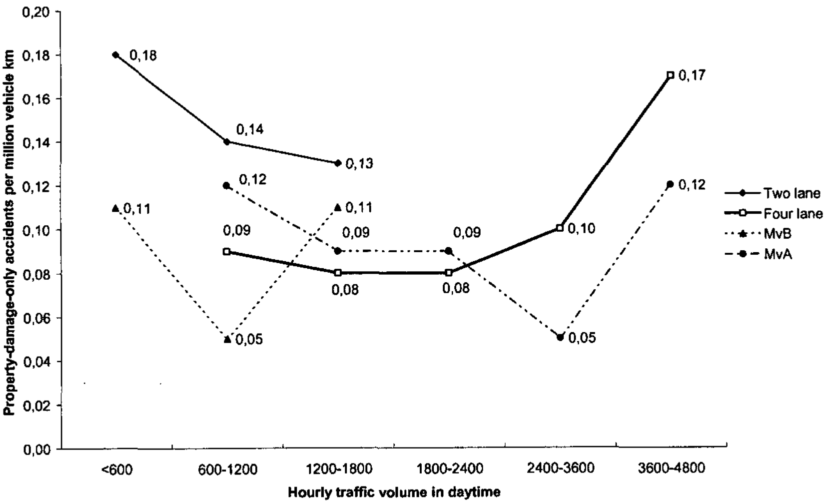


*Figure O.5.3. Relationship between hourly traffic and the traffic in daytime and the risk of property damage only accidents on Finnish roads. Source: Pajunen and Kulmala 1995*

***Effects of measures which influence traffic volume.*** The effects of measures, which are intended to influence traffic volume are considered in greater detail elsewhere in this book.

Table O.5.1 summarises the effects on traffic volume and on the total number of injury accidents of a number of measures affecting traffic volume.

Compacting towns and cities, so that the built area per inhabitant decreases from around $600m^2$ to ca $300m^2$ can reduce the number of kilometres driven by about a third. Thus, the number of injury accidents could be reduced by around 30%. Building new main roads in towns and cities and expanding the road capacity in towns and cities has led to a certain amount of new traffic in Norway, around 10 - 15%. Under otherwise identical conditions, this will lead to more accidents.

*Table O.5.1. The effects on traffic volume and the number of injury accidents of a number of measures which influence traffic volume. Percentage change in traffic volume (km driven) and number of accidents*

| | Percentage change (95% confidence interval) | |
|---|---|---|
| Measure | Traffic volume | Number of accidents |
| Compacting towns from a built area of ca 600m$^2$ per inhabitant to ca 300m$^2$ per inhabitant | -33% (-45%; -15%) | -30% (-40%; -12%) |
| Building new main roads in cities; increased road capacity in cities (Norwegian data) | +13% (+2%; +25%) | +10% (+2%; +20%) |
| Abolition of all vehicle taxation (purchase, ownership and use) | +37% (+35%; +40%) | +33% (+30%; +37%) |
| Introducing toll roads etc in Oslo, Bergen, Trondheim and Tromsø | -7% (-10%; -3%) | -5% (-11%; +1%) |
| Traffic calming in residential areas: traffic volume in local streets which are closed to through traffic | -30% (-35%; -25%) | -25% (-33%; -20%) |

If all the taxes currently imposed in Norway on the purchase, ownership and use of motor vehicles were abolished, and no other taxes or fees were increased, the number of kilometres driven would increase by 35 - 40%. The number of injury accidents would increase by around 33%. This shows that current vehicle taxation in Norway limits travel demand and thus the number of accidents. Introducing toll systems and local petrol taxes in Oslo, Bergen, Trondheim and Tromsø, Norway, reduced the traffic in the cities by around 7% in the first year after the measures were implemented. The number of injury accidents went down correspondingly. Closing local streets to through traffic as part of traffic calming has proved to reduce traffic volume by around 30% and the number of accidents by around 25%.

## Effect on mobility

Measures that limit or reduce traffic volume affect mobility in two ways. Firstly, less traffic on the road means that mobility for the remaining traffic is improved, especially on roads with congestion problems. When congestion problems are severe, the benefits of improved mobility for remaining traffic will generally be greater than the loss of benefit for the traffic which is displaced (Grue, Larsen, Rekdal and Tretvik 1997).

Secondly, the loss of some of the traffic is a loss of benefit for that traffic which disappears. If journeys by car are replaced by journeys using public transport, individual mobility can be more or less maintained, at least where public transport provision is good. The journey time from door-to-door for a given route will normally increase.

**Effect on the environment**

A reduction in traffic volume will, all other conditions being equal, reduce the environmental problems which are caused by road traffic. These include noise and air pollution. Less traffic also means that the need for traffic areas is reduced.

**Costs**

The costs of measures which affect the amount of traffic are of two types: direct costs and indirect costs. The direct costs are the costs of implementing measures influencing traffic volume. The indirect costs are the loss of benefit attributable to a reduced demand for travel.

Both the direct and the indirect costs of measures which affect the amount of traffic are little known and difficult to estimate.

**Cost-benefit analysis**

The benefits of limiting or reducing road traffic vary considerably, depending on the size of the external effects of traffic. In the largest city areas in Norway, the external costs of car use are so high that road pricing, or other exposure control measures particularly at the busiest times of the day, are cost-effective.

If taxation on vehicles were abolished, the number of kilometres driven by cars would increase by 35 to 40 %. Calculating, as a very rough approximation, that the size of the external effects of driving cars would increase correspondingly, this represents an extra cost of around NOK 9-10 billion.

According to a study carried out by Brendemoen and Vennemo (1993), consumers value the benefit of reduced environmental problems achieved through less car traffic more highly than the disadvantages of taxation, no matter what the tax revenue is used for. The external costs of road traffic are currently very probably greater than the vehicle taxation, which means that it is cost-effective to increase these taxes.

Analyses carried out by Ramjerdi (1995) and by Grue, Larsen, Rekdal and Tretvik (1997) show that it is cost-effective to introduce congestion pricing in Oslo. The benefit of this in the form of increased mobility for the remaining traffic is greater than the loss of benefit for traffic that would be suppressed if congestion pricing were introduced.

## O.6 Land use plans (urban and regional planning)

### Problem and objective

The development of large areas without the direction of a long-term land usage plan can lead to unnecessary traffic or a complicated and dangerous traffic system. All other conditions being equal, the number of injury accidents increases approximately in proportion to the number of kilometres driven (Fridstrøm et al 1993, 1995). A development pattern generating much traffic will therefore lead to more accidents than a development pattern generating less traffic.

In urban areas, the risk of injury accidents per kilometre driven is higher than in rural areas (Elvik and Muskaug 1994). An increase in the size of urban areas may therefore increase the accident rate. A Norwegian study of changes in land usage from 1955 to 1992 in the cities of Oslo, Bergen, Trondheim, Fredrikstad and Sarpsborg (Engebretsen 1993) found that the size of urban areas grew faster than the population in this period. A study of 21 towns in Norway found that the urban area per inhabitant increased from 450 $m^2$ in 1970 to 554 $m^2$ in 1990 (Larsen and Saglie 1995). This has created greater distances between different destinations and increased the need for transport in order to carry out daily routines.

The objective of land use planning used as a traffic safety measure is to:

- locate roads, residential areas, workplaces and other industries in such a way that traffic volume and travel distances are minimised
- set up a road network which screens access roads from through traffic and ensures that traffic volume on access roads is as small as possible
- design individual roads so that the accident rate on the road is low
- make the traffic system simple and easily understandable for all road users

Land-use plans may have a number of other objectives including promoting industrial development or housing development, protecting agricultural land, protecting recreational areas, making the flow of traffic more effective or using specific resources more effectively. It is possible that these objectives may conflict with traffic safety objectives. The contents of this chapter are limited to the use of the land use planning for promoting road safety.

### Description of the measure

Land usage in an area can be determined using different types of plans. The most important of these are:

- county plans

- municipal plans
- precinct plans
- local development plans
- building plans

The types of plans can be seen as a hierarchy. This means that county plans contain regulations, which are used as a basis for municipal plans. Municipal plans give guidelines for the development of precinct plans, local development plans and building plans. Local development plans give guidelines for the development of building plans.

**Effect on accidents**

***Ways in which land use plans and land usage can affect traffic safety.*** Land-use plans and land usage can influence traffic safety by (1) affecting traffic volume (number of kilometres driven) in an area, (2) affecting the way in which traffic in an area is distributed over the road network, across different types of roads, (3) affecting the choice of mode of transport, (4) affecting the accident rate on each roads particularly access roads in residential areas (5) locating industries which generate a lot of traffic in such a way that traffic to and from these industries can use public transport or those parts of the road network which have the lowest accident rate.

***The relationship between land usage, the amount of traffic and the number of accidents.*** Certain land use patterns induce more traffic than others. For example, the construction of large numbers of single family houses with gardens, with vehicle access to each house, leads to an increase in the use of private cars and a decrease in the use of public transport (Hall 1975). Nonetheless, it is not obvious exactly which land usage patterns lead to the least amount of traffic (Loder and Bayly 1973, Espedal and Omland 1982, Brindle 1984). It has also proved difficult to quantify the relationship between land usage patterns and traffic volume (Hanssen 1993).

An international overview of the relationship between land use and traffic in 32 cities (Newman and Kenworthy 1989) suggests that development density in a city is an important factor. In the study, development density is described using the number of inhabitants per hectare of urban land (1 hectare = 10,000 $m^2$). Urban land is land that has been built on in some way or another, for example in the form of houses, roads, other traffic constructions or other regulated areas (e.g. park areas). Figure O.6.1 shows the relationship between development density (inhabitants per hectare) and traffic per inhabitant per year (kilometres driven per inhabitant) in the 32 cities, which were included in the study.

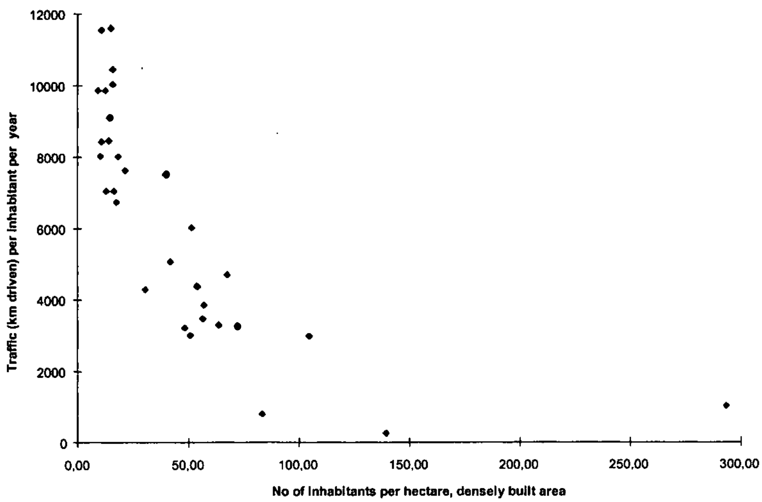


*Figure O.6.1: Relationship between development density and traffic per inhabitant in 32 cities. Source: Newman and Kenworthy 1989*

The figure shows that there is a strong negative relationship between development density and traffic volume. The greater the development density, the less vehicle traffic there is. In 21 towns in Norway, the urban area per inhabitant increased from 450 to 554 $m^2$ from 1970 to 1990 (Larsen and Saglie 1995). This means that the development density went down from 22 to 18 inhabitants per hectare. In an international context, Norwegian towns and cities have a very low development density.

A Norwegian study (Næss 1996) shows that there is a clear relationship between development density and traffic volume. When the development density increases from an urban area of around $600m^2$ per inhabitant to an urban area of $300m^2$ per inhabitant, the amount of traffic per inhabitant goes down by around 33%.

**Distribution of traffic across the road network**

A number of studies show that there are large variations in the accident rate between different types of road. Table O.6.1 summarises the results of these studies in the form of relative accident rates for different types of roads and traffic environments. Sources:

Denmark: Krenk 1985;
Great Britain: UK Department of Transport 1992;
Norway: Elvik and Muskaug 1994, Elvik 1996;
The Netherlands: Poppe 1993;
Sweden: Thulin 1991;

Finland: Tielaitos 1997;
USA: US Department of Transportation 1991

Relative accident rates are used because absolute rates are not directly comparable between different countries, due to differences in accident reporting. It is emphasised that the classification of road types in this table is rough and approximate, and is only intended to demonstrate main patterns. It has not been possible to obtain accident rates for all types of roads in all countries included in the table. Thus some cells do not show any accident rate.

*Table O.6.1. Relative accident rate on different types of roads in different countries. Injury accidents. Accident rate on motorways = 1.00. Source: see the text.*

| | | Relative accident risk of injury accidents in different countries | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Traffic environment | Type of road | DK | FIN | GB | N | NL | S | USA |
| Rural areas | Motorway | *1.00* | *1.00* | *1.00* | *1.00* | *1.00* | *1.00* | *1.00* |
| | Main road | 3.97 | 2.91 | 2.90 | 2.28 | 2.08 | 1.29 | 2.72 |
| | Collector road | 4.67 | 3.27 | 4.10 | 3.46 | 4.17 | 2.34 | 4.56 |
| | Access road | 5.67 | 6.11 | | 5.53 | | 1.34 | 8.66 |
| Urban areas | Main road | 11.00 | 7.86 | 9.60 | 5.22 | 18.44 | 2.15 | 5.68 |
| | Collector | 9.11 | 6.82 | 9.20 | 6.46 | 8.89 | 3.96 | 5.61 |
| | Access road | 9.98 | 7.35 | | 12.13 | 10.32 | 3.09 | 8.81 |
| All | All | 4.61 | 3.75 | 5.65 | 4.04 | 7.30 | 2.22 | 4.64 |

Country abbreviations: DK = Denmark, FIN = Finland, GB = Great Britain, N = Norway, NL = The Netherlands, S = Sweden, USA = USA

Table O.6.1 shows that motorways have the lowest rate of injury accidents of all roads. On average, the accident rate on motorways is about 25% of the average for all public roads. Main roads in rural areas also have a lower accident rate than the average for all public roads.

All roads in urban areas have a higher rate of injury accidents than the average for public roads. The accident rate on access roads in densely populated areas is on average around 7, when the accident rate on motorways is set equal to 1.00. It follows from this that the more traffic there is on access roads in densely populated areas, the higher the number of accidents will be. Traffic volume on access roads in densely populated areas can be limited by building roads in such a way that through traffic is prevented, by building short access roads and by building access roads in such a way that speeds are kept down.

***Design principles for roads and road systems.*** A number of studies have evaluated the relationship between different design principles for roads and street systems and the number of accidents. The factors which have been evaluated include:

1. *Degree of separation and differentiation of the road network in residential areas*
   The road network in an area is fully separated if all the roads in a residential area have physically separated facilities (foot and cycle paths or pavements) for pedestrians and cyclists, while at the same time the road network does not carry through traffic. If only parts of the road network fulfil these criteria, the area is partially separated and differentiated. If these criteria are not fulfilled at all, the area is not separated and undifferentiated.

2. *Types of connection between the local road network and the main road network (feeder principle)*
   A distinction is made between internal feeding, where the main road goes into or through an area with branches in the form of collector roads on both sides and external feeding, where a main road goes around an area.

3. *Through traffic on local roads*
   A distinction is made between cul-de-sacs, or dead-end streets, and open streets where through traffic is possible.

Studies evaluating the effects of these design principles for safety in residential areas include:

Hvoslef 1976 (Norway; degree of separation)
Bennett and Marland 1978 (Great Britain; through traffic)
OECD 1979 (several countries, all design principles)
Hvoslef 1980 (Norway; degree of separation)

These studies are relatively old and are to some extent based on simple comparisons. In the studies, the public health risk attributable to road accidents in different areas is used as a measure of safety. The public health risk is defined in terms of the number of injured persons per 1000 inhabitants per year. Table O.6.2 shows the best estimates of the effects of different design principles on the public health risk attributable to road accidents in residential areas (percentage change in health risk).

Table O.6.2 shows that fully separated and differentiated residential areas have fewer accidents than areas not separated or differentiated, that external feeding is associated with a lower risk than internal feeding and that roads which cannot carry through traffic are safer than those permitting through traffic. The latter is probably related to the fact that where through traffic is not allowed, traffic volume goes down.

*Table O.6.2 Effects of design principles for the road network in residential areas on the public health risk attributable to traffic accidents. Percentage change in health risk*

| Design principle | Groups compared | Best estimate | 95% confidence interval |
|---|---|---|---|
| Degree of separation | Totally separated vs. not separated | -64 | (-66; -61) |
| Form of connection | External vs. internal feeding | -33 | (-52; -6) |
| Through traffic | No through traffic vs. through traffic possible | -72 | (-75; -70) |

***The effect of the nature of the surroundings and the design of access roads.*** Roads in urban areas have a higher accident rate than roads in rural areas. As shown in table O.6.1 this applies to main roads, collector roads and access roads. However, accident rate is influenced not just by the degree of development, but also by the nature of the activity along the road. A distinction can be made between residential areas, industrial areas and areas with mixed land usage. A Norwegian study (Blakstad 1990) and a German study (Köhler and Schwamb 1993) have compared the accident rate on roads in areas with different land usage. Table O.6.3 shows the results of these comparisons (injury accidents per million vehicle kilometres).

*Table O.6.3: Relative accident rates on roads in urban areas depending on the type of activity along the road*

| Country | Building density | Type of building | Relative risk |
|---|---|---|---|
| Norway | Medium density | Housing | 1.00 |
| | | Industrial | 0.86 (0.70; 1.05) |
| | Dense | Housing | 1.00 |
| | | Industrial | 1.03 (0.84; 1.27) |
| Germany | Medium density | Housing | 1.00 |
| | | Mixed | 0.97 (0.84; 1.12) |
| | | Industrial | 1.24 (1.04; 1.47) |
| | Dense | Housing | 1.00 |
| | | Mixed | 1.59 (1.39; 1.82) |
| | | Industrial | 1.42 (1.23; 1.63) |

The accident rate on roads in residential areas is set equal to 1.00. The accident rate on roads in areas with other forms of buildings is expressed as a multiple of the accident rate in residential areas. In Norway, there does not appear to be a significant difference in accident rate between residential areas and other areas. In Germany a tendency has been found for the accident rate to be higher in industrial areas and areas with mixed land usage than in residential areas.

The accident rate on access roads in residential areas depends on the design of the road and the number of dwellings it serves. A British study (Bennett and Marland 1978) found that the health risk attributable to accidents on access roads in residential areas increased with an increasing number of dwellings served by the access road. The relationship between the number of houses served by a road and health risk is shown in figure O.6.2.

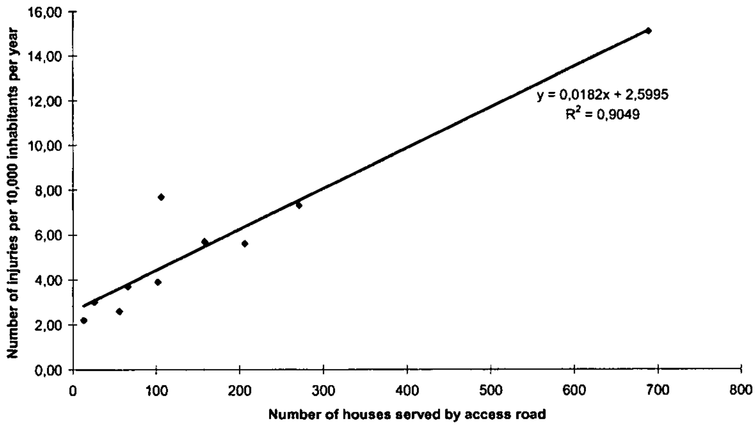


*Figure O.6.2: Relationship between the public health risk attributable to traffic accidents in residential areas and the number of houses served by access roads. Source: Bennett and Marland 1978*

The relationship shown in figure O.6.2 may be explained by differences in traffic volume. Access roads connecting many houses lead to more traffic than access roads serving only a few houses.

A Norwegian study has calculated the accident rate on access roads, depending on speed limit and on speed humps (Blakstad and Giæver 1989). The results of the study are summarised in table O.6.4. Accident rates on access roads in residential areas can be reduced by lowering the speed limit level and introducing physical speed reduction measures.

***Relocation of businesses.*** Land-use plans are usually regarded as very long-term tools in social planning. The physical structure of society changes slowly..

*Table O.6.4: Accident rate on access roads with different forms of traffic control, Norway. Source: Blakstad and Giæver 1989*

| | Injury accidents per million vehicle kilometres | | |
|---|---|---|---|
| Building density | Speed limit | Physical measure | Accident rate |
| Medium density | 50 | None | 1.43 (±0,51) |
| | 40 | None | 1.43 (±1,98) |
| | 30 | None | 0.74 (±0,51) |
| | 30 | Speed humps | 0.48 (±0,54) |
| Dense | 50 | None | 1.95 (±3,82) |
| | 40 | None | 3.17 (±2,07) |
| | 30 | None | 1.96 (±0,75) |

Nonetheless, relocation is common. Even though the actual building mass in an area may change little, the relocation of industries within in an area may have major consequences for transport.

Studies of the relocation of businesses show that the length of the journey to work may increase and that the modal split of transport may change (Hanssen 1993, 1995). When Gjensidige moved from the centre of Oslo to the outskirts of the city (Lysaker), for example, the proportion of those who drove to work increased from 17 % to 35%.

Studies of the relocation of offices from the city centre in San Francisco found that the employees had roughly the same distance to travel, but the proportion using public transport went down from 56% to 3%, while the use of cars tripled (Strand 1993).

Moving the banking industry out of the centre of Trondheim was associated with a reduction of 69% of the number of those using public transport, and a reduction of 67% of the number of those walking or cycling to work. Car usage increased by 190% (Lervåg 1985).

A study of the modal split of transport in a company which moved from a more peripheral location to a more central city location in Oslo found that the proportion of those travelling by public transport and the numbers walking or cycling to work increased. At the same time, the number of car journeys went down by 35% (Fosli 1995).

The studies indicate that locating workplaces in a city centre contributes to increasing the numbers using public transport and reduces the number of cars used to get to work. Locating a business on the outskirts of a large city will often increase the total amount of transport (number of person kilometres) on journeys to and from work.

## Effect on mobility

Few studies have attempted to quantify the effect of land use plans and land usage patterns on mobility. In an overview of land usage and transport in 32 major cities in the world (Newman and Kenworthy 1989) information concerning the average speed on the main road network in the cities was also obtained. Such information was available for 30 cities. Figure O.6.3 shows the relationship between the number of kilometres driven per inhabitant per year in the cities and the average speed on the main road network.

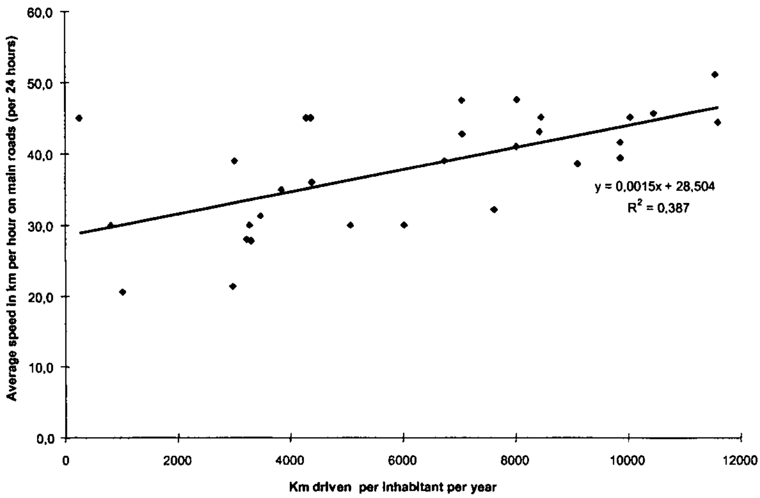


*Figure O.6.3. Relationship between the number of kilometres driven per year per inhabitant and the average speed on main roads in 30 major cities. Source: Newman and Kenworthy 1989*

Figure O.6.3 shows a tendency, albeit with significant spread, for the average speed to increase when the number of kilometres driven per inhabitant per year increases. Figure O.6.1 shows that the number of kilometres driven per inhabitant per year in different cities is highest in cities with low development density. This implies that the average speed is highest in a dispersed development pattern with low density, and lowest in a dense development pattern with relatively low land usage.

**Effect on the environment**

The severity of environmental problems caused by road traffic is strongly related to traffic volume. All other conditions being equal, a land use pattern inducing a lot of traffic will increase environmental problems. In general, a reduction in traffic volume will lead to a reduction in noise and pollution. Studies indicate that inhabitants in cities with a low development density use on average 25% more energy for transport than inhabitants in cities with high density (Næss 1996).

The construction of large shopping centres near main roads can generate increased traffic (Engebretsen 1991).

Speed-reduction measures on access roads in residential areas can have adverse effects on both noise and on air pollution. When heavy vehicles, of which there are very few in residential areas, cross speed humps, rattling from the truck bed and the movable mechanical fittings on the vehicle can increase noise. At very low driving speeds, the emission of exhaust gases also increases. See also chapter 3.12, speed reducing devices.

**Costs**

The costs of land use planning and the development of an area vary considerably depending on local conditions. A development pattern requiring the construction of new roads will normally be more expensive than a development pattern where existing roads can be used to a large extent. Norwegian studies indicate that concentrated development patterns produce somewhat lower total investment and operating costs than dispersed patterns (Næss 1996).

The factors which affect the costs of the development of an area most strongly are the topography (terrain), the type of land, the type of building, building density, the installation of main technical systems, alignment, dimensions and mass balance for technical installations. Roads comprise approximately one third of building land costs and by establishing building plots on both sides of the road, and/or reducing the width of the plot, the number of road metres per plot can be reduced (Fiskaa and Stabell 1988). Under otherwise identical conditions, narrower roads are cheaper than wide roads (Hoffmann 1982; Kolbenstvedt and Strand 1986).

### Cost-benefit analysis

Examples of formal cost-benefit analyses of land use plans, where costs and benefits of different development principles are quantified, have not been found. It is difficult to do good cost-benefit analyses of land use planning, because the measure has a large number of objectives, which cannot always be expressed in a meaningful way. Among the qualities valued by many people in a residential area are the view, pretty countryside, little pollution, little traffic, few accidents, a low crime rate, peace and quiet and low living expenses. In industrial areas, good accessibility is valued highly. At present, no satisfactory monetary valuation of all these qualities is available. The basis for cost benefit analyses of land use plans is therefore inadequate.

## O.7 ROAD PLANS AND ROAD CONSTRUCTION

### Problem and objective

In order to ensure a high level of road safety, road planning needs to be based on the best knowledge available of the effects of road design on road safety. Formal road planning, as a traffic safety measures should:

- locate roads and industries so that traffic volume is as small as possible
- establish a hierarchy of roads, so that traffic is segregated according to different characteristics and needs
- design roads in such a way that the highest possible level of safety is built into them
- ensure that no easily preventable traffic hazards exist before roads are opened to traffic
- identify places which have particular needs for safety measures and introduce effective measures at such sites

### Description of the measure

In this chapter, the effects on road safety of the following elements of road plans and road construction is considered:

- technical standards for roads - road design standards
- whether new roads are safer than old roads
- whether new traffic is induced by new roads or by expanding existing roads

## Effect on accidents

***Elements of design standards.*** The road design standards specify in detail the correct design of different elements of a road. These standards are not based exclusively on the results of research showing which road design is the safest (Hauer 1988, Jenssen 1988). They have been developed gradually as increasing vehicle traffic has made it necessary to plan better roads. Knowledge of the effects of road design on safety is therefore incomplete. However a number of characteristics of roads have known effects on road safety. Table O.7.1 summarises the knowledge of effects on the number of accidents of a number of design elements for roads. More detailed results are presented in other chapters, particularly in chapter 1, part III, road design and road equipment.

*Table O.7.1: Effects of standard requirements for roads on the number of injury accidents. Summary of results from the chapter on road design and road equipment*

| | | Percentage change in the total number of injury accidents | |
|---|---|---|---|
| Elements of design standards | Traffic environment/ Alternative | Best estimate | 95 % confidence interval |
| Road width | Rural areas | -5 | (-7; -3) |
| | Urban areas | +11 | (+7; +15) |
| Road shoulder | Rural areas | -8 | (-16; +0) |
| General alignment | Rural areas | -23 | (-28; -17) |
| Sight triangle at intersections | Rural areas | -3 | (-18; +14) |
| Use of grade separated interchanges | T-junction | 0 | (-20; +25) |
| | X-junction | -50 | (-55; -45) |
| Upgrading roads to current design standards | Rural areas | -20 | (-25; -15) |
| | Urban areas | -7 | (-12; -1) |

Increasing the width of the road reduces the number of injury accidents on roads in rural areas but may result in an increase in urban areas. Roads with shoulders have fewer accidents than roads without shoulders. The standards for alignment include a number of alignment elements and are summarised to form a general indicator of alignment standards. Roads with a good standard of alignment have around 25% fewer injury accidents than roads with poor alignment standards. Improving sight distances at intersections appears to have little effect on accidents. Grade separated interchanges are safer than crossroads, but not safer than three leg junctions (T-junctions). General upgrading of roads to current design standards reduces injury accidents by around 20% in rural areas and 7% in urban areas.

***Safety on new and old roads.*** In an American study (Chatfield 1987) the fatality rate on roads opened to traffic in the years 1967-71 was compared with the fatality rate for roads opened to traffic before 1967. Figure O.7.1 shows the results of the study.

Figure O.7.1 shows that the new roads had around 20% (-28%; -12%) fewer fatal accidents per 100 million vehicle miles than the older roads. On both older and new roads the fatality rate drops dramatically with increasing traffic volume. This may in part be due to the fact that heavy traffic means that speeds drop, so that accidents are less serious. The standard of roads with heavy traffic is often better than that of roads carrying little traffic.

In a Swedish study (Björketun 1991) the accident rate on roads designed and built in the 1950s, the 1960s and the 1970s were compared. Table O.7.2 shows the results of the study, stated in terms of the number of injury accidents per million vehicle kilometres on roads built in different decades and with different road widths.

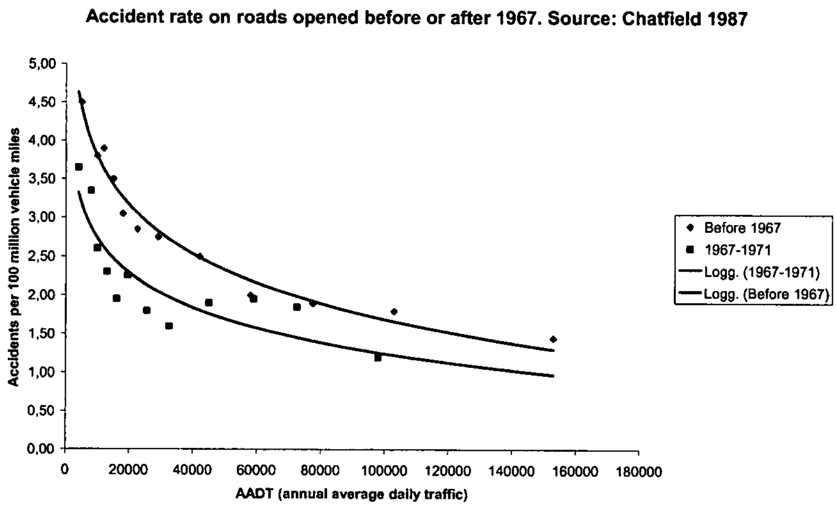


*Figure O.7.1: Number of fatal accidents per 100 million vehicle miles on roads in the USA opened at different times. Source: Chatfield 1987.*

*Table O.7.2: Injury accidents per million vehicle kilometres on roads built in different decades and with different road widths in Sweden. Source: Björketun 1991*

| | Reported injury accidents per million vehicle kilometres | | | |
|---|---|---|---|---|
| Construction decade | Narrow roads | Average width | Wide roads | All roads |
| 1950s | 0.31 | 0.29 | 0.28 | 0.30 |
| 1960s | 0.32 | 0.28 | 0.41 | 0.33 |
| 1970s | 0.28 | 0.26 | 0.26 | 0.27 |
| All decades | 0.29 | 0.27 | 0.31 | 0.29 |

From the 1950 to the 1960s there was no decrease in the accident rate. Roads built in the 1970s, however, have a lower accident rate than older roads. On these roads, the rate of injury accidents is around 18% lower than on roads built in the 1960s and around 10% lower than on roads built in the 1950s. (Björketun 1991).

A number of Norwegian studies provide information about the accident rate on roads built in recent years and make it possible to compare these with roads built earlier. This information is available for a stretch of motorway in Akershus (Smeby 1992) and a stretch of motorway in Sør- and Nord-Trøndelag (Holt 1993). Table O.7.3 compares information from these sources. Information about normal accident rates on different roads is taken from Elvik and Muskaug (1994).

*Table O.7.3: Accident rate (injury accidents per million vehicle kilometres) on a number of new roads in Norway compared with the normal accident rate on these types of roads*

| | | | Injury accidents per million vehicle km | |
|---|---|---|---|---|
| Stretch of road | Type of road | Opened | On new roads | On all roads |
| Dal-Hammerstad | Motorway-B | 1988 | 0.10 | 0.12 |
| Ranheim-Reitan | Motorway-B | 1988 | 0.13 | 0.12 |
| Jessheim-Dal | Motorway-B | 1989 | 0.08 | 0.12 |
| Reitan-Hommelvik | Motorway-B | 1990 | 0.13 | 0.12 |

The accident rates in table O.7.3 do not show any systematic pattern. Some of the new stretches of road have lower accident rates than normal for this type of road, while others have higher rates.

***New traffic induced by new roads.*** One question which has been discussed, particularly in connection with the development of the main road network in large cities where the road network has capacity problems, is whether new roads induce so much new traffic that the benefit of a lower accident rate per kilometre driven is offset by an increase in the number of kilometres driven. The following Norwegian studies indicate how much new traffic results from a road construction:

Haakenaasen 1980 (bypass road in Gol)
Kolbenstvedt et al 1989 (The Vålerenga tunnel in Oslo)
Amundsen and Gabestad 1991 (The Oslo tunnel in Oslo)
Sandelien 1992 (a number of road projects in Norway)
Holt 1993 (motorway between Trondheim and Værnes)
Statens vegvesen Sør-Trøndelag 1996 (expansion from two to four lanes in Trondheim)

*Table O.7.4: Percentage of new traffic or new journeys on roads in Norway.*

| | | Induced traffic (percentage) (journeys) | |
|---|---|---|---|
| Type of road | Time period for increase in traffic | Best estimate | 95% confidence interval |
| Roads to areas without roads | First year | +220 | (+127; +351) |
| Bridge to relieve ferry | On opening | +69 | (+41; +97) |
| Bridge to relieve ferry | After ten years | +67 | (+25; +109) |
| Tunnel which reduces distance | On opening | +73 | (+22; +124) |
| New main roads in cities | First 2-3 years | +11 | (-8; +30) |
| Increased road capacity in cities | First 3-8 years | +14 | (+3; +25) |

The amount of induced traffic depends on a number of conditions (Sandelien 1992), including what road provision the area had previously (if any), the size of the increase in road capacity, whether there were previously road capacity problems or not, how much time can be saved by using a new road, whether the new road is a toll road etc. Table O.7.4 shows the percentage of induced traffic for a number of road projects in Norway.

Table O.7.4 shows that roads to areas that did not previously have a road, or roads replacing ferries or tunnels shortening existing road connections are associated with a considerable amount of new traffic. The construction of new main roads in cities and increasing the capacity of existing main roads in cities do not appear to generate as much new traffic.

## Effect on mobility

It is important to take account of accessibility and mobility in road planning. A main objective of road construction is to ensure more effective and less time-consuming travel.

The Norwegian Public Roads Administration has set the following main targets for accessibility on different roads in Norway (Statens vegvesen, handbook 158, 1991; excerpts from a total of 10 points):

1. In the ten largest urban areas, the journey time between given destinations on the national highway network in the rush hour should not be more than twice as long as outside the rush hour, with 90% probability.
2. On the main road network road users should be able to calculate their journey time based on an average speed of 70-75 km per hour.
3. On the regional road network, road users should be able to calculate their journey times based on an average speed of 60-70 km per hour.
4. There are no objectives for journey time for the rest of the national road network.
5. Pedestrians and cyclists should have separate paths where there are more than 1000 vehicles per day on the national highway and where the combined pedestrian and cycle traffic is greater than 75 per day.

One question which is often discussed is whether developing roads in large towns and cities improves mobility, or whether the roads soon fill up with increased traffic, so that mobility becomes as bad as before (Downs 1962, Mogridge 1996). A study in California (Hansen and Huang 1997) estimated that the number of vehicle kilometres increased by 0.7-0.9% for each percentage increase in road capacity, measured in lane kilometres. This implies that the growth in traffic almost keeps level with the increase in road capacity and that the flow of traffic does not particularly improve, no matter how large road capacity is provided.

### Effect on the environment

Many road projects affect the environment. Estimates made on the basis of the Norwegian road and road traffic plan for the period 1998 - 2007 (Elvik 1996) show that the number of people exposed to unacceptably high noise along national highways (trunk roads excepted) is expected to go down from 83,668 in 1998 to 76,602 by the year 2008 if the recommended strategy is adopted. The number of people exposed to particularly high concentration of particles in the air is expected, during the same period to go down from 20,735 in 1998 to 14,611 in 2008.

### Costs

In 1993, the Norwegian Public Roads Administration spent NOK 332 million on planning national highway constructions in Norway. This represented 5.3 % of the construction costs (Statens vegvesen 1994). In 1987, around NOK 24 million was used for county road construction planning, which corresponded to 3.5% of the construction costs.

## Cost-benefit analysis

Cost benefit analyses are carried out for all investment projects on national highways in Norway. Five alternative investment strategies were developed for the road plan period 1998 - 2007:

1 a mobility strategy
2 an environmental strategy
3 a road safety strategy
4 a district strategy (only in 15 of 19 counties)
5 a recommended strategy

The strategies are named according to the policy objective given highest priority in the strategy. The recommended strategy is a mixture of the other four strategies. Figure O.7.2 shows the estimated total benefit and estimated costs of the alternative strategies for the period 1988-2007 (Samferdselsdepartementet, St meld 37, 1996-97).

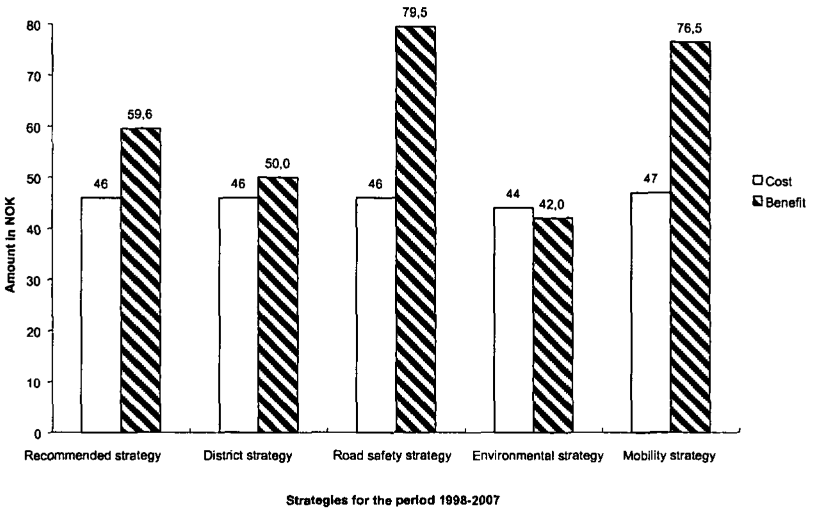


*Figure O.7.2: Costs and benefits of alternative strategies for the road plan period 1998 - 2007 in Norway. Source: Samferdselsdepartementet, St meld 37, 1996-97.*

The estimated benefits are the sum of benefits for mobility, road safety and the environment. Figure O.7.2 shows that the road safety strategy gives the greatest total benefit and has the best benefit-cost ratio. In the recommended strategy, the benefit (present value) is around NOK 20 billion less than in the road safety strategy.

## O.8 ROAD SAFETY AUDITS

### Problem and objective

The design of public roads, road maintenance and traffic control in Norway are based on a comprehensive set of regulations and guidelines which have been produced by the Norwegian Public Roads Administration. These regulations and guidelines also include the road design standards, the manual on uniform traffic control devices, maintenance standards and other legislation and specifications.

One of the objectives of detailed technical regulations governing road design, road maintenance and traffic control is to ensure road safety. The intention is to base the design of road and traffic facilities on knowledge of how the design affects the accident rate and by setting criteria for the use of different traffic control devices which are designed to ensure that the devices are used in a way that gives the best possible effect for road safety.

What is special about the regulations issued by the Norwegian Public Roads Administration regarding road design, road maintenance and traffic control is that the regulations are primarily intended for use by the same agency that issues them. It has been documented that these regulations are not always followed in practice. Exceptions are made from the road design standards when new roads are planned often in order to reduce the construction costs.

Road safety audits are intended to detect defects in road design or traffic control, and ensure that these are corrected in order to prevent accidents.

### Description of the measure

Road safety audits have been introduced in Denmark (Jørgensen and Nilsson 1995) and Great Britain (Brownfield 1996) amongst other countries. A proposal for a handbook has been drawn up in Norway (Amundsen 1996). The handbook contains a set of checklists, or items to be investigated in a road safety audit. Separate checklists have been drawn up for:

- municipal plans
- local development plans
- construction plans
- traffic control at intersections
- signal control
- roundabouts
- signal controlled or marked pedestrian crossings
- traffic islands

- facilities for pedestrians and cyclists
- road tunnels
- bridges

Road safety audits are currently at the test stage in Norway. The intention is to make such audits a permanent arrangement.

**Effect on accidents**

Only one study has been found where an attempt was made to quantify the effect on accidents of road safety audits. This is a Danish study (Jørgensen and Nilsson 1995) of 13 road construction projects where road safety audits were carried out. It was concluded that the auditor's comments led to improvements that were estimated to prevent 25 - 28 accidents (injury accidents and property damage only accidents) per year. The safety audit entailed an additional cost around DKR 12 million. The total construction costs were around DKR 1 billion.

In addition, there is one American study of the effects on accidents of improving incorrect signs (Lyles, Lighthizer, Drakopoulus and Woods 1986). The study evaluated the effects of upgrading road signs in cities so that they complied with the "Manual on Uniform Traffic Control Devices (MUTCD)". The study found that upgrading signs to conform with MUTCD led to a 15% decrease in the number of injury accidents (-25%; -3%). The number of property damage only accidents went down by 7% (-14%; -0,3%). The authors of the study wrongly concluded that improving incorrect signs did not reduce the number of accidents, on the basis of an inadequate statistical analysis of the data.

**Effect on mobility**

No effects on mobility of road safety audits have been found.

**Effect on the environment**

No effects on the environment of road safety audits have been found.

### Costs

In Denmark (Jørgensen and Nilsson 1995) the costs of road safety audits are calculated to be around DKr 1 million per audit. This amount consists of 0.2 million kroner per audit for the audit work itself, and around 0.9 million kroner for additional costs for the implementation of the measures proposed by the auditors. The additional cost of implementing measures proposed by the auditors comprised 1.15 % of the total construction costs of the roads.

### Cost-benefit analysis

A Danish cost benefit analysis of road safety audits calculated the benefit of 13 audits to be DKR 19.9 million in the form of reduced accident costs in the first year. The costs were estimated to be DKR 13.6 million. This gives a so-called first year rate of return of around 146 % (Jørgensen and Nilsson 1995). Assuming that the measures produce a benefit lasting for 25 years, the present value of the benefit can be estimated at DKR 232 million. This is considerably more than the cost of the measure and shows that road safety audits, as they are practised in Denmark, are very cost-effective.

No cost benefit analyses of upgrading incorrect signs have been found. On the basis of the information given above, a numerical example can be worked out to indicate possible effects of the measure. It is assumed that upgrading incorrect signs costs around NOK 10,000 per kilometre of road. It is assumed that the measure is implemented on a national highway in a town, with an annual average daily traffic of 6,000 vehicles and 0.40 injury accidents per million vehicle kilometres. It is assumed that the number of injury accidents goes down by 15% and the number of property damage only accidents goes down by 7%. The effect of the measure is assumed to last for five years.

The benefit is around NOK 1.24 million per kilometre of road. This is more than 100 times the cost of the measure. In other words, upgrading incorrect signs is very cost-effective, even if the true effect on accidents were to be considerably smaller, or the costs considerably higher than assumed in this example.

## O.9 MOTOR VEHICLE TAXATION

### Problem and objective

Using a motor vehicle gives rise to a number of costs for society. These costs include the construction and maintenance of public roads, traffic control, police enforcement, accident costs, environmental costs, time costs and congestion costs.

The extent to which motor vehicles are used depends on how much users have to pay to acquire, own and use the vehicle (Fridstrøm and Rand 1993). The amount of traffic, and thus the number of accidents, can therefore be affected by changing the level and form of vehicle taxation.

Many of the costs of owning and using a motor vehicle are paid for by the users in the form of direct out-of-pocket expenses. However, this does not apply to all costs. Some accident costs and a very large part of the environmental costs, i.e. the cost of all types of environmental problems which road traffic inflicts on society, are external, that is to say, they are not charged to those who bring about these costs. The bulk of congestion costs on roads are also external.

An issue which has often been discussed is whether the users of motor vehicles pay the full costs to society associated with the use of vehicles through taxes on the purchase, ownership and use of motor vehicles. If the external costs are not covered by taxation, this implies that society is subsidising the use of motor vehicles. In principle, it is possible to affect the number of traffic accidents through taxing the purchase, use and ownership of motor vehicles. Possible objectives of systems of vehicle taxation include:

1 Managing travel demand. This can be achieved both by affecting the number of vehicles bought and affecting how long each vehicle is driven.
2 Limiting the number and use of vehicles with particularly high levels of risk. This can be done by imposing particularly high taxes on such vehicles.
3 Promoting the safest possible composition of the vehicle fleet with regard to age, size or other characteristics, which can affect the number of accidents or injuries. This can be done by grading the taxation levels on the basis of the characteristics to be affected.
4 Promoting the increased use of safety equipment which is not compulsory, and which is not standard equipment. This can be achieved by giving tax rebates for such equipment.

In addition to these objectives, vehicle taxation has a purely fiscal objective, i.e. it is an appropriate source of revenue for the state.

## Description of the measure

The costs of using motor vehicles can be divided into internal and external costs (Larsen 1991). Internal costs are all costs that the users of motor vehicles cover themselves and take into account when they are deciding whether to buy a vehicle and how much it will be used. External costs are all costs which are not covered by the users of motor vehicles themselves, but which are inflicted on other members of society, such as people who are affected by noise and pollution from road traffic, or the public sector.

A number of attempts have been made to estimate the external costs of using motor vehicles in Norway. In connection with the work on parliamentary report no. 32, on the main principles of transport and communications policy (Samferdselsdepartementet, 1996), an estimate was made (Eriksen and Hovi 1995). The most important results from this study are shown in table O.9.1.

*Table O.9.1: External costs of the use of motor vehicles in Norway. Source: Eriksen and Hovi 1995*

| | Amount in NOK million (1993-prices) | |
|---|---|---|
| Cost post | Best estimate | Confidence interval |
| Wear and tear on roads | 1,580 | (1,580; 1,580) |
| Road accidents | 8,022 | (8,022; 8,022) |
| Noise | 2,857 | (2,857; 2,857) |
| Air pollution | 10,733 | (7,708; 15,990) |
| Total | 23,192 | (22,167; 28,449) |

The external costs of using motor vehicles in Norway in 1993 were estimated at almost NOK 23.3 billion. The Norwegian government's income from special taxes on motor vehicles in 1993 was NOK 20.2 billion (Opplysningsrådet for veitrafikken 1996).

## Effect on accidents

No studies have been found which show the effect on accidents of changes in vehicle taxation. The effect will be indirect, by affecting travel demand, which in turn affects the number of accidents.

***Simulated effects of alternative tax systems.*** On the basis of the national transport model for Norway, Fridstrøm and Rand (1993; see Fridstrøm 1993) have estimated the expected effects on the total number of journeys of different possible changes in vehicle taxation. Table O.9.2 summarises the results of the calculations.

*Table O.9.2: Expected effects on the amount of travel (number of person km) of different possible changes in vehicle taxes in Norway. Source: Fridstrøm and Rand 1993*

| | Percentage change in number of person km | | | |
|---|---|---|---|---|
| | Private cars | | Bus | |
| Change in tax | Short term | Long term | Short term | Long term |
| Increasing annual tax by NOK 2,000 | | -8 | | +6 |
| Increasing petrol prices by NOK 5 per litre | -10 | -26 | +6 | +24 |
| Vehicle taxes abolished, no increase in other taxes | | +27 | | -4 |
| Vehicle taxes abolished, income tax increased correspondingly | | +25 | | -4 |
| 50% lower purchase tax, and ca 50% higher fuel tax | | +2 | | -3 |
| 50% increase in fixed costs of keeping a car | | -17 | | +16 |
| 50% reduction in fixed costs of keeping a car | | +14 | | -6 |
| 50% increase in variable costs of keeping a car | -8 | -20 | -2 | +8 |
| 50% reduction in variable costs of keeping a car | +16 | +26 | +2 | -3 |

Short-term effects are immediate adaptations, given the current vehicle fleet. Long-term effects also include adaptations in the form of changes in the vehicle fleet. The estimates show that vehicle taxes influence travel demand. If vehicle taxation were abolished, the number of person kilometres driven by car would increase by 25 – 30%. The number of vehicle kilometres would increase even more, by 35 - 40 %, because the use of cars would become more individual. If traffic were to increase by this amount, the number of injury accidents would be expected to increase by 25-30%.

The figures presented above indicate that the total taxation on vehicles needs to increase by around 25% in Norway in order for the taxes to cover the external costs of the use of vehicles. This increase in taxation would reduce the amount of traffic by around 10 to 15%, depending to some extent on how the increase in taxation is implemented. This could reduce the number of injury accidents by 5 – 10%.

***Increases in tax for high risk vehicles.*** From 1 January 1974, purchase tax for new motorcycles increased considerably in Norway (NOU 1975:42). In 1974, fewer new motorcycles were registered than in previous years. The number of motorcycles registered for the first time before and after 1974 were:

| 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|
| 4,203 | 3,821 | 3,598 | 3,638 | 3,710 | 3,462 | 3,525 | 3,949 |

There was a decrease of 248 in the number of motorcycles registered for the first time between 1973 and 1974. This decrease was no greater than the corresponding decrease in the number of motorcycles registered for the first time between 1969 and 1970. In both 1975 and 1976, the number of motorcycles registered for the first time increased again. Increases in taxation therefore appear to have had only a short-term, limited effect on the number of new motorcycles.

***Use of taxes to affect the composition of the vehicle fleet according to age and size.*** In public discussions on vehicle taxation, it is claimed that older cars are less safe than new cars and that the taxation system should therefore encourage a faster renewal of the car fleet. In 1996, the scrap fee in Norway was temporarily increased from NOK 1,000 to NOK 6,000 for specific groups of older cars. The number of scrapped cars increased significantly in 1996 in relation to previous years.

The relationship between the age of the car and accident rate is not well known. Without further study, it is not possible to say what effect the age of the car has on the risk of injury accidents in Norway today.

The relationship between the weight of the vehicle and its crashworthiness has also been much discussed. In 1984, a Norwegian public committee (NOU 1984:6) proposed changing the form of purchase tax to encourage the purchase of heavier vehicles, partly on the basis of studies showing that occupants of larger cars are injured less often in accidents of a given severity than occupants of small cars.

The effect of car weight (mass) on the risk of injury is dealt with in chapter 4.19. It is correct that heavy vehicles protect occupants from injury. On the other hand, they represent an increased risk of injury for occupants of lighter cars. The difference in the level of protection against injury between cars of different weights in the current car fleet is entirely due to differences in mass, not to mass as such. A British calculation of the effects of changes in mass of the car fleet (Broughton 1995) concluded that if the average mass were reduced by 5%, the number of injured drivers would be reduced by around 1.5%. This calculation indicates that there would be a favourable effect on safety in Norway if everyone had smaller cars than they do today, and if the differences in weight between cars were reduced.

**Effect on mobility**

Vehicle taxation contributes to reducing travel demand. This leads to less traffic on the roads than there would have been if all vehicle taxation were abolished.

In and around the larger cities and towns in Norway, the road network is congested during certain times of the day. On these roads, less traffic will have a favourable effect on the flow of traffic for the remaining traffic. However, general vehicle taxation is not designed to affect the amount of traffic on any specific road. Nonetheless, it affects the total amount of traffic and thus the total amount of traffic congestion.

### Effect on the environment

The severity of environmental problems associated with road traffic is closely related to traffic volume (Kolbenstvedt, Silborn and Solheim 1996). Current Norwegian vehicle taxation contributes to curbing travel demand and thus the total extent of environmental problems. General vehicle taxation is not designed with a view to affecting local environmental problems.

In a Norwegian study of the effects of environmental taxation effects on transport (Fridstrøm, Ramjerdi, Svae and Thune-Larsen 1991), the effects of increasing the $CO_2$ tax on fuel were estimated. An extrapolation of current developments (the reference alternative) was compared to a policy where the taxes on fossil fuels were increased (taxation alternative). It was estimated that emissions of $CO_2$ in 2000 would be 4% lower in the taxation alternative than in the reference alternative. For 2025, a reduction in emission of 14% was estimated if the taxation alternative were chosen instead of the reference alternative.

### Costs

The social opportunity costs of motor vehicle taxation are not well known. These costs consist of the direct collection costs and the net value of gains or losses in efficiency caused by the taxation. Amongst the gains in efficiency is the limitation of the external effects of road traffic. These external effects have been estimated to be around NOK 25 billion for Norway in 1995. The costs include the loss of consumer surplus for journeys not made, due to current taxation. This loss is unknown.

In an estimate of the marginal costs of different forms of taxation, Brendemoen and Vennemo (1993) conclude that taxes on petrol, mineral oil and $CO_2$ emissions are clearly the most cost-effective forms of taxation in Norway. The explanation for this is that these forms of taxation contribute to limiting environmental problems. When the environmental costs of different forms of consumption are included, petrol taxation, mineral oil taxation and $CO_2$ taxation have a negative social marginal cost in Norway. This means that the advantages these taxes in terms of less environmental problems are valued more highly than the costs which they entail in terms of a reduction in consumption causing environmental problems (Brendemoen and Vennemo 1993).

On the basis of this study, it is concluded that general vehicle taxation does not lead to any net opportunity costs in Norway.

**Cost-benefit analysis**

If vehicle taxation in Norway were to be abolished, the number of kilometres driven by cars would increase by 35 – 40%. Calculating, as a very rough approximation, that the external effects of driving would increase correspondingly, this represents an added cost of around NOK 9-10 billion.

According to Brendemoen and Vennemo's study (1993), mentioned above, Norwegian consumers value the benefit of reduced environmental problems more highly than the costs of taxation. The external costs of road traffic are currently very probably greater than vehicle taxes, which implies that it would be cost-effective to increase these.

## O.10 ROAD PRICING

**Problem and objective**

The costs to society of using motor vehicles vary considerably across different types of road and traffic flow conditions. On roads with light traffic which run through undeveloped areas, the external effects of driving motor vehicles in the form of accidents, noise, air pollution emission, undesirable land usage and barriers for local travel are relatively small. In dense rush-hour traffic on main roads in large towns and cities, these external effects are considerably greater. Furthermore, traffic congestion inflicts large costs on all road users.

Eriksen and Hovi (1995) have estimated the external costs of road traffic in Norway for different types of vehicles. A distinction is made between urban and rural areas. Costs that were included in the estimates are costs associated with: road wear and tear, accidents, noise, emission of $CO_2$ (contributing to the global greenhouse effect), local exhaust gas emissions and local emission of dust and particles. Figure O.10.1 shows the results of the calculations for private cars (petrol driven), mopeds and motorcycles, buses, vans and lorries. The figure gives the marginal external costs per kilometre driven in towns, in rural areas and in all areas taken together. In addition, taxes that are proportional to the distance driven are also given, per kilometre driven.

Figure O.10.1 shows that the external costs per kilometre driven in Norway are higher in towns than in rural areas for all types of vehicle. Furthermore, the average external costs are higher than the taxation rates for all types of vehicle. In rush hour traffic in the largest cities, the external congestion costs, which are not included in figure O.10.1, are considerable. For example, the congestion costs in Oslo in the rush hour are of the order of magnitude of NOK 1-2 per kilometre driven (Grue, Larsen, Rekdal and Tretvik 1997).

Road pricing makes it possible to charge road users for the full costs which they inflict upon society. Road pricing refers to paying for the use of public roads, based on the extent of use and the costs this imposes on society. The objective of road pricing is to ensure that road users make their travel behaviour choices, based on the best available information of the social costs, which their choice entails

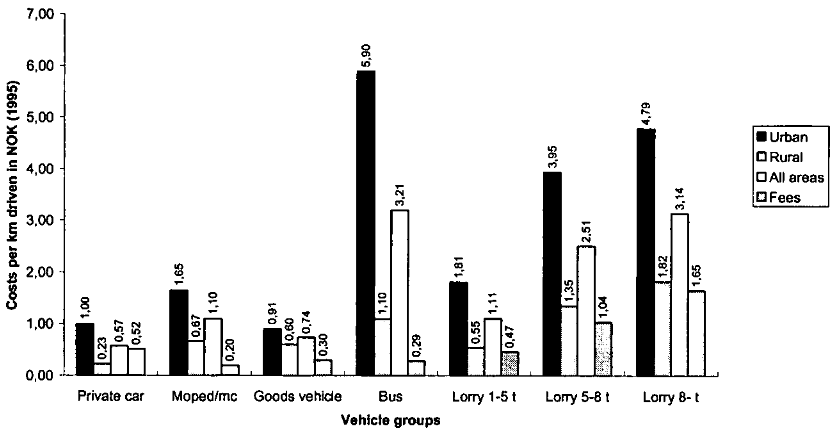


*Figure O.10.1: Marginal, external costs per vehicle kilometre of travel for different forms of transport in Norway. Based on Eriksen and Hovi, tables 8.6, 8.8, 8.8b and 8.9b.*

## Description of the measure

Road pricing is not primarily intended as a road safety measure. As a rule, the measure is regarded as a traffic control measure designed to reduce rush-hour traffic or to spread this in time (Newbery 1990, Winston 1991, Jones and Hervik 1992, Jansson 1994, Lindberg 1994, Verhoef 1994, Bergan and Wærness 1995, Larsen and Minken 1995, Mayeres, Ochelen and Proost 1996, Meland 1996). The reason for using road pricing in this way is that it is not considered feasible to expand the road capacity in large cities to such an extent that congestion will disappear.

Here the concept of road pricing will be used in a looser sense to cover all forms of direct user payments on public roads, whatever the objective. Such payment is currently found in Norway in three forms (Meland 1996):

1. Tolls
   On a number of roads, tolls are paid by road users as part of the means of financing the road construction. Tolls are collected to finance a number of bridges and other major road constructions

2. Toll rings
   In Bergen, Oslo and Trondheim, toll rings have been set up around the cities to finance the development of the main road network in and around the cities. All traffic which passes through the toll ring road towards the city must pay a fee. In Bergen, the toll ring was set up on 2 January 1986. Tolls are paid from Monday to Friday between 0600 hours and 2200 hours. The rates do not vary in this period. The toll ring in Oslo was opened on 1 February 1990. Tolls are paid all day, every day. The rates do not vary over the 24-hour period. In Trondheim, the toll ring was opened on 14 October 1991. Tolls are paid from Monday to Friday between 0600 hours and 1700 hours. Tolls are higher between 0600 hours and 1000 hours than between 1000 hours and 1700 hours.

3. Local fuel tax
   In Tromsø a special local tax on petrol of 50 øre per litre was introduced on 1 July 1990 to finance road construction in the city.

Internationally, road pricing has been much discussed in recent years, but is seldom used. The most famous system is the Area Licensing scheme in Singapore (Meland 1996), which is a payment system introduced to limit the amount of the vehicle traffic in the central areas of the city.

**Effect on accidents**

***Tolls with alternative choice of road.*** A study of route choices in the area around Drammen, Norway in 1977 between destinations where it was possible to use both the toll road and national highways where no tolls were payable, found that around 18% of traffic between these points used the old national road network (Kristiansen and Østmoe 1978). The study estimated that half of the traffic which chose the old national highway network, i.e. around 9% of the total traffic, would have chosen the toll road if no fees were payable on that road. The effect on accidents of this displacement of traffic were not quantified in the report.

The toll road is a four-lane motorway with a median. The national highway is a two-lane road with some development along the road. On the basis of normal accident rates for national highways in the period 1977-80 the accident rate on the roads in question at the time the study was carried out (1977) can be estimated to be around 0.08 injury accidents per million vehicle kilometres on the toll road and around 0.40 injury accidents per million vehicle kilometres on the national highway (Muskaug 1985).

Using these figures as a basis, they indicate that, with no fees, the total number of accidents on the two roads would have been around 17% lower than the actual number. Traffic on the national highway would then have been considerably lower, while traffic on the toll road would have increased about 12.5%

***Effects of toll ring roads in Bergen, Oslo and Trondheim and of local fuel taxes in Tromsø, Norway.*** The effects on traffic volume of the toll rings in Bergen, Oslo and Trondheim, and the local fuel tax in Tromsø, have been the subject of a number of studies (Bergen: Larsen 1987, 1988; Oslo: Solheim 1992, Ramjerdi 1995; Trondheim: Meland 1994, Polak and Meland 1994; Tromsø: Samferdselsdepartementet (Ministry of Transport and Communications) 1993). In Bergen, the decrease in vehicle traffic during the first year following the opening of the toll road, during the part of the day when tolls were payable is estimated to be 6 - 7%. No transfer to public transport was found. In Oslo, the decrease in car traffic is estimated to be 3 - 10% for the first year after the toll ring was opened. No transition to public transport could be found in Oslo either. In Trondheim, the decrease in vehicle traffic in the period when tolls are payable was estimated at 8% for the year after the ring road was open. In Tromsø the decrease in vehicle traffic was estimated at 7% during the first year after the local fuel tax was introduced.
A decrease in traffic around 5- 10% can be expected to reduce the number of injury accidents by approximately the same percentage. Table O.10.1 shows changes in the number of injury accidents per year from before to after the introduction of tolls/taxation systems in the four Norwegian cities (Bergen: 1985-1986; Oslo: 1989-1990; Trondheim 1990-1992; Tromsø: 1989-1991).

*Table O.10.1: Changes in the number of injury accidents in Norwegian cities with toll rings, compared with towns in the rest of Norway*

| | Accidents in the four cities | | Accidents in other towns | | |
|---|---|---|---|---|---|
| City | Before | After | Before | After | Change [(1)] |
| Bergen | 525 | 458 | 4189 | 4375 | -16% |
| Oslo | 1108 | 1122 | 3089 | 3194 | -2% |
| Trondheim | 274 | 239 | 4042 | 3771 | -7% |
| Tromsø | 70 | 62 | 4127 | 4170 | -13% |
| All | 1977 | 1881 | 15447 | 15510 | -5% |

[(1)] Net change in the four cities, controlled for changes in other towns

In all the cities where toll rings or local fuel taxes have been introduced, the number of injury accidents went down in the first year after these systems were introduced. On average, the decrease is around 5% (-11%; +1%), which corresponds well with the reduction of traffic in the cities.

***Possible effects of a fully developed road pricing system.*** The closest example to a fully developed and road pricing system is to be found in Singapore. This system was introduced in 1975 and reorganised in 1989. It has led to a significant reduction in vehicle traffic in the centre of Singapore (Menon, Lam and Fan 1993). Effects on accidents have not been evaluated.

In Sweden, possible effects of a fully developed road-pricing system in the Gothenburg area have been simulated using a traffic assignment programme as part of the so-called TOSCA-project (Test Oriented Scenario Assessment) (Delegationen för Transporttelematik 1994). It was assumed that each vehicle was automatically debited (using electronic micro chips) for a sum corresponding to the marginal, external costs of driving. If the system were fully developed, it was calculated that accidents could go down by 15%.

A corresponding simulation of the effects of time-differentiated toll rates in the current toll ring in Oslo (Larsen and Rekdal 1996) found that traffic volume at the peak time during the morning could be reduced by 19%. For the whole 24-hour period, price differentiation would not change the amount of traffic. In the hours when traffic is lower, speeds would increase; in the hours when traffic increases, speeds would be reduced. The net effects of these changes on the number of accidents are difficult to predict.

Maher, Hughes, Smith and Ghali (1993) estimated the effects on journey times and accidents of optimal road choice for a simulated road network in a city. One of the objectives of road pricing is the optimal distribution of traffic on the road network. The simulations indicated that the distribution of traffic, which was associated with the smallest total journey time produced the greatest number of accidents, and vice-versa. The explanation for this is that total journey time is shortest when traffic is spread as evenly as possible across the whole network, so that no part of the road network is more congested than another. However, this form of traffic distribution creates many conflict situations at intersections, and thus contributes to an increase in the number of accidents.

Bonsall and Palmer (1997) studied the effects on driver behaviour of congestion pricing. Congestion pricing means that the road user pays a higher fee per time unit the longer the journey takes for a given distance. The study was carried out in a driving simulator. It found that driver behaviour became less careful when congestion pricing was introduced. Drivers increased their speed, overtook more often, drove closer to the car in front etc., in order to get to their destination as quickly as possible and thus reduce the size of the fee they were required to pay.

These studies show that it is difficult to predict the effect on accidents of a fully developed road pricing system. If this type of system leads to less traffic overall, the number of accidents will probably go down. On the other hand, the number of accidents may increase if the speed of the remaining traffic also increases.

### Effect on mobility

The effects of road pricing on mobility depend on the design of the system. A toll road will normally have better mobility than the old road network.

With a fully developed road pricing system, some of the current rush-hour traffic will disappear (will be priced out) or will travel at different times. This will reduce congestion. Estimates for Oslo show that the benefits of differentiating prices (Ramjerdi 1995) in the toll ring according to the amount of traffic are greater than the costs. In other words, the benefits in the form of increased mobility for the remaining traffic are greater than the costs in the form of loss of benefit for the displaced traffic.

Simulations for the Gothenburg area show that a fully developed road-pricing system can lead to an increase in the average speed of around 10% (Delegationen för Transporttelematik 1994).

### Effect on the environment

The effects on the environment of road pricing depend on the design of the system. If there is toll financing of a road where other road choices exist, any possible environmental benefits of the new road construction may be reduced, because tolls will make a number of road users choose the old road.

An estimate of the effects of increased toll rates in rush hour in the toll ring in Oslo found that fuel consumption in rush hour could be reduced by around 23-28% (Larsen and Rekdal 1996). For the whole of Oslo and Akershus, Norway, taken together, the decrease in fuel consumption over the whole 24 hour period is estimated to be 1 - 4%. All other conditions being equal, reduced fuel consumption will reduce air pollution.

A simulation of a fully developed road pricing system in the Gothenburg area found that the total emissions from road traffic would be reduced by around 11% (Delegationen för Transporttelematik 1994).

### Costs

The costs of road pricing and toll ring roads are of two types: direct costs and indirect costs. The direct costs are costs of collecting payment. These consist of building and running toll systems, including manning the toll stations and debt collection from those who do not pay. The indirect costs are as follows: (A) delays at toll stations for people who have to pay. With a fully developed road pricing system based on electronic microchips and automatic vehicle identification, such delays can be avoided. (B) Loss of benefit from cancelled journeys due to tolls or road pricing. The total costs are the sum of the direct and indirect costs.

In a fully developed road pricing system these costs are offset in the form of savings in journey time for the remaining traffic. As mentioned above (under Effects on mobility), in given cases these savings can be greater than the gross costs of a road pricing system.

For the Norwegian toll ring in Bergen, Oslo and Trondheim, Meland (1996) gives costs in NOK million (table O.10.2). The cost figures in table O.10.2 cannot be added, since they are a mixture of investment costs and annual costs. Ramjerdi (1995) has converted the investment costs for the toll ring in Oslo to an annual capital cost. This amounts to NOK 27 mill.

*Table O.10.2: Costs of the Norwegian toll ring in Bergen, Oslo and Trondheim. Source: Meland 1996*

| | Amount in NOK million (1992-1993) | | |
|---|---|---|---|
| Place | Cost of installation | Operating costs per year | Fees paid per year |
| Bergen | 19 | 12.5 | 64.8 |
| Oslo | 255 | 74.0 | 634.7 |
| Trondheim | 57 | 6.0 | 74.0 |

## Cost-benefit analysis

Ramjerdi (1995) has carried out a cost-benefit analysis of alternative road pricing system in Oslo, Norway. The results of the analysis are shown in table O.10.3.

*Table O.10.3. Costs and benefits of different road-pricing systems in Oslo, Norway. Source: Ramjerdi 1995*

| | Annual amount in NOK million (1993) | | | | | |
|---|---|---|---|---|---|---|
| | Current road network | | | Fully developed main road network | | |
| Costs and benefits | Current system | Optimal toll ring | Optimal road pricing | No tolls | Current system | Optimal toll ring |
| Benefit for remaining traffic | 55.4 | 114.5 | 170.2 | 224.0 | 266.7 | 299.0 |
| Loss of benefit for lost traffic | 33.6 | 19.4 | 19.3 | -3.5 | 28.8 | 13.8 |
| Loss of time when paying tolls | 4.8 | 1.1 | Not known | 0.0 | 5.4 | 0.5 |
| Total benefit | 17.0 | 94.0 | 150.9 | 227.5 | 232.5 | 284.7 |
| Costs of collecting tolls | 96.6 | 70.0 | Not known | 0.0 | 96.6 | 70.0 |
| Net benefit | -79.6 | 24.0 | Not known | 227.5 | 135.9 | 214.7 |

Table O.10.3 shows that introducing road pricing in Oslo will give greater benefits than the current toll ring. It is cost-effective to introduce road pricing in Oslo, whether or not the main road network is to be financed by an extension of the current toll stations or not.

## O.11 CHANGES IN THE MODAL SPLIT OF TRAVEL

### Problem and objective

The risk of personal injury varies considerably between different forms of transport. Figure O.11.1 shows the estimated risk of being injured as a driver or passenger when using different forms of transport in Norway at the beginning of the 1990s. The risk is stated in terms of the number of injured persons per million person kilometres and is based on official accident statistics (NSB's driftsuhellsstatistikk; Elvik 1996D).

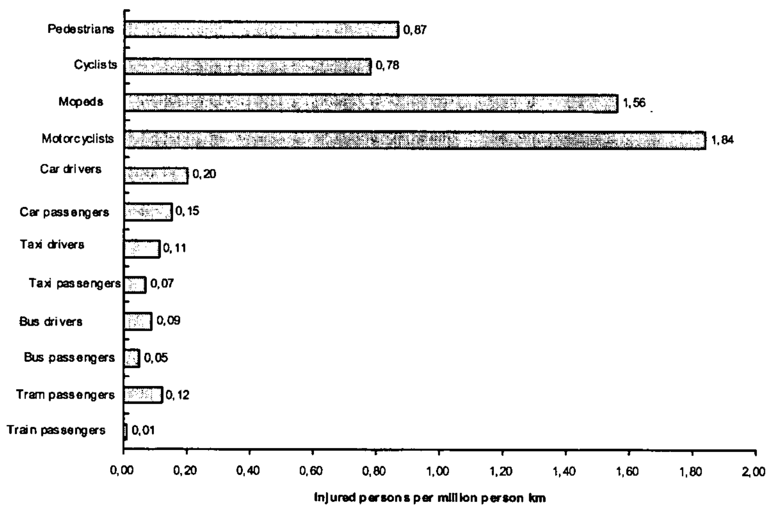


*Figure O.11.1: Injured persons per million person kilometres using different forms of transport in Norway. Based on official accident statistics.*

Figure O.11.1 shows that all forms of individual transport involve a higher risk of personal injury than public transport. The risk of injury is particularly high for pedestrians, cyclists and riders of mopeds or motorcycles.

Similar differences in the risk of injury between different forms of transport have been found in a number of countries. Table O.11.1 shows the relative risk of injury for different forms of transport in six different countries, estimated on the basis of injuries recorded in the official accident record in these countries and travel behaviour surveys made in the same countries (Norway: Elvik 1996, Denmark: Danmarks Statistik 1982, Sweden: Thulin and Nilsson 1994, Göteborgs Trafikkontor 1995; The Netherlands: Poppe 1993, Germany: Köhler 1990; Great Britain: UK Department of Transport 1992). The risk for a car driver is set equal to 1.00. The risk when using other forms of transport is expressed as a ratio to the risk for a car driver.

*Table O.11.1: Relative risk of injury of different methods of transport in different countries*

| | Relative risk of injury in different countries. Drivers' risk = 1.00 | | | | | |
|---|---|---|---|---|---|---|
| Means of travel | Norway | Denmark | Sweden | The Netherlands | Germany | Great Britain |
| Pedestrian | 4.35 | 6.65 | 4.13 | 6.07 | 3.50 | 7.15 |
| Cyclist | 3.90 | 7.76 | 5.73 | 5.67 | 9.50 | 14.02 |
| Moped/mc | 8.30 | 29.94 | 17.87 | 197.60 | 31.25 | 20.26 |
| Car driver | *1.00* | *1.00* | *1.00* | *1.00* | *1.00* | *1.00* |
| Car passenger | 0.75 | 1.94 | 0.87 | 1.13 | 1.50 | 1.25 |
| Bus | 0.25 | 0.12 | 0.13 | 0.20 | 0.13 | 0.59 |
| Tram | 0.60 | | 0.87 | 0.02 | 0.25 | |
| Train | 0.05 | 0.04 | 0.13 | 0.02 | 0.05 | 0.22 |

In all countries represented in table O.11.1, the risk of injury, estimated on the basis of official accident records, is lower for all types of public transport than for car drivers. In all countries, pedestrians, cyclists and riders of mopeds or motorcycles have a higher risk of injury than car drivers. On the basis of the figures in figure O.11.1 and table O.11.1, it is reasonable to believe that the number of persons injured in traffic could be reduced if a higher proportion of journeys were made using public transport, and a lower proportion using private means of transport.

Nonetheless, it is important to be aware of the fact that the risk estimates based on official accident statistics, can give misleading results as far as differences in risk between different forms of transport are concerned (Vaa 1993). This is primarily due to the fact that the level of under-reporting of injuries in official statistics varies between different forms of transport. Furthermore, public transport cannot be used from door-to-door to the same extent as private forms of transport. Using public transport normally means that a larger proportion of a specific journey must be done on foot, or by means of a personal form of transport, than when private transport is used for the whole journey.

Changes in the modal split of travel is intended to contribute to reducing the total number of injuries in traffic by encouraging people to use the modes of travel which have the lowest expected number of injuries for a given travel distance.

## Description of the measure

The term "changes in the modal split of travel" is used here to denote changes in the distribution of a given number of person kilometres across difference forms of travel. The phrase "main mode of travel" refers to the mode of travel used for the largest part of the distance on any journey. More than one mode of travel can be used during a single journey. The following measures are discussed:

- changes in the supply of public transport
- changing the main mode of transport for journeys of a given length
- the accident rate on roads and streets with and without public transport
- measures which can affect the demand for public transport

## Effect on accidents

***Changes in the supply of public transport.*** The effect on accidents of major changes in the supply of public transport have been studied by:

Boot, Wassenberg and Van Zwam 1982 (The Netherlands, public transport strikes)
Allsop and Turner 1986 (Great Britain, fare increases)
Allsop and Robertson 1994 (Great Britain, increases and decreases in fares)

Table O.11.3 gives best estimates of the effect on accidents of the different measures (percentage change in number of accidents):

*Table O.11.3: Effect on accidents of changes in the availability of public transport*

| Accident severity | Type of accident affected | Best estimate | 95% confidence interval |
|---|---|---|---|
| | ***Pubic transport strike (very limited public transport)*** | | |
| Injury accidents | All accidents | +18 | (-1; +41) |
| Property damage only accidents | All accidents | +31 | (+25; +38) |
| | ***Higher fares (transition from public to private transport)*** | | |
| Injury accidents | All accidents | +4 | (+3; +6) |
| | ***Lower fares (transition from private to public transport)*** | | |
| Injury accidents | All accidents | +0 | (-1; +1) |

Public transport strikes in The Hague in the Netherlands from 7 to 27 May 1981 led to a very large reduction in the supply of public transport. Only regional buses were running. Compared to the corresponding days in the years 1978, 1979 in 1980, the number of injury accidents increased by 18%. The number of property damage only accidents increased by 31%. The increase in injury accidents only affected bicycle accidents and accidents involving mopeds and motorcycles. The increase in property damage only accidents was largest for cars, but also included other types of vehicles. Traffic counts showed that cycle traffic increased by 45% during the strike. Car traffic increased by 10 % (Boot, Wassenberg and Van Zwam 1982).

In 1982, fares for London Transport in London (buses and Underground) increased by about 90%. In the first year after the increase in prices, the number of injured persons in London was about 4% higher than otherwise expected. The number of injured pedestrians and bus passengers went down. The number of injured cyclists, moped riders, motorcyclists and car passengers increased. Rush hour traffic using London Transport in and out of central areas of London went down by 14% from 1981 to 1982. Rush hour traffic by individual means of transport in and out of London increased in the same period by 19% (UK Department of Transport 1989).

In 1983, fares on London Transport were reduced by 25%. The total number of injured persons did not change. The number of injured pedestrians and bus passengers increased, the number of persons in other road user groups who were injured, went down. Rush hour traffic using London Transport increased from 1982 to 1983 by 11%. Rush hour traffic for other modes went down by 10%.

***Individual risk with different forms transport - changing form of transport.*** A number of studies have been carried out where the injury risk to an individual traveller of different forms of transport have been estimated:

Forsström 1982 (Sweden)
Lie and Muskaug 1982 (Norway)
Jørgensen 1988 (Denmark)
Vaa 1993 (Norway)
Hagen and Ingebrigtsen 1993 (Norway)
Elvik 1997A (Norway)

These studies are based on somewhat different assumptions and are therefore not suitable for a synthesis in the form of a meta-analysis.

Forsström (1982) studied the risk of injury on door-to-door journeys in the Gothenburg area. He found that the risk of being injured on average was about 12% higher when a form of public transport was used as the main mode of transport, (i.e. for the major part of the journey) than when an individual form of transport was used as the main mode of transport. However, the injuries were less serious when public transport was used. The study found that pedestrians, cyclists and people on mopeds and motorcycles could reduce their risk by using public transport. However, car drivers and car passengers would run a higher risk by changing to public transport. This is due to the fact that the increased walking distance to and from bus stops will lead to more falls if public transport is used.

Lie and Muskaug (1982) estimated the risk for door-to-door journeys on the basis of risk figures for Haugesund, Norway. They found that buses were the safest form of transport. Jørgensen (1988) found in a study for Greater Copenhagen that the risk was lowest when using suburban trains. The study also found that car users could reduce their total risk of injury by using regional trains or buses. These estimates were based on risk figures estimated on the basis of the official accident record.

Vaa (1993) calculated the risk for door-to-door journeys where buses are used as the main mode of transport. The study shows that official accident figures give a very misleading picture of the risk of injury on bus journeys. According to the official statistics, 303 people were registered as injured in traffic accidents in Norway where buses were involved. The actual figure, estimated on the basis of the injury record at the National Institute for Public Health was estimated to 632. There were a further 156 people who were injured in falls on board buses, without the bus being involved in a traffic accident, and 2,389 people injured in falls walking to or from the bus stop. In total, the number of persons injured on bus journeys was estimated to 3,177 per year, of whom only 303 were registered in the official accident statistics.

Hagen and Ingebrigtsen (1993) used Vaa's risk figures to estimate the potential for reducing the number of injured persons by changing from using cars to using the train or bus for journeys to work in Akershus county in Norway. They found that a transition from car to bus did not reduce the expected number of injured persons. However, the transition to train could reduce the number of persons injured, especially if the journey to the railway station was made by car.

Elvik (1997A) estimated possible changes in injury risk in Norway when changing from bicycle, moped, motorcycle or car to either bus or train. The estimates were carried out both on the basis of official injury figures and estimated true injury figures. The calculations were carried out for the whole country and for Oslo. For Oslo, trams were also included. Furthermore, a separate estimate was made for travellers aged between 18 and 24 years of age. The study contains a very large number of results.

The study shows that the number of injured persons can be reduced if cyclists and people on mopeds or motorcycles start using buses or trains. This applies whatever the length of the journey and independently of whether estimates rely on official accident statistics or on estimates of the total number of injuries. The study found that for car drivers, the official number of injured persons could probably be reduced by using buses or trains. The unrecorded injuries from falls will, however, increase so much that no overall gain in safety can be expected if car users start using buses or trains. This applies at least for short journeys.

The main tendency in the results of the studies presented above can be summarised in the following points:

1 The number of injured persons can be reduced if cyclists and people using mopeds or motorcycles start using buses or trains.
2 The registered number of injured persons in official Norwegian accident statistics can probably be reduced if car users start using the bus or the train. It is, however, probable that such a modal change will increase the number of unrecorded injuries, in particular involving falls on the way to or from the bus or train.
3 Trams are the least safe form of public transport. On short journeys, buses are safest and on long journeys, trains are the safest.
4 Falls when walking to or from public transport stops contribute substantially to the total risk of door-to-door journeys using public transport. A fine-masked route network with short distances between bus stops can reduce walking distances and thus the number of injuries. Better road maintenance, especially during the winter can also reduce the number of falls.

***Accident rate on roads with and without public transport.*** Two Norwegian studies (Hvoslef 1973, 1974; Blakstad 1990) have compared the accident rate on roads and streets with and without public transport. The results of these studies are shown in table O.11.4.

*Table O.11.4 Number of injury accidents reported to the police per million vehicle km on roads and streets with and without public transport, Norway. Sources: Hvoslef 1973, 1974; Blakstad 1990*

| | | Public transport | | |
|---|---|---|---|---|
| Study | Type of road or street | None | Bus alone | Bus and tram |
| Hvoslef 1974 | Two-lane densely populated | 1.35 | 1.49 | 2.88 |
| Blakstad 1990 | Four lanes, medium density of population | (0.42) | 0.70 | (0.57) |
| | Two lane, medium density of population | 0.31 | 0.43 | (0.91) |
| | Four lanes, densely populated | 1.18 | 1.24 | 1.00 |
| | Two lanes, densely populated | 0.94 | 0.91 | 1.36 |

Accident rates given in brackets are based on only a few accidents and are very uncertain

The accident rates in table O.11.4 show a tendency for the accident rate to be higher in streets with public transport than in streets without public transport. The accident rate is particularly high in streets with both buses and trams.

This may be partly due to the fact that public transport generates more pedestrian traffic than is found in streets without public transport, and that public transport, in particular trams, are less able to make evasive manoeuvres in critical situations than private cars and other smaller vehicles.

***Measures which affects the demand for individual and public transport.*** Among the measures which affect the demand for individual and public transport are:

- prices for transport services, including fuel prices and vehicle prices
- journey times, including waiting times and walking time
- other aspects of public transport, such as availability of seats

The effects of these factors with respect to individual choices of transport in Norway has been summarised by Fridstrøm and Rand (1993) and Stangeby and Norheim (1995). Table O.11.5 is based on these reports. The table shows the effect of different factors in the form of demand elasticities. A demand elasticity shows the percentage by which demand changes when the factor which influences demand is changed by one per cent. A distinction is made between short-term and long-term elasticity. Short-term elasticity refers to the direct effects on transport demand, occurring within a period of 1 - 3 years. Long-term elasticity shows more long-term effects, occurring within a period of 8 -10 years.

*Table O.11.5. Demand elasticities for individual and public transport, Norway. Sources: Fridstrøm and Rand 1993 and Stangeby and Norheim 1995*

<table>
<tr><th></th><th colspan="3">Elasticity of demand in the short and long term</th></tr>
<tr><th>Factor</th><th>Mode of transport</th><th>Short term</th><th>Long term</th></tr>
<tr><td>Costs of keeping a car (+1%)</td><td>Car</td><td></td><td>-0,41</td></tr>
<tr><td></td><td>Bus</td><td></td><td>0,26</td></tr>
<tr><td></td><td>Train</td><td></td><td>0,27</td></tr>
<tr><td></td><td>Aeroplane</td><td></td><td>0,24</td></tr>
<tr><td>Car usage costs (+1%)</td><td>Car</td><td>-0,21</td><td>-0,43</td></tr>
<tr><td></td><td>Bus</td><td>-0,05</td><td>0,12</td></tr>
<tr><td></td><td>Train</td><td>-0,01</td><td>0,18</td></tr>
<tr><td></td><td>Aeroplane</td><td>0,02</td><td>0,17</td></tr>
<tr><td>Journey time by car (+1%)</td><td>Car</td><td></td><td>-0,51</td></tr>
<tr><td></td><td>Bus</td><td></td><td>-0,04</td></tr>
<tr><td></td><td>Train</td><td></td><td>0,14</td></tr>
<tr><td></td><td>Aeroplane</td><td></td><td>0,23</td></tr>
<tr><td>Public transport ticket price (+1%)</td><td>Bus</td><td>-0,30</td><td>-0,65</td></tr>
<tr><td></td><td>Train</td><td>-0,70</td><td>-1,10</td></tr>
<tr><td></td><td>Underground</td><td>-0,20</td><td>-0,40</td></tr>
<tr><td></td><td>Car</td><td colspan="2">0,16</td></tr>
<tr><td>Journey time by public transport (+1%)</td><td>Departure time</td><td colspan="2">-0,24</td></tr>
<tr><td></td><td>Waiting time</td><td colspan="2">-0,37</td></tr>
<tr><td></td><td>Travel time</td><td colspan="2">-0,26</td></tr>
<tr><td></td><td>Car driving</td><td colspan="2">0,16</td></tr>
<tr><td>Frequency of departures (+1%)</td><td>Public transport</td><td colspan="2">0,15</td></tr>
<tr><td></td><td>Car journeys</td><td colspan="2">-0,04</td></tr>
</table>

Increases in car ownership costs (the cost of purchasing and owning a car) lead to less driving and a somewhat increased demand for public transport. The percentage decrease in car driving is greater than the increase in public transport. The same applies if car usage costs increase. Increased journey time by car reduces the use of cars, but does not in itself lead to significantly more public transport.

Increased fares on public transport lead to less use of public transport and more car driving. The same applies if journey times with public transport become longer. Increasing the number of departures increases the use of public transport and can reduce car traffic.

**Effect on mobility**

Journey times on most of the road network in Norway are scarcely affected by the modal split of transport. In and around the larger cities, however, mobility can be affected by the model split of travel. Cars take up more road space per person per kilometre than public transport, and therefore consume more road capacity for a given number of person kilometres (Kolbenstvedt, Silborn and Solheim 1996). By switching to public transport, road capacity is utilised more effectively, so that the flow of traffic improves.

**Effect on the environment**

Emissions from different forms of transport into the air vary according to traffic flow patterns and the technical condition of the vehicle. Typical emission coefficients are shown in table O.11.6 (Solheim, Hammer and Johansen 1994).

Table O.11.6 shows that public transport vehicles for the majority of pollutants pollute more per kilometre driven than cars. Electrically powered transport does not emit air pollution. Nonetheless, a certain amount of emission for these forms of transport has been stipulated, in order to take account of the fact that producing electricity can pollute, and that electricity used for transport has alternative uses. The emission per person kilometre depends on how well public transport utilises its capacity. The more person kilometres are performed for a given number of public transport kilometres, the lower the amount of emissions per person kilometre. On the basis of the emission figures in table O.11.6, Solheim, Hammer and Johansen estimated the expected effects on the total emissions in Oslo and Akershus, Norway of the following measures to affect the modal split of travel:

1. increasing fuel prices by 30%
2. reducing bus driving times by 25%
3. reducing fares by 25%

4. increasing the number of km driven by public transport by 25%

*Table O.11.6: Emission coefficients in grams per kilometre driven from vehicles, Norway. Source: Solheim, Hammer and Johansen 1994*

| | Emission in grams per km driven | | | | |
|---|---|---|---|---|---|
| Type of pollutant | Car | Bus | Train (2) | Underground (2) | Tram (2) |
| $NO_x$ | 2.3 | 24.6 | 1.13 | 0.91 | 1.03 |
| $SO_2$ | 0.03 | 1.5 | 1.89 | 1.51 | 1.72 |
| VOC (1) | 0.0 | 2.6 | 0.15 | 0.12 | 0.14 |
| CO | 21.0 | 4.8 | 0.01 | 0.01 | 0.01 |
| Particles | 0.08 | 1.1 | 0.09 | 0.08 | 0.09 |
| $CO_2$ | 310.0 | 1104.0 | 1210.09 | 968.07 | 1102.52 |

(1) VOC = Volatile, organic compounds (largely hydrocarbons)

(2) = The emissions are calculated by assuming that electricity is produced by oil fired power stations

The effects of different combinations of these measures were also estimated. Figure O.11.2 shows the results of the estimates in the form of percentage changes in emissions. The figure shows that measures transferring travel to public transport can be expected to reduce pollution. Increasing fuel prices has the greatest effect, because this produces the greatest decrease in car traffic. Increasing the supply of public transport, seen in isolation, has little effect on pollution.

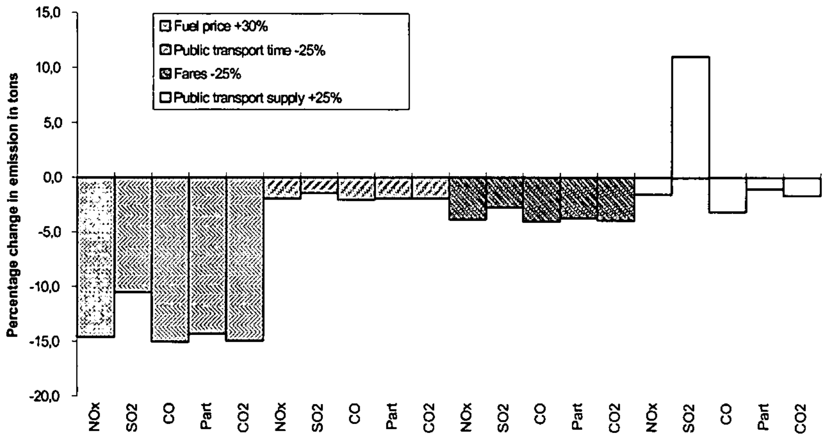


*Figure O.11.2: Percentage change in emissions as a result of measures affecting the modal split of travel in Oslo and Akershus, Norway. Based on Solheim, Hammer and Johansen 1994*

## Costs

The costs of running public transport are considerable. Parliamentary report 32 (1995 - 1996) Samferdselsdepartementet 1996) gives the following figures for state subsidies for public transport in Norway in 1994:

| Type of subsidy | NOK million |
|---|---|
| County council subsidies for local routes | 2,678 |
| Oslo municipality's subsidy for Oslo Sporveier | 519 |
| State operating subsidy for the Norwegian State Railway | 772 |
| State subsidy for domestic flights | 289 |
| State subsidy for Hurtigruten (coastal express) | 220 |
| Total state subsidies for public transport | 4.478 |

In total, public subsidies for running public transport are close to NOK 4.5 billion per year. In addition, in recent years, the state has given around NOK 200 million per year for investments in public transport in the larger cities.

## Cost-benefit analysis

A cost-benefit analysis of subsidies to Oslo Sporveier (Larsen 1993) tried to estimate how large a subsidy should be offered to Sporveien based on an objective of achieving the greatest possible social benefit from the subsidy (maximising the consumer surplus). The social benefit in this case was measured on the basis of consumer surplus (see the glossary). Generalised travel costs, the sum of direct expenses and time costs, were used as a basis for calculating the consumer surplus. The optimal subsidy for Sporveien was estimated under different assumptions.

The annual subsidy for Oslo Sporveier when the study was carried out (1992) was NOK 481 million. If Sporveien were to be given complete freedom to select an optimal combination of fares and routes, while at the same time road pricing was introduced to ensure that car drivers were charged the social marginal costs of car driving, the optimum subsidy would be NOK 296 million. If road pricing were not introduced, the optimal subsidy would be NOK 514 million, because car traffic in Oslo would then be too. The analysis found that under most of the assumptions made, it is optimal to give Oslo Sporveier a greater subsidy than the company receives today.

## O.12 ROAD TRAFFIC LEGISLATION

### Problem and objective

Road user behaviour is of great importance for road safety. In order to make behaviour as predictable and as safe as possible, government has issued rules to regulate traffic behaviour. The idea is everyone travels more safely when these rules are adhered to than when they are violated. In order to ensure that the rules are complied with, the police enforce them. Violating the rules can be sanctioned with fines, traffic tickets or imprisonment, plus the withdrawal of driving licences.

The number of traffic accidents does not depend only on road user behaviour. The design of the traffic system, including vehicles, also affects safety. The design of vehicles, roads and traffic control are among the factors influencing road user behaviour. In order to ensure that the rules of the road and other rules directed at road users are complied with, it is important that other parts of the system are adapted to suit this. Road traffic legislation also includes the standards set by government regarding the design of roads, traffic control and vehicles.

Road traffic legislation is intended to reduce the number of traffic accidents by banning particularly dangerous behaviour and regulating behaviour so that it becomes homogeneous and predictable.

### Description of the measure

Road traffic legislation in Norway denotes regulations with the force of law which are part of the Road Traffic Act or which are based on this. These regulations are comprehensive and detailed, but a detailed description will not be given here.

### Effect on accidents

***The relationship between drivers' violation rates and their accident rate.*** A number of studies have evaluated the relationship between the number of traffic violations a driver has been convicted for, and the driver's accident rate. These studies include:

Peck, McBride and Coppin 1971 (USA)
Harrington 1972 (USA)
Goldstein 1973 (USA)
Chipman 1982 (Canada)
Evans and Wasielewski 1982 (USA)

Evans and Wasielewski 1983 (USA)
Wasielewski 1984 (USA)
Smiley, Persaud, Hauer and Duncan 1989 (Canada)
West, Elander and French 1992 (Great Britain)

All these studies show that drivers who have been convicted for numerous violations have a higher accident rate per driver than drivers who have been convicted for few or no violations. Both the probability of being convicted and the number of accidents per driver are closely related to the driver's annual driving distance. It is therefore important to control for annual driving distance when studying the relationship between the number of traffic convictions and accident rate. Only the studies carried out by Chipman (1982) and West, Elander and French (1992) have controlled for driving distance. Figure O.12.1 shows the relationship between the number of traffic convictions and accident rate according to Chipman's study.

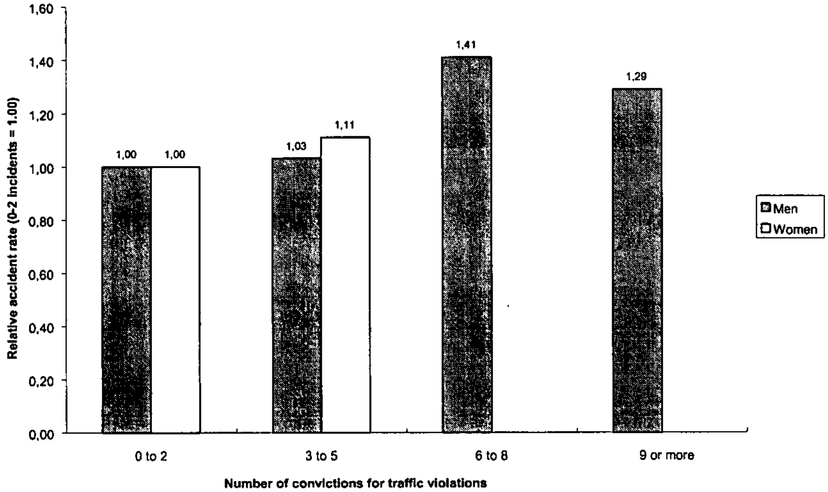


*Figure O.12.1: The relationship between the number of traffic violations for which a driver has been convicted for and the driver's accident rate, Canada. Source: Chipman 1982*

Figure O.12.1 shows that the accident rate increases with an increase in the number of violations, but not dramatically. There were too few women with 6 or more convictions to estimate their accident rate.

***Possible effects on the number of people killed or injured of 100% compliance with road traffic legislation.*** An estimate has been made of the potential for reducing the number of people killed or injured in traffic in Norway if road traffic legislation were complied with 100 % (Elvik 1997B). The results of this estimation are given in table O.12.1.

*Table O.12.1: Potential for reducing the numbers killed and injured in traffic in Norway assuming 100 per cent respect for road traffic legislation. Source: Elvik 1997B*

| | Percentage decrease in number (95% confidence interval) | |
|---|---|---|
| Main group of regulations | Injured | Killed |
| Speed limits | -9 (±5) | -15 (±8) |
| Use of safety equipment | -5 (±3) | -14 (±8) |
| Drink driving regulations | -3 (±2) | -10 (±7) |
| Other behaviour regulations in traffic | -8 (±6) | -7 (±5) |
| Technical requirements for vehicles | -1 (±1) | -1 (±1) |
| Driver requirements | -1 (±1) | -1 (±1) |
| Total potential | -27 (±18) | -48 (±30) |

Table O.12.1 only covers those violations of the law where respect for the regulations and the effects on the number of accidents of perfect compliance with the regulations are sufficiently well known to allow an estimate. It seems clear that better respect for road traffic legislation would improve traffic safety.

***Effects of change in legislation.*** A number of changes have been made to road traffic legislation in Norway. The effect of a number of these changes on the number of accidents has been studied. This applies to the following changes:

- Repeal of the requirement for renewed driving tests, 1975 (see chapter 5.6)
- Mandatory use of helmets when riding mopeds and motorcycles, 1977 (see chapter 3.14)
- Tightening up the yield requirement for pedestrians on pedestrian crossings, 1978 (Hvoslef 1984)
- Introducing fines for non-use of seat belts 1979 (Elvik 1995A)
- Mandatory use of seat belts for adults in the rear seats of cars 1985 (Elvik 1995B)
- Introducing automatic daytime running lights on new cars 1985 (Elvik 1993A)
- Mandatory use of daytime running lights on all cars, 1988 (Elvik 1993A)
- Mandatory use of child restraints in cars 1988 (Elvik 1995B)
- Changes in punishment legislation for drink driving 1988 (Vaas and Elvik 1992)

Table O.12.2 summarises the results of studies that have evaluated the effects of these measures on the number of injury accidents or the number of people injured in traffic. The figures refer to the effects in the measure's target group, not the total. For example, the target group for the compulsory use of helmets on mopeds and motorcycles is drivers and passengers on mopeds and motorcycles. The target group for tightening up the yield requirement on pedestrian crossings is pedestrians who cross roads using pedestrian crossings.

*Table O.12.2: Effects of changes in road traffic legislation in Norway, number of person - injury accidents or number of persons injured in traffic. Sources: see the text*

| | Percentage change in the number of injury accidents or the number of persons injured in the target group with each change in law | |
|---|---|---|
| Changes in the law | Best estimate | 95% confidence interval |
| Repeal of renewed driving test 1975 | +1 | (-7; +9) |
| Compulsory helmets for mopeds/motorcycles in 1977 | +42 | (+31; +57) |
| Sharpening up yield requirements at pedestrian crossings in 1978 | +11 | (-2; +26) |
| Fines for non-use of seatbelts in 1979 | -6 | (-10; -3) |
| Compulsory use of seatbelts in the rear seats in 1985 | -6 | (-10; -2) |
| Daytime running lights on new cars in 1985 | -2 | (-10; +7) |
| Compulsory daytime running lights on all cars in 1988 | -5 | (-13; +4) |
| Compulsory use of child restraints in 1988 | -11 | (-17; -5) |
| Changes in punishment for drink driving in 1988 | +3 | (-5; +13) |

Repeal of renewed driving tests in 1975, tightening up the yield requirement for pedestrians on pedestrian crossings in 1978, mandatory daytime running lights on new cars in 1985, mandatory use of daytime running lights on all cars in 1988 and changing the punishment for drink-driving in 1988 do not appear to have led to statistically significant changes in the number of accidents. The mandatory use of seat belts in cars, whether in the front seat or the rear seat, together with child restraints, appear to have reduced the number of injured persons. On the other hand, mandatory use of helmets for drivers of mopeds and motorcycles does not appear to have reduced the number of injuries. The numbers increased after the helmet wearing law was introduced. The explanation for this increase is not known. An increased level of reporting of accidents involving mopeds or motorcycles is one possible explanation. Another possibility is changes in behaviour amongst moped users and motorcyclists after they started to wear helmets.

### Effect on mobility

The effects of road traffic legislation on mobility vary, depending on the content of the legislation. Some of the regulations in the road traffic legislation limit mobility in order to promote traffic safety. Speed limits are the best example of this, but drink-driving legislation may also be regarded as reducing travel opportunities. Road traffic legislation also contains regulations prohibiting behaviour that unnecessarily hinders traffic, and parking which creates obstacles for traffic. The net effect on mobility of the legislation is not known and is difficult to judge on an informal basis.

### Effect on the environment

The effects of road traffic legislation on the environment have not been documented. The Norwegian regulations also cover noise levels and emission levels for motor vehicles. Since 1989, catalytic converters have been mandatory on all new cars in Norway. It has been documented that this contributes to reducing air pollution (Statens forurensningstilsyn 1993). Mandatory use of daytime running lights contributes to an increase in fuel consumption and an insignificant increase in pollution emissions (Ørjasæter and Bang 1993). Other effects on the environment of road traffic legislation have not been documented.

### Costs

The costs involved in road traffic legislation are of two types: direct costs and indirect costs. The direct costs consist of the costs of drawing up legislation and the cost of enforcement and sanctions. The indirect costs are additional costs which road users incur in the form of more expensive vehicles or increased journey times.

One of the characteristics of legislation as a policy instrument is that the direct costs are often small and the indirect costs are often large (Friedman 1987). No estimates of the total costs of road traffic legislation are available. Table O.12.3 compiles available estimates of costs (Elvik 1993B; Hagen 1994).

*Table O.12.3: The cost of road traffic legislation in Norway. Most important sources: Elvik 1993B, Hagen 1994*

| | Annual costs in NOK millions (1995) | |
|---|---|---|
| What the cost affects | Costs in public budgets | Costs for road users |
| Drawing up legislation etc. | 10 | |
| Police enforcement | 320 | |
| Roadside vehicle inspections | 186 | 339 |
| Punishments for violations | 143 | |
| Vehicle safety standards etc. | | 975 |
| Training requirements etc. | | 778 |
| Total, all legislation | 659 | 2.092 |

The estimate shows that the annual costs of road traffic legislation Norway currently amount to around NOK 2.75 billion. Of this, around NOK 660 million is charged to public budgets, while the rest are costs incurred by road users. Road user costs consist both of direct outlays, for example in the form of payment for mandatory driving lessons, and costs of time incurred as the result of different measures, such as vehicle inspections.

### Cost-benefit analysis

A distinction can be made between cost-benefit analyses of (1) existing regulations, (2) new regulations, (3) enforcement of existing regulations and (4) sanctions of violations of road traffic regulations. Table O.12.4 shows cost-benefit analyses of selected regulations, taken from other chapters in this book (Elvik 1997B).

The table shows that all items of current legislation, which have been analysed are cost-effective. The introduction of additional, high mounted stop lamps on all vehicles would also be cost-effective. Increasing the amount of enforcement is cost-effective. Any benefit to road users of violating the law is not included in a cost-benefit evaluation of the enforcement measures (Elvik 1997B).

*Table O.12.4: Cost-benefit analysis of selected legislation of road traffic*

| Legislation or measure | Benefit-cost ratio |
|---|---|
| ***Existing regulations*** | |
| Mandatory use of daytime running lights on vehicles | 3.3 (±0.4) |
| Mandatory use of daytime running lights on mopeds/motorcycles | 8.7 (±10.0) |
| Mandatory use of helmets of mopeds/motorcycles | 18.0 (±6.0) |
| Mandatory use of seatbelts for drivers | 31.7 (±5.7) |
| Mandatory use of seatbelts for front-seat passengers | 13.3 (±3.5) |
| Mandatory use of seatbelts for rear-seat passengers | 1.3 (±0.9) |
| Mandatory use of child restraints in cars | 1.3 (±0.6) |
| Mandatory use of under ride guard rails on lorries | 4.0 (±2.0) |
| ***Possible new regulations*** | |
| Compulsory use of additional high-mounted stop lamps on cars | 3.6 (±0.3) |
| ***Enforcement measures*** | |
| Tripling stationary speed enforcement | 6.5 (±3.9) |
| Tripling drink-driving enforcement | 1.2 (±0.4) |
| Tripling seatbelt enforcement | 3.6 (±2.2) |
| Current use of speed cameras | 8.9 (±2.9) |
| ***Sanctions*** | |
| Withdrawing driving licences for drink-driving | 9.2 (±1.0) |

## O.13 REGULATING COMMERCIAL TRANSPORT

### Problem and objective

It is estimated that around 10 to 15% of traffic on public roads in Norway is commercial transport (Rideng 1996). Commercial transport is often carried out using large, heavy vehicles, such as buses or articulated lorries. The time such transport takes affects the income for much of commercial transport. The combination of time pressure and large vehicles suggests that commercial transport on roads can represent a particular risk. Partly for this reason, the government of Norway has regulated commercial transport since the 1940s.

Regulation is based on the basic rule that, in order to start a transport business, you must obtain formal permission from the government. In order to obtain permission, the business owner must normally satisfy a number of specific conditions. In Norway, commercial transport is regulated by the Transport and Communications Act of 1976. The Act covers all commercial transport, that is to say car hire, taxis, buses and commercial goods transport.

One of the objectives of the Transport and Communications Act is to reduce noise and pollution, and to improve safety on the roads (§ 1, 3rd section).

### Description of the measure

The Transport and Communications Act of 1976 was originally much more stringent than it is now. The Act has gradually been liberalised through changes in the law adopted in 1979, 1982, 1986, 1991 and 1993.

The liberalisation of the law is part of an international trend towards the deregulation of commercial transport. A similar development has occurred in other countries, including Sweden (Kristiansen 1996), Great Britain (Evans 1994), Canada (Withers 1989), the United States (Moses and Savage 1989) and New Zealand (Frith and Derby 1986). Broadly speaking, a distinction can be made between the following types of changes in the legislation of commercial transport:

1. Regulation, i.e. the introduction of regulation where those running such businesses were previously free or were not directly regulated,
2. Liberalisation, i.e. the introduction of less stringent regulations, although the requirement for permissions is retained,
3. Introducing competition, i.e. tenders for the allocation of permissions for transport and people,
4. Deregulation, i.e. allowing unrestricted access to set up new business.

The legal changes which were introduced in Norway after 1979 are a combination of liberalisation and the introduction of competition, in the form of tenders for permissions for local transport, and deregulation.

People who run commercial transport companies are nonetheless subject to a number of official regulations, including regulation of driving and resting hours and regulations governing vehicle inspections. Deregulation only means that the authorities cannot try to regulate the number of people running such businesses or the competition between them.

## Effect on accidents

The effect on accidents of regulating commercial transport has been studied by:

Frith and Derby 1986 (New Zealand, deregulation)
Corsi and Fanara 1989 (USA, new businesses)
Astrop, Balcombe and Finch 1991 (Great Britian, deregulation)
Phillips and McCutchen 1991 (USA, deregulation)
Evans 1994 (Great Britian, deregulation)
Elvik 1997C (Norway, regulation and deregulation)

The majority of studies concern deregulation. Table O.13.1 shows, on basis of these studies, best estimates of effects on accidents of changing the legislation of commercial transport (percentage change in injury accidents):

*Table O.13.1: Effect on accidents of changing the regulation of commercial transport. Percentage change in the number of injury accidents*

| Accident severity | Type of accident affected | Best estimate | 95 % confidence interval |
|---|---|---|---|
| | ***Introduction of regulation of commercial goods transport (Norway)*** | | |
| Injury accidents | Accidents involving lorries | -10 | (-15; -6) |
| | ***Liberalisation of commercial goods transport (Norway)*** | | |
| Injury accidents | Accidents involving lorries | -10 | (-12; -7) |
| | ***Deregulation of commercial goods transport*** | | |
| Injury accidents | Accidents involving lorries | +6 | (+0; +13) |
| | ***New companies compared with older companies*** | | |
| Unspecified | Accidents involving lorries | +27 | (-11; +82) |
| | ***Deregulation of bus transport*** | | |
| Injury accidents | Accidents involving buses | -10 | (-11; -9) |

In the first three years (1977-79) following the introduction of the 1970 Transport and Communications Act in Norway, the number of lorries involved in injury accidents was about 10 % lower than for the four years (1973 -76) before the Act was introduced. The number of other motor vehicles involved in injury accidents is then used as a comparison group. The later liberalisation of the Act does not appear to have led to an increase in the number of lorries involved in injury accidents. At the same time, however, the number of technical inspections of heavy vehicles has increased (Elvik 1996A). This may have contributed to reducing the number of accidents.

The deregulation of commercial goods transport is associated with a small increase in the number of accidents. The increase is probably attributable to two factors. Firstly, deregulation will normally lead to an increased amount of transport. Secondly, deregulation makes it easier to set up new companies. Newly established companies have been found to have a higher accident rate than older companies (Corsi and Fanara 1989).

Deregulating bus transport does not appear to lead to more accidents. Studies in Great Britain have shown a decrease of 10% in the number of accidents per bus kilometre associated with deregulation.

On the basis of these results, it is concluded that regulating commercial transport appears to have little direct effect on road safety. Road safety appears to be adequately protected by means of other legislation.

## Effect on mobility

The effects on mobility of regulating commercial transport have not been documented. There are increasing returns to scale in the commercial transport of goods (Hagen 1995). This means that the transport costs per ton kilometre are lowest for the largest vehicles, with high annual driving distances. In an unregulated transport market, companies offering the cheapest transport would strengthen their position, which may result in an increase in the number of large articulated lorries driving long distances. This is good for transport economics, and in theory could be advantageous for safety. A concentration of transport into fewer large vehicles implies that a given quantity of goods can be transported in fewer vehicle kilometres than if a larger number of smaller vehicles are used.

## Effect on the environment

Big lorries take up a lot of space, make a lot of noise and produce relatively high amounts of air pollution emissions, especially when they are heavily loaded and driving as fast as their loads and the nature of the roads allow. Maximum speed governors have now been introduced on some heavy vehicles (with a total weight of about 3.5 tons). In a study of the marginal costs of transport (Eriksen and Hovi 1995), the following emission coefficients are given for goods vehicles and goods trains for different types of pollutants (table O.13.2).

*Table O.13.2: Emissions in grams per kilometre for lorries and goods trains. Source: Eriksen and Hovi 1995*

| Component | Goods vehicle 1-4.9 tons | Goods vehicle 5-7.9 tons | Goods vehicles 8 tons and above | Goods train |
|---|---|---|---|---|
| $CO_2$ (#) | 3.17 | 3.17 | 3.17 | 3.11 |
| $SO_2$ | 2.20 | 2.20 | 2.20 | 4.39 |
| CO | 20.15 | 26.66 | 20.03 | 6.97 |
| $NO_x$ | 24.67 | 36.11 | 40.52 | 10.00 |
| Particles | 4.19 | 3.32 | 3.42 | 0.91 |
| VOC (§) | 5.40 | 6.66 | 5.58 | 1.97 |

(#) Emission given in kg per kilometre

(§) VOC are volatile organic compounds (hydrocarbons)

The figures for goods trains are based on the actual distribution between diesel-powered and electrically powered goods trains. Electric trains do not directly emit pollution. Nonetheless, in some cases a nominal emission rate has been assigned, on the assumption that the electricity could also have been used for heating buildings and thus would have reduced emissions from oil heating.

The effects of regulation of commercial transport on the environment are not known.

## Costs

The direct cost of administering the Transport and Communications Act are small. The Act is administered by the county councils. On the basis of accounting figures for the county councils (Statistisk sentralbyrå 1997), the costs of transport administration can be estimated to be around NOK 85 million per year. It is not known how much of this applies to the Transport and Communications Act and how much to other duties.

No evidence is available showing the cost of the Act for people applying for transport permits. Any indirect costs of the Act, for example, in the form of higher transport prices than would otherwise have existed, are also unknown.

### Cost-benefit analysis

No cost-benefit analyses of the regulation of commercial transport in Norway are available. American studies (Moses and Savage 1989) indicate that deregulating air travel and truck transport in the USA has led to lower prices and more transport. Safety does not appear to have been affected. An analysis of cost changes in domestic goods transport in the period 1983 - 1993 (Hagen 1995), shows that in this period there was no noticeable increase in the prices of lorry transport in Norway. In Sweden, on the other hand, prices increased considerably in the same period, so that the previous price differences between Norway and Sweden disappeared. It is not known whether this development is due to deregulation of the transport market in Norway.

## O.14 PROVISION OF MEDICAL SERVICES

### Problem and objective

A number of factors affect the outcome of traffic accidents in the form of injuries. One of these factors is the provision of medical services. The faster an injured person gets expert first aid or other medical treatment, the greater the chances of surviving and making a full recovery. In the course of the last 20 - 30 years, the provision of medical services has improved in many motorised countries.

Figure O.14.1 shows, for selected countries, changes from 1970 to 2000 in the percentage who were killed of those killed or injured in road accidents. In Great Britain, for example, this percentage was 2.1 in 1970, and was reduced to 1.1 in 2000. A similar pattern is seen in most of the selected countries.

It has been hypothesised that the reduction in the proportion killed of all those who are involved in injury accidents is, at least in part, attributable to an improved provision of emergency medical services.

The objective of the provision of medical services is to ensure fast first aid and transport to a treatment centre (hospital or similar) in the event of traffic accidents and to maximise the probability of survival and full recovery through professional treatment of injuries.

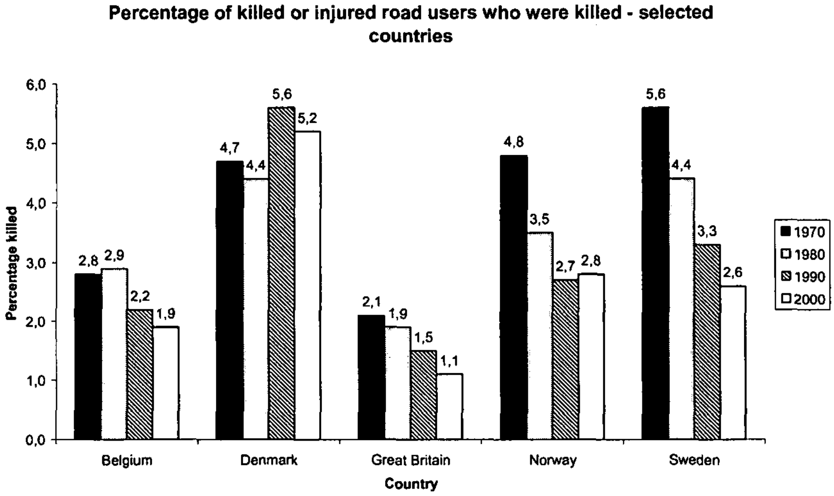


*Figure O.14.1: Percentage killed of all who were killed or injured in road accidents in selected countries – changes from 1970 to 2000.*

## Description of the measure

Provision of medical services includes:

- access to first aid and ambulance transport
- access to treatment in hospitals and other medical institutions
- rehabilitation facilities for injuries which require long-term treatment and retraining

This chapter describes studies which have evaluated the effects on the number of road accident fatalities of the following:

- availability of ambulances and their response times
- doctors on board ambulances
- availability of ambulance helicopters
- treatment in hospital

## Effect on accidents

***The number of road accident fatalities that can be prevented by faster emergency responses.*** A Swedish study assessed the survivability of fatal accidents in which a total of 474 people were killed (Henriksson, Öström and Eriksson 2001). It was concluded that 48% of those who died had sustained injuries that were non-survivable under any circumstances. 12% of those killed could have survived if they had been transported more quickly to a hospital. A further 32% could have survived if transported more quickly to an advanced trauma centre. 5% of the victims were not located in time to save their lives.

***Availability of ambulances and response times.*** A number of studies have evaluated the effects of the availability of ambulances and ambulance response times for the chances of surviving traffic accidents. The studies differ and are not suitable for synthesis in the form of meta-analysis. Instead, each study is presented with comments.

Brown (1979) studied the relationship between ambulance response times in traffic accidents and the probability of surviving accidents. The main results of the study are shown in figure O.14.2. Figure O.14.2 shows that the proportion killed in traffic accidents increases with increasing ambulance response times. The response time is defined as the time from when the ambulance is called out until it reaches the accident spot. Response time is strongly related to population density.

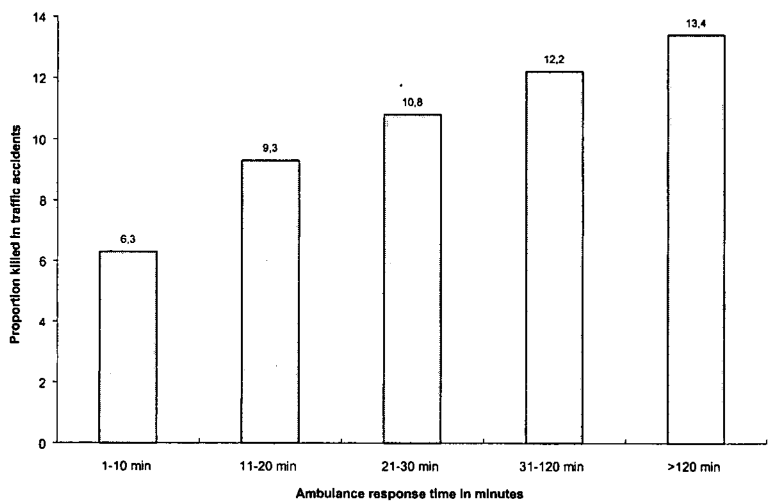


*Figure O.14.2: Relationship between ambulance response times for traffic accidents and the proportion killed in accidents. Source: Brown 1979*

Brodsky and Hakkert (1983) studied the relationship between the availability of ambulance services and fatalities in traffic accidents in Texas, USA. They divided the study area into three, based on the availability of ambulances: good availability (i.e. short response time), average availability and poor availability. The average response time for the different availability groups is not stated. In each group, the number of fatal accidents among all injuries was registered. A comparison of the three areas gave the results shown in table O.14.1.

The proportion of fatal accidents was lowest where ambulance availability was best, and highest where ambulance availability was poor. This pattern holds when controlling for other factors affecting the probability of surviving a traffic accident, for example the speed at the time of the accident and the person's age.

*Table O.14.1 Proportion of fatal accidents in areas with different ambulance availability in Texas. Source: Brodsky and Hakkert, 1983.*

| Availability of ambulance | Fatal accidents | Accidents with serious injuries | All injury accidents | Fatal accidents as a percentage of serious | Fatal accidents as a percentage of all |
|---|---|---|---|---|---|
| Good | 108 | 559 | 2,869 | 19.3% | 3.8% |
| Average | 188 | 684 | 3,026 | 27.5% | 6.2% |
| Poor | 184 | 596 | 2,256 | 30.9% | 8.2% |

Bentham (1986) studied the risk of becoming a traffic fatality for men aged between 15 and 24 in counties in Great Britain, depending on whether there was a hospital in the area or not. The study controlled for the number of cars per inhabitant and social conditions in the region. He found that the risk of death was around 12 % lower in areas with hospitals than in areas without hospitals. The difference was statistically significant at the 1% level.

Brodsky (1990) has studied the effect of response times on the number of fatalities in fatal road accidents in the USA. He chose accidents where more than one road user was involved, but where at least one road user was killed. He studied how the proportion of accidents where more than one person was killed varied, depending on the response time for ambulances. The assumption was that the probability of more than one person dying depends on how quickly medical help arrives at the scene of the accident.

In the majority of fatal accidents involving two road-users, only one dies. Both of those involved will only die on average in 5.5 % of fatal accidents involving two road users. The results of Brodsky's studies for different numbers of road users involved in accidents are shown in figure O.14.3.

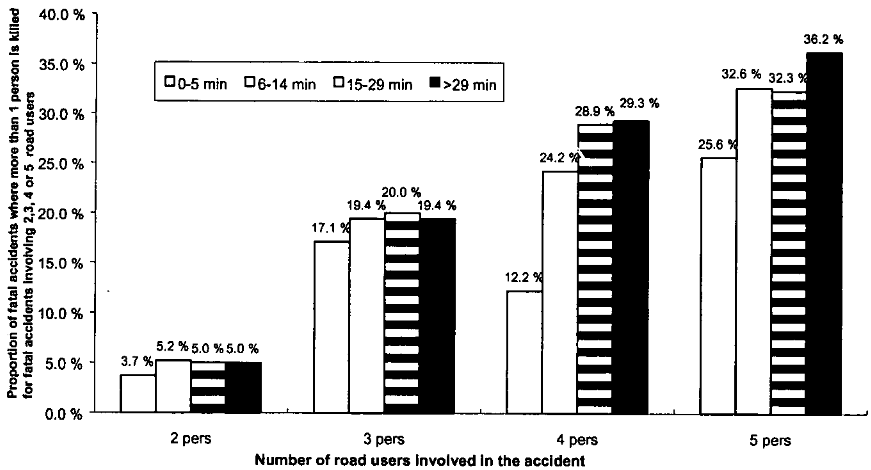


*Figure O.14.3: Proportion of fatal accidents where more than 1 person is killed by numbers of persons involved in fatal accidents in road traffic in the USA, depending on the ambulance response time to the accident. Source: Brodsky, 1990*

Figure O.14.3 shows a tendency for the proportion of fatal accidents where more than one person is killed to increase when the ambulance response times increases from less than 5 minutes to more than 29 minutes. This applies irrespective of number of road users involved in the accident.

Maio, Burney, Lazzara and Takla (1990) studied the relationship between different indicators of access to medical resources in an area and road accident mortality in the same area. They found a negative relationship, i.e. the better the access to medical services in an area, the lower the accident fatality rate in traffic in that area. Nonetheless, the relationship was relatively weak (correlation coefficient between around –0.15 and –0.20).

In a later study Maio, Green, Becker, Burney and Compton (1992) were not able to reproduce these results. They found a higher accident fatality rate in traffic accidents in rural areas than in more densely populated areas (i.e. a higher proportion of those involved in traffic accidents in rural areas will die compared to those involved in accidents in urban areas). However, there was a very strong correlation between population density and access to medical services. It was therefore not possible to say whether the higher rate of fatalities in rural areas is due to poor access to medical services or to differences in accident characteristics, such as speed.

Jones and Bentham (1995) studied the relationship between ambulance response times and fatalities in traffic in Great Britain. The main results of the study are shown in figure O.14.4.

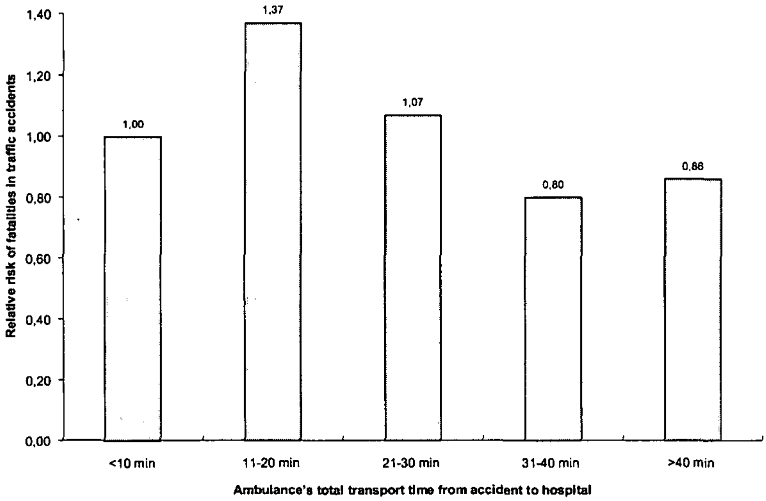


*Figure O.14.4: Relationship between ambulance response times and the relative risk of fatalities in traffic accidents. Source: Jones and Bentham 1995*

In this study, the response time is measured as the total transport time from the time of the accident to arrival at the hospital. Figure O.14.4 shows that there is no uniform tendency towards an increase in case fatality rates with increasing response times for ambulances. This result conflicts with the results of the majority of other studies.

***Doctors in ambulances.*** Alexander, Pons, Krischner and Hunt (1984) studied the relationship between fatalities in traffic accidents and the availability of advanced first aid (first aid units with doctors) in different areas (counties) in Florida, USA. They defined a mortality index, which took into account the number of inhabitants in different areas and traffic volume (number of kilometres driven) in the same areas. A comparison of areas with and without access to advanced first aid units gave the following results (table O.14.2):

*Table O.14.2: Fatalities in traffic in Florida according to availability of advanced first aid. Source: Alexander et al, 1984.*

| Availability of advanced first aid | Average mortality rate | Standard deviation for mortality rate | Proportion of call-outs with response time under five minutes |
|---|---|---|---|
| Yes | 9.4 | 15.9 | 60.5% |
| No | 44.1 | 45.8 | 36.7% |

In areas without access to advanced first aid, the mortality rate was around four times higher than in areas with access to advanced first aid. The response time for call outs was also longer in areas without access to advanced first aide units.

Figure O.14.5 shows the relationship between the proportion of injury accidents where a doctor was called and the proportion of accident victims who were killed in injury accidents reported to police in Germany in the years 1985, 1987, 1989 and 1991 (Bundesminister für Verkehr 1992). In these years, the proportion of injury accidents where a doctor was called to the scene of the accident varied between 28.1 % and 33.4 %. The proportion killed in accidents varied between 2.56 % and 2.33 %. Figures O.14.5 shows that there is a tendency for the proportion killed in injury accidents to go down when the proportion of accidents where a doctor is called increases. A regression line is drawn in figure O.14.5 indicating that an increase of one percentage point in the proportion of accidents where a doctor is called reduces the proportion killed by 0.038 percentage points. Figure O.14.5 does not control for other factors affecting the probability of dying in traffic accidents. Results therefore show only a statistical relationship, not necessarily a causal relationship.

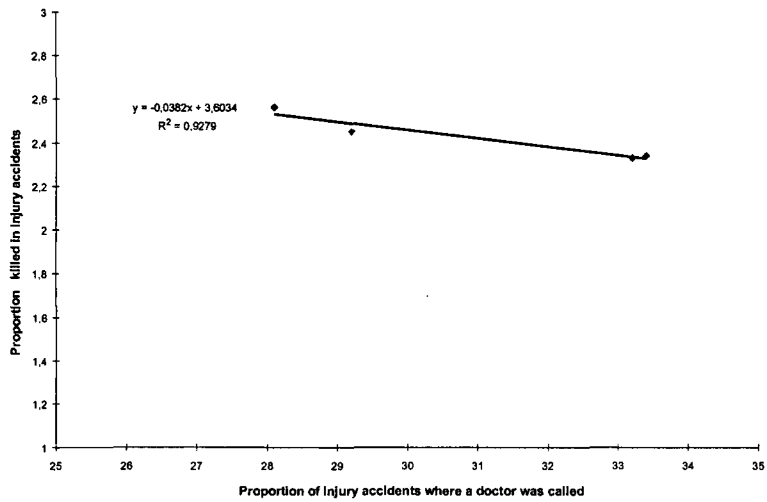


*Figure O.14.5: Relationship between the proportion of injury accidents where a doctor was called and the proportion killed in accidents. Germany. Source: Bundesminister für Verkehr 1992*

***Availability of ambulance helicopters.*** A number of studies have evaluated the effect of ambulance helicopter transport on the probability of surviving an accident or an acute illness. The results presented here, are based on these studies:

Baum 1980 (Germany)
Larsen et al 1981 (Norway)
Baxt and Moody 1983 (USA)
Søreide et al 1985 (Norway)
Harboe et al 1985 (Norway)
Baxt et al 1985 (USA)
Baxt and Moody 1987 (USA)
Schiller et al 1988 (USA)
Boyd, Corse and Campbell 1989 (USA)
Schwartz et al 1990 (USA)
Karper et al 1991 (Norway)
Magnus and Kristiansen 1992 (Norway)
Heggestad 1993 (Norway)
Nicholl, Brazier and Beeby 1994 (Great Britain)
Wisborg et al 1994 (Norway)
Nicholl, Brazier and Snooks 1995 (Great Britain)
Hotvedt et al 1996 (Norway)
Cunningham et al 1997 (USA)
Oppe and De Charro 2001 (Netherlands)

These studies differ in three important respects: (1) How the effect of ambulance helicopter transport on survival probability has been defined and measured, (2) Whether helicopter transport was compared to surface transport or not, and (3) Whether initial survival probability was controlled for or not in evaluating the effect of ambulance helicopters.

The results presented below are based on actual mortality, a comparison of helicopters to cars and a stratification of results with respect to initial probability of survival. Table O.14.3 shows estimates of the effects of ambulance helicopters on probability of surviving an accident or an acute illness.

*Table O.14.3: Effects of ambulance helicopter transport on probability of surving an accident or acute illness*

| | Percentage change in probability of dying | |
|---|---|---|
| Initial probability of survival | Best estimate | 95% confidence interval |
| Below 0.25 | -7 | (-28; +20) |
| 0.25-0.49 | +5 | (-24; +46) |
| 0.50-0.74 | -8 | (-32; +25) |
| 0.75-0.90 | -12 | (-37; +23) |
| Above 0.90 | +68 | (+33; +112) |

The studies show that using helicopters to transport patients does not influence their probability of survival very much. It would seem that for patients whose initial probability of survival is high, there is an adverse effect of using helicopters. Explanations for this finding are not known.

***Hospital treatment.*** Only one study has been found which indirectly indicates the effect of the quality of treatment given in hospitals for the number of road accident fatalities. The study is Belgian (Janssens and Thomas 1996). In this study, the development of the ratio between the numbers killed in traffic within a 30 day period (the official definition) and the numbers killed in traffic before arrival at a hospital, (i.e. in the accident itself or on the way to the hospital), from 1950 to 1994 was studied. Figure O.14.6 shows the development of this ratio from 1950 to 1994.

From 1950 to 1970, the number who died within 30 days in hospital increased. After 1970, the numbers went down and now comprise only around 10% of those killed in traffic accidents in Belgium. This indicates that the quality of medical treatment, which is given in hospitals, has improved since 1970. It is not known why the ratio between the numbers killed within 30 days and the numbers killed immediately increased before 1970.

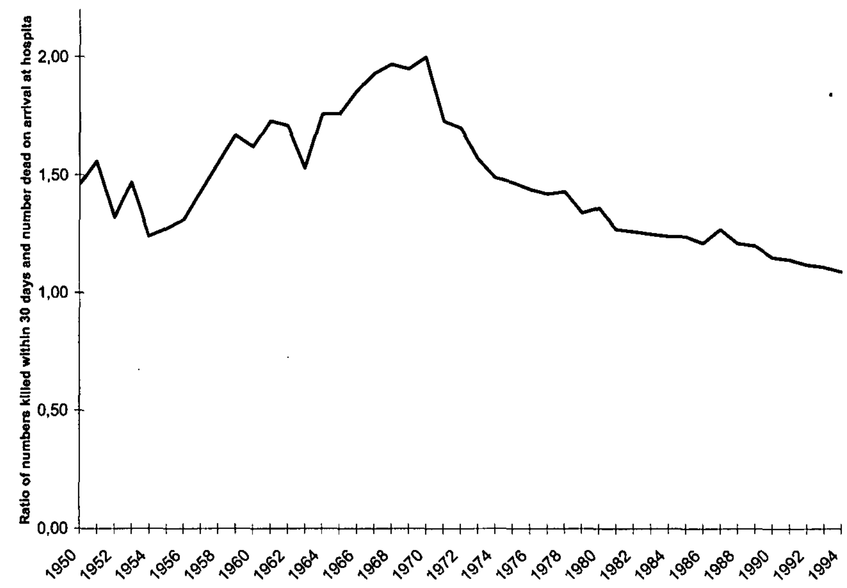


*Figure O.14.6: Ratio of those dying in traffic accidents within 30 days to those killed before arriving at hospital in Belgium 1950-1994. Source: Janssens and Thomas 1996*

## Effect on mobility

Better provision of medical services has no documented effects on mobility in traffic. If an accident scene is cleaned up more quickly, the hindrance to other traffic caused by an accident may be reduced.

## Effect on the environment

Better provision of medical services has no documented effects on the environment in traffic.

## Costs

No cost figures are available for improved availability of medical services for those injured in traffic accidents. Transport by ambulance helicopters is known to be expensive, but cost figures are not available.

**Cost-benefit analysis**

No cost-benefit analyses of improved provision of medical services for those injured in traffic accidents have been found. A cost-benefit analysis of the national air ambulance helicopter service (Elvik 1996E) concluded that the current service in Norway carried out by these helicopters had a benefit-cost ratio of around 5.4. Rescue helicopters carry out both search and rescue missions and ambulance transport. For the search and rescue missions, the benefit-cost ratio of current services is around 4.9. For ambulance services, the benefit-cost ratio was calculated to be around 5.9.

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