COSTS AND BENEFITS OF ROAD SAFETY MEASURES
REPORT OF
THE SIXTY THIRD ROUND TABLE
ON TRANSPORT ECONOMICS

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on the following topic:

COSTS AND BENEFITS
OF ROAD SAFETY MEASURES

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT
THE EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT (ECMT)

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INTRODUCTION

20th Century "Homo Economicus", or rather the modern state which is his emanation, has tried to rationalise his investments. Certainly, as shown by Keynes, any investment at all can be useful in "pump-priming" and thus reviving economic growth, but it is not better to develop methods for selecting those investments which have the most beneficial effects for the well-being of the population? This is the idea behind the PPBS (Planning Programming Budgeting System) created in the United States and adapted in France under the name of RCB (Rationalisation des Choix Budgétaires). The backbone of RCB is made up of cost-benefit calculations and the main field of application in the French administration has been precisely road safety.

We are thus at the very heart of our subject - the costs and benefits of road safety measures. The fact is that in France when road safety cost-benefit analyses are discussed, mention is invariably made of the first large scale experiment which was the pilot study for the rational preparation of decisions concerning road accidents (known as the PRDA study - Préparation Rationnelle des Décisions concernant les Accidents de la Route) a demonstration of RCB in road safety. This will therefore form the basis for our attempt to describe what has been done in France in this field.

Part 1 deals with methodology, describing what is involved in cost-benefit calculations and the problems and difficulties encountered in practice.

Part 2 describes the example of RCB in road safety and its applications in French planning.

Part 3 describes in more detail the application of cost-benefit analyses in the different areas of road safety.

Part 4 attempts to draw lessons from experience to date, detect new orientations and look at the possible future, in France, for cost-benefit evaluations.
1. METHODOLOGY: THE PRINCIPLE OF COST-BENEFIT ANALYSES - THEORETICAL PROBLEMS OF EVALUATION

1.1. DEFINITION

1.1.1. Comparison with cost-effectiveness and multicriterion analysis

In the field of road safety problems, scientific evaluation methods are aimed at optimising the use of the limited economic resources available. Several methods are possible:

- cost-benefit analysis;
- cost-effectiveness analysis;
- multicriterion analysis.

The cost-benefit analysis uses a common denominator - generalised money value. A money value is attributed to the market and non-market effects of decisions for both costs and benefits.

Cost-effectiveness analysis focuses on the goal aimed at, in this case improved road safety, a goal which can be quantified, for example, by a reduction in the number of people killed or injured. Thus those measures are selected whose monetary cost per human life saved is the least.

Multicriterion analysis is more complex. This involves a set of techniques for choosing priorities, the principle being a comparison of decisions on the basis of the foreseeable effects and the decision-makers' multiple objectives.

Each method is therefore suited to a particular purpose:

- When the aim of the policy pursued is to improve the well being of the community, its "quality of life", road safety being one aspect of this, the effectiveness of a measure can be estimated as the weighted sum of all the contributions the measure concerned makes to the quality of life, with respect to its cost. Multicriterion analysis thus appears the most appropriate method.
- When from the outset the objective pursued is improved road safety, the effectiveness of a measure can be assessed in terms of the reduction in the number of accidents or victims, while at the same time the costs of this measure can be estimated. The most appropriate method is then cost-effectiveness analysis.

- When road safety policy is subject to strict limitations on financial resources, the effectiveness of measures can be defined as the ratio between the savings corresponding to the reduction in the number of accidents, translated into money terms, and the cost of implementing the measures envisaged. It is then cost-benefit analysis which is the most appropriate method.

Very often in practice, however, the dictates of necessity mean that these distinctions are not so clear-cut because of practical difficulties in evaluation. Thus a projected multicriterion analysis may end up as a simple cost-benefit analysis because of difficulties in measuring and weighting effects other than those whose economic costs are easy to assess and the reduction in accidents. Similarly, due to a lack of agreement on the proper values to attribute to the benefits of a reduction in accidents, values which include a good measure of subjectivity, a projected cost-benefit analysis may be abandoned and a cost-effectiveness analysis accepted in its stead.

1.1.2. Description of the method

Cost-benefit analyses are designed to allow government programmes in different sectors to be compared in order to obtain the optimal allocation of resources.

The values attributed to the costs and benefits are derived from the national accounts. This reduces the bias due to the subjectivity of the analyst and makes the results obtained more objective.

We shall return at a later stage to the problems which nevertheless remain as regards the estimation of costs and benefits. At this point we shall simply explain the criteria for decision in a cost-benefit analysis.

Three criteria for decision are generally used:

- net present value;
- benefit-cost ratio;
- internal rate of return.
Net present value

This is the estimated difference at the present time between the values of the benefits $A$ and the costs $C$:

$$V_i = A_i - C_i$$

where,

$V_i = \text{net present value}$

$A_i = \text{present value of benefits}$

$C_i = \text{present value of costs}$

The present value of benefits depends on the period over which these benefits accrue (this period itself being a function of the length of life of the measure) and the social discounting rate which may be applied to future benefits, so that:

$$A_i = \sum_{j=1}^{n} \frac{A_j}{(1+i)^j}$$

where $i = \text{social discounting rate}$.

Similarly, the present value of costs depends on the period over which these costs are incurred and the discounting rate used;

$$C_i = \sum_{j=1}^{n} \frac{C_j}{(1+i)^j}$$

In order for a road safety measure to be considered effective according to this criterion, the present value has to be positive. In choosing among several measures, those whose present value is the highest are selected.

Benefit/cost ratio

This is the quotient of the present values of benefits and costs:

$$R = \frac{A_i}{C_i}$$

where $R$ is the benefit/cost ratio.

This quotient has to be greater than unity for the measure to be considered effective. Among several measures, the one with the highest ratio is selected.
It can easily be seen that the results of the two criteria - net present value and benefit/cost ratio - are the same.

**Internal rate of return**

This corresponds to the discounting rate which would have to be adopted to equate the net present values of benefits and costs.

If \( r \) is the internal rate of return, we therefore have:

\[
A_1 = C_1
\]

where

\[
A_1 = \sum_{j=1}^{n} \frac{A_j}{(1+r)^j}
\]

and

\[
C_1 = \sum_{j=1}^{n} \frac{C_j}{(1+r)^j}
\]

Measures are thus effective when \( r \) is greater than \( i \), the social discounting rate. Where there are several effective measures, the one selected will be that with the highest internal rate of return.

The three criteria are equivalent as regards determining whether a measure is effective or not, but they may differ as to which measure is to be selected among several.

Thus, where there are budgetary constraints, the net present value criterion is not satisfactory because it favours the biggest projects, those whose net present value is the greatest, but which very often also have the highest costs. By contrast, the benefit/cost ratio is perfectly suited to selecting the best projects within a given budget. This criterion, however, raises the problem of the appropriate form to be given to the costs appearing in the denominator of the ratio. Thus these costs may include all foreseeable negative effects, including those which do not have a market value, e.g. the delays caused by roadworks. The budgetary constraint then applies to the whole of the costs, these non-monetary costs being considered in the same way as public investment expenditure. Another method can be adopted, however, the non-monetary costs being directly deducted from the expected benefits, these costs then being considered negative benefits. This means that the budgetary constraint applies only to actual expenditure incurred by the authorities, which seems much more natural.
The internal rate of return criterion can lead to a different ranking to that of benefit/cost ratio, according to the time distribution of these benefits and costs. The fact is that for a project whose internal rate of return is acceptable, i.e. higher than the social discounting rate, the benefits are brought to a present value using this internal rate which is by definition higher than the social rate. As compared with the benefit/cost ratio, the result is a relative depreciation of longer-term benefits as against more immediate benefits. Thus a project which has the advantage of offering more rapid benefits but which, overall, is equivalent to another project according to the benefit/cost criterion, would be given a better internal rate of return.

In short, each of these individual criteria has its merits, without it being possible to say that one is better than another. In practice, it is usual to make an assessment according to each of these criteria in turn in order to be able to see any possible differences in ranking and make a choice on the basis of the most complete information possible.

1.2. THEORETICAL PROBLEMS OF EVALUATION

Apart from some difficulties in estimating benefits and costs in specific units, a problem to which we shall return later, it can be seen that certain benefits and costs of road safety measures can be very easily expressed in money terms, e.g. labour costs and capital investment which give rise to transactions and thus have a price fixed by the market. Other cost and benefit categories give rise to more tricky problems of evaluation. It is in fact necessary in particular to determine the value of time lost (e.g. as the result of speed limits) and the value of the benefit represented by a human life saved or an injury avoided.

Lastly, another problem is that of aggregating benefits (or costs) which are spread out over time. This was mentioned above in discussing the social discounting rate when describing the method. It remains to be seen whether this discounting rate can be determined.

1.2.1. The value of time

This value should be calculated on the basis of average per capita income, but in France it was in fact fixed empirically by the Direction des Routes et la Circulation Routière (DRCR) in 1964 while studies were being carried out in the Paris area on the distribution
of traffic between competing routes(1). At that time, the DRCR proposed Frs.8 per hour for light vehicles and Frs.15 for heavy vehicles. For the 1970 PRDA study the value was set at Frs.11 per vehicle, i.e. approximately Frs.5 per hour per user.

These calculations are not very satisfactory, however. The fact is that it is not the same to make 1,200 users lose 5 minutes, (i.e. a total of 100 hours) or 100 users lose 1 hour or 10 users lose 10 hours even though these losses also total 100 hours. It is not very rational to quantify small time losses for thousands of users caused by speed limits, when the time lost can be more than compensated by less nervous tension and tiredness on arrival, thus enabling productive activity to be undertaken immediately. It would, on the other hand, be more acceptable to put a value on the loss of driving pleasure as the result of speed limits, if it were not for the fact that such quantification would be particularly difficult.

1.2.2. The value of human life

The question of calculating the value of human life in road safety has caused a lot of ink to flow. Finally, however, there remain four main bases for evaluation:

- loss of production;
- the implicit value deriving from community choices in the allocation of resources;
- surveys on the populations' willingness to pay;
- the implicit value deriving from the behaviour of individuals as regards expenditure on protection against road accidents and their consequences.

These methods will now be examined in detail.

1.2.2.1. Loss of production

This is in fact the most important component in the economic cost to the community when one of its members dies. "There is no riches but men". How is this loss of production to be assessed? Should we take the gross loss or the net loss after deducting the dead man's virtual consumption? This has given rise to much controversy, but the fact is that this consumption is part of the well-being of the community of which he was a member. It

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therefore does not seem logical to deduct it. Furthermore, old people who consume but no longer produce would then have a negative value and the same is true of the unemployed.

In France, calculations of the price of a human life in economic decisions were made by C. Abraham and J. Thédie (1960), who were followed up by M. Le Net (1960).

An interesting variant has been proposed by H. Duval (1983) who, taking account of the widespread unemployment in the Western world at the present time, calculates the monetary value of the years of life lost. This is a micro-economic approach, very different in principle from the approaches of Abraham-Thédie and Le Net. For the individual the most precious good of all is life, since this is what determines the enjoyment of all other economic goods. Loss of life in a road accident means that the victim loses a certain number of years he would have lived had it not been for that accident. It is thus necessary to assess the value of these lost years. The approach used is close to that used in methods of determining preferences. It results in defining the implicit value of time on the basis of a model which attempts roughly to reflect present socio-economic conceptions.

Studying the time budgets for each broad socio-occupational category led Duval to break down time for each into seven components:

- compulsory schooling time;
- post-compulsory schooling time;
- official working time;
- unofficial working time;
- time spent on housework;
- free time;
- physiological time (mainly sleep).

After grouping related components together, he maximises the corresponding utility functions under constraints in an aggregative model and then uses certain assumptions to derive implicit values of time.

The effort of working is taken into account, on the one hand through using the willingness to pay method (broadly speaking, a person stops working when the effort becomes equal to the marginal utility), and on the other hand through imputing entirely to it the variations in life expectancy according to socio-occupational category.

Thus the method succeeds in attributing money values to the three social values represented by the individual's occupational capacity, housework and free time.

The approach differs from that of Abraham and Thédié in the nature of the aspect quantified: while the former puts a value on production, Duval puts a value on the consumption aspect (wellbeing). However, while the philosophy differs, the results in practice are similar because Duval on the one hand subtracts the value of the effort of work from the national income and on the other adds the social value of free time, these two factors being completely disregarded by Abraham and Thédié.

Lastly, it should be noted that Duval's method has the merit of linking the monetary value of life to the value attributed to time in road safety (see above) and thus improving the coherence of the estimates.

Other costs additional to this loss of production

The writers who have estimated the price of human life on the basis of the loss of production have, without exception, added other factors to this loss of production.

These additional costs are of two types:

- economic costs: medical treatment, funeral expenses, social expenses (police, insurance);
- affective factors, essentially the pain and suffering of family and friends. Abraham and Thédié add an affective prejudice suffered by the nation, for which the preservation of its subjects' lives is an imperative duty, and the "pretium vivendi" which reflects the desire to live of those whose lives are threatened. Conversely, the very nature of Duval's approach is such that this "pretium vivendi" is not counted separately, but included in the value of free time and the individual's future consumption, from which the effort of work has to be deducted. The family's pain and suffering is evaluated on the basis of the compensation paid by insurance companies.
1.2.2.2. The implicit value resulting from community choices

The value of human life as calculated using the previous method is a predetermined value which is subsequently used in the choice of accident prevention measures. Here, on the other hand, the value of human life is determined post facto by assessing decisions already taken. This simply establishes a lower limit to the value of human life for a given decision-maker and a given decision and not an exact value. This assumes the rationality of economic agents and the absence of external effects. It is only when these conditions are fulfilled that a lower limit to the value of human life can be determined for a given decision-maker, a given risk and given population at a given time.

Applying this method to our field of interest, it can be seen that in France this value varied by a factor of 6 to 1 during the period of the Vth plan (1971-1975), according to whether the life saved resulted from measures concerning: ice control, seat belts, road markings, elimination of accident black spots, the campaign against drink and driving and speed limits. This is shown in the following table:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Average annual cost for one death avoided(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campaign against drink and driving</td>
<td>4,513</td>
</tr>
<tr>
<td>Speed limits</td>
<td>2,222</td>
</tr>
<tr>
<td>Ice control</td>
<td>14,583</td>
</tr>
<tr>
<td>Road markings</td>
<td>7,250</td>
</tr>
<tr>
<td>Seat belts</td>
<td>13,055</td>
</tr>
<tr>
<td>Elimination of accident black spots</td>
<td>5,550</td>
</tr>
</tbody>
</table>

(*) In 1969 Francs with a discounting rate of 10 per cent.
1.2.2.3. The survey of willingness to pay

This method exists mainly in theory only since it has been very little used in practice. So far as we are aware it has never been used in the field of road safety.

The only examples known are from the United States, and as stated above are outside the field of road safety.

Thus Cohen (1970) carried out a survey among radiologists to find out what financial compensation would suffice to make them accept exposure to one unit of radiation. The answer ranged from $10 to $5,000. Assuming a linear relationship between exposure and the probability of death, and a lethal dose of 1,000 units, the value of life would lie between $10,000 and $5 million, with the average being $250,000.

For Otway (1972), the approach was a little less direct. He questioned a sample population about major disasters and observed that respondents referred first of all to material damage as against loss of life when the amount of damage exceeded $250,000 per victim. He deduced from this an unconscious consensus assessing the price of a human life at $250,000.

In 1973, Acton carried out a survey with a sample of 100 people to find out what sum they would accept to pay to reduce their chances of dying from a heart attack from 2 in 5 to 1 in 5, knowing that the risk of such an attack is 1 per cent. The average worked out at $56, which would put the price of a human life at $28,000.

It can be seen from these three examples that individual willingness to pay to avoid the risk of death varies greatly.

1.2.2.4. The implicit value deriving from individual behaviour regarding expenditure on protection against road accidents

The purchase of motor cycle helmets, seat belts, etc., is the behaviour of somebody wishing to improve his level of safety when travelling by road.

Such considerations are not a sufficient basis to enable the price individuals put on their own lives to be calculated, however, the more so because certain items of equipment may to a greater or lesser extent increase the ease of driving at the same time as safety. Furthermore, the subjective assessment of the increase in safety does not necessarily correspond to the real improvement.
This is why this method, although intellectually tempting, has not really been applied in practice. It is in any case only a variant of the previous method, being based on the same principle, but not using the survey approach.

One attempt to assess the price of human life using this principle in the labour market can be cited. Thaler and Rosen (1973) analysed the differences in the wage rates of different occupations according to the risk involved. Through a multiple regression analysis they estimated the value of a human life at about $200,000.

1.2.3. The cost of injury

The cost of injuries can be broken down into two basic components:

- the loss of production due to the victim's inability (temporary or permanent, partial or total) to work.

This incapacity is assessed on the basis of insurance company estimates which allow a number of days for temporary incapacity or points for permanent invalidity. Thus 5 points permanent invalidity means that the victim will never be able to work at more than 95 per cent of his previous capacity.

- the cost of hospitalisation and treatment. This calculation does not present any particular problems.

1.2.4. Discounting rates

The more or less lasting effects of road safety measures mean that costs and benefits rise at different times. They need to be made comparable through applying an appropriate procedure to bring these costs and benefits to a present value at a given date. In order to do this it is therefore necessary to fix a social discounting rate, a concept which was discussed in describing the method. The determination of this rate has given rise to much discussion in the economic literature. This discussion involves the concepts of social preferences over time and the social opportunity cost of capital, both of which raise problems of estimation. In practice, it can be seen that most governments simply take the ruling interest rate on the open market or the rate paid on government loans. In France, it is the General Commission for the Plan which fixes this discounting rate on the basis of a macro-economic model. Thus the rate adopted for the VIIth Plan (1976-1980) was 10 per cent per annum.
2. THE USE OF COST-BENEFIT METHODS FOR ROAD SAFETY IN GENERAL (RATIONALISATION OF BUDGETARY CHOICE IN ROAD SAFETY)

2.1. RATIONALISATION OF BUDGETARY CHOICE - DEFINITION - ITS VALUE IN THE FIELD OF ROAD SAFETY

Rationalisation of budgetary choice (a specifically French concept known as RCB) is a set of procedures aimed at improving administrative decision-making. An attempt is made to measure the advantages and disadvantages of all the alternative solutions envisaged. The analysts try to look at each phenomenon in its context and as far as possible to examine all aspects through calling upon specialists from different disciplines.

RCB is characterised by three main features:

- first, the search for a coherent procedure for preparing, implementing and monitoring decisions at each level of responsibility;
- second, the use of well-defined techniques at different stages of the study: systems analysis, graphical techniques, morphological analysis, cost-benefit analysis, techniques for determining choices in the presence of multiple criteria, etc.;
- third, the wish to very closely associate analysts and decision-makers.

Why was RCB chosen in the field of road safety?

2.1.1. RCB is particularly well-suited to the field of road safety

In the first place, road safety is a very important problem at the national level. At the time of the 1968 study, there were 226,598 accidents in France, which caused 14,284 deaths and 317,868 injuries. The cost was reckoned at over Frs.10 billion at that time, or five times the national expenditure on road and motorway investment. In addition to the Ministry of Transport, this problem concerns most other major ministries: Interior, Justice, Finance and Economy, Defence, Education, Health, Industry and Research, Posts and Telecommunications. The result is a great many decisions
centres and consequently a great need for a method of ensuring the coherence of decisions in this field.

It is also necessary in such a field to develop co-operation and consultation between the analysts and the different decision-makers so that each of those responsible always has the necessary information at hand and in particular is aware of the effects the partial decisions he is called upon to make will have on the field of road safety as a whole.

In addition, road safety is a field where constant adjustment is necessary. Because of the quantitative growth in the volume of traffic, new possibilities for controlling it, technical developments in vehicles and infrastructure characteristics, there is a constant need to be able to rethink the problem of road accidents and constantly adjust the decisions taken in this evolving area. One of the essential characteristics of RCB is precisely the establishment of an integrated process: observation - study decision - management - observation ... which should ensure the constant adjustment of administrative decisions to the general evolution of external data.

Lastly, another advantage of RCB is the possibility of obtaining results rapidly. Traffic and road safety having already been the subject of partial studies and a good deal of data having been collected, the team of RCB analysts was immediately able to call upon the findings of many studies and the experience of a number of specialists in certain sub-sectors. It was thus possible to get results within a few months.

2.1.2. Conversely, the road safety study was able to improve the RCB method

In the first place, the road safety project promoted the study of non-market benefits. These were discussed above in examining the problems raised by attributing money values to certain benefits and costs.

In addition, road safety promoted the spread of RCB methods throughout the civil service because of the numerous ministries concerned. The RCB road safety study was the occasion for training civil servants in different departments and ministries and making people aware of this type of method, an essential preliminary to the general use of RCB throughout the French administration.
2.2. PILOT STUDY FOR THE RATIONAL PREPARATION OF DECISIONS CONCERNING ROAD ACCIDENTS (PRDA)

This study was carried out as part of the RCB project submitted to the Council of Ministers in April 1968. It systematically analysed possible measures aimed at reducing the number of accidents and their harmful consequences. Its findings served not only to illuminate budgetary choice but also led to proposals for administrative and regulatory decisions.

2.2.1. Specific nature of the PRDA study

2.2.1.1. First characteristic - extension and better definition of the field of study

RCB involves a systematic exploration of the methods which could be used to perform well-defined functions. In order to do this in the PRDA study, specialists in different disciplines were called upon: engineers, economists, a statistician, psychologists, sociologists, doctors (surgeon and psychiatrist). Each time the need was felt, representatives of the different ministries concerned were called in. Working with a multidisciplinary team led to multiple criteria being taken into account:

- monetary costs and benefits for the community;
- budgetary expenditure or revenue;
- monetary costs and benefits for users;
- number of lives saved;
- number of injuries avoided;
- time savings or losses;
- psycho-sociological impacts (reaction of public opinion, feelings of frustration for individuals, aggressiveness);
- impact on certain groups particularly concerned (car manufacturers, producers of alcoholic drinks, regional interests, etc.);
- international repercussions (regulation, imports and exports);
- long-term effects.

2.2.1.2. Analysis of the different aspects of the problem to enable a programme structure to be defined

A traffic accident can be analysed as a breakdown in a complex system, which puts men, vehicles and an environment, including the infrastructure, at risk.
An attempt is therefore made to ensure the proper functioning of such a system (accident prevention) and subsequently, if accidents nevertheless occur, to mitigate the harmful consequences (repair). The action taken to fulfill these tasks may concern one of the sub-systems, such as men, vehicles or infrastructures, or again the links between these sub-systems, such as man-vehicle or man-vehicle-infrastructure links.

Measures concerning people are classified according to the changes they are intended to produce. Thus a distinction is made between measures aimed at:

- increasing knowledge;
- increasing psychological fitness to drive;
- adjusting individual behaviour to driving in traffic.

This reasoning leads to the establishment of a programme structure in the form of a logical, and so far as possible complete, catalogue of all methods of fulfilling the tasks set.

2.2.1.3. Different possible road safety policies defined on the basis of the programme structure; these policies compared by means of cost-effectiveness and cost-benefit analyses

These analyses attempt to establish relationships between measurable parameters or indicators:

- characterising the action programme (programme indicators);
- indicating the effect of measures on the environment (impact indicators);
- gauging the effectiveness of the measure with respect to the objectives pursued (outcome indicators).

These indicators correspond to the list of criteria set out above.

2.2.1.4. Extension of the pilot study beyond the strictly budgetary fields through the examination in particular of the effect of road safety regulations

2.2.2. Procedure

In view of the above, the PRDA study, after determining the logical classification of possible basic road safety measures, should have constructed a whole set
of alternative action programmes combining these numerous basic measures in different mixes. Once all these programmes had been drawn up they should have been compared by means of assessing the costs and benefits to the community, their effectiveness being measured by means of a general outcome criteria or indicators. This ideal procedure for deciding choices came up against the practical impossibility of determining all the alternative programme technically, politically and psychologically feasible and evaluating the costs and benefits for each, since it would have necessitated a considerable number of surveys and hence investigation instruments disproportionate to the resources available. Furthermore, there was no question of considering the basic measures as being truly independent. Evaluation of the impact of a programme, its cost and benefits, can be done only for the programme as a whole, because it is not simply the sum of the impacts of each of the basic measures comprising it.

The PRDA team was thus forced to make a selection and group together these basic measures into a certain number of non-exhaustive fields of activity. It appeared under these circumstances reasonable to orient research towards areas which met the following criteria, among others:

- the greatest expected effectiveness according to common sense and expert opinion;
- the possibility of leading rapidly to conclusions and then to decisions;
- appropriateness (need to test a certain number of measures on the point of being implemented);
- best use of the skills of the analysts participating in the study.

The logic of this approach, obviously open to criticism, was determined by the constraints imposed by the group's possibilities within the time allowed.

On the basis of consideration of ends and means, the objective-programme structure was able to determine the qualitative relationship between measures and objectives. The subsequent cost-benefit analyses provided a quantitative assessment of the effect of these measures. These analyses were often made difficult, however, first because of the lack of data and then because of the above-mentioned interdependence on measures. A comprehensive road safety model would probably be impracticable, while an over-simplified model would ignore important inter-relationships. An attempt was therefore made to assess first of all the effects of a number of specific measures (individual studies) using both econometric calculations and the experience of experts (Delhi technique). These studies are described
in detail below where each of the main sectors of road safety action is discussed.

2.2.3. Outcome of the study

The results obtained on completion of this work were submitted to the various ministries concerned so that these latter could take account of them in their proposals for 1970. These proposals were subsequently confronted with one another at an interministerial meeting in which the Budget Directorate participated. This was the first time that such a procedure had been employed - analysis of a single problem by the different ministries concerned then confrontation of their proposals at an interministerial meeting dealing with this precise subject. This procedure, completely in line with the spirit of RGB, has the advantage of ensuring the coherence of all the decisions taken. Finally, in October 1969 it was decided to allocate Frs.28.5 million to road safety measures and studies.

Other results of this PRDA study were the convening of a road safety round table in 1970 and, above all, the drawing up of a final road safety programme for the period of the VIth Plan (1971-1975).

2.2.4. Conclusions regarding this PRDA study

2.2.4.1. Its design enabled the study to take account of many different standpoints and of the influence of the environment. The overall approach used was able to ensure unity and coherence while examining the problem from these different standpoints.

In addition, the operational method adopted was due to the initiators' concern for effectiveness - the study was designed not so much with regard to achieving an optimum at a given moment, but rather with regard to the future, the aim being to promote the subsequent integration of decisions and verify the reasonableness of these decisions.

2.2.4.2. In carrying out the project, a study and research effort was made in order to understand the problem and analyse the measures envisaged in quantitative terms, while at the same time an effort was made to inform decision-makers so that they could put the best solutions into practice. The optimum may therefore be understood as a decision made on the basis
of a method appropriate to the problem providing a maximum of information on the various alternatives and their probable consequences.

2.3. THE VIth PLAN'S TARGETED ROAD SAFETY PROGRAMME

The PRDA study provided all the information necessary for drawing up a large-scale safety programme for the medium term. This "Targeted Road Safety Programme", (Programme Finalisé de Sécurité Routière) extending over the period 1971-1975, was adopted by the parliament under the VIth Plan. Through this programme the legislative and executive undertook to give priority for five years to diverse large-scale, specifically-targeted road safety operations.

2.3.1. Objectives

The programme was intended to hold the number of road deaths down to 15,000 in 1975 (i.e. the same level as in 1970), while the rate of increase was such that 18,000 deaths were forecast for that year if no new measures were undertaken. At the same time the programme aimed to reduce the number of accidents and injuries, but no numerical targets were set.

2.3.2. Financing and sectoral content

For practical convenience the general programme was broken down into eight sub-programmes which are summarised below.

As regards financing, when the programme was drawn up in 1970, total expenditure on all the operations envisaged was expected to be Frs. 2,325 million, Frs. 1,404 of which fell to the State. The contribution of local authorities and other agents was estimated at Frs. 391 and 529 million respectively.

Sub-programme 1: improvements in the open country and in built-up areas with less than 20,000 inhabitants.

The operations involved (improvements at dangerous crossroads, road markings, development of priority roads, improvements to road shoulders to reduce the severity of accidents, non-skid treatment in slippery areas) were restricted to ad hoc measures and excluded, for example, integrated safety measures such as the design of motorways and new roads.
Sub-programme 2: improvements in urban areas: built-up areas of over 20,000 inhabitants

Action in urban areas was essential because of the large number of accidents recorded. The measures consisted of improvements at intersections (traffic lights, islands, pedestrian crossings) and traffic engineering and safety plans.

In 1973, preliminary studies for traffic engineering and safety plans were carried out for 41 towns. In 1974 and 1975 traffic engineering developed vigorously as regards both study and actual implementation.

Sub-programme 3: Road use.

The two measures adopted were enforcement of speed limits and the campaign against drink and driving.

Sub-programme 4: Vehicles

Two measures were adopted:

- regulations concerning the construction of vehicles and their equipment, in particular heavy vehicles. Action in this field could not be embarked upon entirely freely by France alone because such regulation is subject to international agreement;
- technical inspection of vehicles. The idea was either spot checks by specialised police units or periodical compulsory inspection by authorised garages.

Sub-programme 5: Emergency services

Four measures were adopted:

- first aid training for ambulance men and police;
- improvements to the alarm system. This is based on the local SAMU (Système d'Aide Médicale d'Urgence), which comes under a teaching or other hospital. Radio communications enable precious time to be saved. 57 primary networks (20 to 30 km radius) were set up in 1973 and by the end of 1974 there was a total of 200 primary networks and 10 secondary (30 to 60 km radius);
- development and better use of ambulances, some being "médicalisées" (having a doctor and a certain minimum of equipment on board);
- installation of reanimation units in certain hospitals.
Sub-programme 6: Driver training, teaching the rules of the road in school.

Four measures were adopted:

- driver training. This was aimed at the first place at the drivers of heavy vehicles whose rate of involvement in fatal accidents is particularly high. They are offered driver training courses on really "heavy vehicles". A grant was to cover half the cost of the training given by specialised bodies. A subsidy could also assist the training of driving instructors;
- driving test. Any decisive action on driver training should necessarily be accompanied by measures concerning the driving test. By way of experiment it was proposed as part of this operation to build special tracks for learner drivers;
- teaching the rules of road in school. This was a matter of putting into effect legislation which had existed for a long time and whose effectiveness seemed to be demonstrated by United States experience;
- National register of drivers. This would be set up gradually. It was planned to have two sub-files, one in the Ministry of the Interior (information concerning licences, registration documents, decisions restricting the validity of licences) the other in the Ministry of Justice (convictions for driving offenses, including sanctions imposed on French drivers abroad and reported to the Ministry under international agreements).

Sub-programme 7: Information and publicity.

This is the essential accompaniment to all the measures envisaged. It is a matter of bringing road users' knowledge up-to-date and modifying their behaviour. It was planned to rationalise publicity campaigns by improving the preparatory studies, using the mass media in a co-ordinated way and systematically monitoring their effectiveness.

Sub-programme 8: Study and research.

Various study or research projects were undertaken as part of the targeted programme. First effectiveness studies of the measures implemented, so as to quickly assess the value of the operation concerned and thus decide the pattern of its future development, then studies to be carried out either in the field of technology (Organisme National de Sécurité Routière;
Union Technique de l'Automobile, du Motocycle et du Cycle), or of driver information - knowledge of advanced driving techniques and of accidents.

2.3.3. Practical implementation

The unprecedented expenditure involved in this targeted programme amounted to about Frs.1,400 million for the central government.

At the end of 1975 (end of the VIth Plan and hence of the programme), the government had spent Frs.1,230 million on road safety. Taking account of changes in the value of money and the various adjustments made during the programme, the rate of implementation can be assessed at about 80 per cent, which is remarkable in comparison with the other major projects of the VIth Plan. It represented a very considerable improvement over the previous situation and the targeted road safety programme can be considered a success.

2.4. THE PRIORITY ACTION PROGRAMME (PAP) OF THE VIIth PLAN: TO IMPROVE ROAD SAFETY

2.4.1. Objective

The aim of the programme was to hold the number of road accident victims during the period of the VIIth Plan below that of 1975, i.e. 13,170 killed and 354,000 injured, despite a constantly increasingly volume of road traffic.

The main outcome indicator was the number of road deaths in a given year (with the definition of road deaths in French statistics being death within six days of the accident).

The number of injured for the year is considered less significant because of the heterogeneous nature of this category.

2.4.2. Management of the programme

2.4.2.1. Chief Minister: the Prime Minister (General Secretariat of the Inter-Ministerial Road Safety Committee).
2.4.2.2. The main ministries participating in the programme were:

Ministry of the Interior
Ministry of Defence
Ministry for Equipment
Ministry of Health
Ministry of Education.

In addition the following were associated according to need and the nature of the measures considered:

Ministry of Justice
Ministry of Industry and Research.

2.4.2.3. The head of the project was the Secretary-General of the Interministerial Road Safety Committee

In general the head of the project took or initiated the decisions necessary for the proper execution of the programme. He ensured interministerial co-ordination thanks to an administrative group made up of representatives of the Ministries concerned by the programme, the Ministry of Economics and Finance and the General Commission for the Plan.

The head of the project was to hold at least two meetings of the group each year, the first before the preparatory phase of the annual central government budget, the second to examine the items of the annual report relating to the execution of the programme submitted by the ministries concerned.

Lastly, the head was to submit to the Interministerial Road Safety Committee proposals for any new legislative or regulatory measures he considered necessary for the objectives of the programme to be met.

2.4.3. Content of the programme

The road safety policy which the authorities were to pursue through this programme included two types of measure, different in nature but very closely interrelated:

- regulatory and legislative action, the general outline of which was proposed without it being possible to establish a strict timetable in advance;
- action of a physical nature involving budgetary expenditure.
2.4.3.1. Action 1: regulatory and legislative measures

New regulatory or legislative measures, some of them short-term, were envisaged for the period 1976-1980. These were closely related to the physical measures, the two together forming an inseparable whole constituting the essence of the road safety policy planned by the authorities.

The main fields were:

- speed limits;
- drinking and driving;
- the wearing of seat belts;
- driving licences;
- technical inspection of vehicle;
- vehicles components;
- sundry regulations.

2.4.3.2. Action 2: safety improvements on country roads and in small built up areas (Communities of less than 20,000 inhabitants)

This action includes six operations:

- 1: improvements at intersections and individual danger spots;
- 2: speed limits at individual danger spots;
- 3: protection against going off the road;
- 4: elimination of slippery surfaces;
- 5: installation of emergency telephones;
- 6: general infrastructure studies.

2.4.3.3. Action 3: enforcement penalties

This action includes 7 operations:

- 1: enforcement of speed limits in urban areas;
- 2: campaign against drink and driving (responsibility of the Police Nationale);
- 3: checks on the wearing of seat belts and helmets (two wheelers) in urban areas;
- 4: technical inspection of vehicles - superficial spot checks associated with pollution control;
- 5: speed limits in the open country and small built up areas (responsibility of the Gendarmerie Nationale);
- 6: campaign against drink and driving (responsibility of the Gendarmerie Nationale);
- 7: checks on the wearing of seat belts (responsibility of the Gendarmerie Nationale).

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2.4.3.4. **Action 4: Safety of vehicles**

Action financed by the Ministry for Equipment (Roads and Road Traffic Directorate).

2.4.3.5. **Action 5: Emergency services**

This action includes five operations:

- 1: staff training;
- 2: alarms;
- 3: harmonization of services;
- 4: teaching elementary survival procedures to road users;
- 5: study and research into road accident rescue services.

2.4.3.6. **Action 6: Improving the behaviour of road users**

This includes two operations:

- 1: teaching road safety in schools;
- 2: training for learner drivers and driving test examiners.

2.4.3.7. **Action 7: Information for road users and operation of the General Secretariat of the Interministerial Road Safety Committee**

This action includes two operations:

- 1: informing road users about road safety;
- 2: operation of the general secretariat of the Interministerial Road Safety Committee.
3. COST-BENEFIT STUDIES IN THE DIFFERENT SECTORS OF ROAD SAFETY

We have just seen how the large-scale road safety programmes during the VIth and VIIth economic and social development Plans were determined on the basis of the RCB (Rationalisation of Budgetary Choice) method.

It is now necessary to examine the cost-benefit studies actually carried out in the main fields in which road safety measures have been implemented, i.e. infrastructure, vehicles, driver training, user information, regulation and enforcement, emergency services, study and research. This is the subject of part 3.

3.1. INFRASTRUCTURE

This has been a major area for economic analyses as there are many possibilities for safety measures, whose cost is high, but easy to assess. Expenditure on road works being very heavy, it is particularly important to allocate resources in the best possible way, or in economic terms, to "maximise utility".

However, cost-benefit analyses have been carried out only on a fairly limited number of operations, which it is worthwhile recalling here.

3.1.1. Improvements at intersections and individual danger spots ("accident black spots")

The idea of "black spots" is one of the oldest in road safety, but their definition remains difficult because of the fairly random location of accidents. Any intersection is a potential black spot and will be so designated once the number of accidents exceeds a certain level.

Even before the PRDA study, safety improvements at danger points had been made on the initiative of the Public Works Directorate at "département" level, the project being submitted for approval by the Roads and Road Traffic Directorate. The latter spent
Frs. 29 million on such improvements in 1967, the marginal profitability being about 25 per cent according to the scales employed at the time by the Ministry for Equipment(5).

The PRDA study, while wishing to step up such action, recommended a follow-up study of the effectiveness of improvements to black spots over a period of three years.

This was done in subsequent years by the CETE (Centre d'Etudes Techniques de l'Equipement), of Lyon, Lille and Metz. The only exhaustive follow-up study was that by the Metz CETE, covering 85 improvements carried out between 1964 and 1967 - 39 intersections, 36 bends and 10 other improvements.

The vast majority of those operations proved effective, the reduction in the number of accidents ranging from 15 to 100 per cent. Nevertheless, there were particular cases where changes at an intersection brought about a subsequent increase in accidents, hence a negative effect on safety (almost one third of cases).

The average profitability of positive improvements is 60 per cent, but the overall figure is 39 per cent when the cases of negative improvements are included. Certain modifications improved traffic flow to the extent of causing higher speeds and lower safety. The outcome was a recommendation to review the methodology of the operation, bringing a team of multidisciplinary specialists at the time of deciding the remedy to be applied, the aim being to bring the average profitability up to at least 60 per cent.

Since this time, profitability studies of improvements to accident black spots have continued at the local level without there being anything very new to report.

3.1.2. Non-skid treatment

A particular form of black spot is associated with skiddy surfaces, this being due to moisture (rain) or occurring only in winter (ice, snow).

5. Cost of a road death Frs. 230,000, an injured person Frs. 10,000, material damage in such accidents Frs. 3,500.
3.1.2.1. Skiddy black spots (wet weather)

When the VIIth Plan was being drawn up, a balance sheet of operation 6 - "elimination of skiddy surfaces" - was drawn up. It covered the treatment of 51 such black spots distributed over 6 CETE areas, the improvement being carried out between 1971 and 1972. (Although the operation had covered 175 skiddy black spots treated between 1971 and 1973 a fairly long observation period was required after the improvement.

The results of this study are shown in the following table as the annual average figures for the 51 spots considered. The number of accidents before improvement was calculated over an observation period of three to four years centred on 1969, the number of accidents after improvement over a period of 6 to 18 months centred on 1972.

Thus the number of accidents on wet roads was reduced by 90 per cent, this resulting in particular in ten less deaths each year over the 51 black spots.

The profitability of the operation was also extremely high:

- the average cost of an improvement, calculated on the basis of work carried out in 1971 and 1972, was about Frs.66,300 (taking into account the cost of preparatory studies which in fact only made up 3 per cent of the total);
- the average annual benefit resulting from the observed reduction in the total number of accidents (taking a factor of 1.3 for the increase in the number of accidents between 1969 and 1972 - this figure being justified by the fact that the average number of accidents on dry roads increased from (1.67 - 1.25) or 0.42 to (0.68 - 0.15) or 0.55, a rise of 30 per cent, and taking the average cost of an accident as Frs.53,000):

\[(1.67 \times 1.3 - 0.68) \times 53,000 = \text{Frs.79,000}\]

The profitability of the investment at the end of the 12 month period following the work is therefore 79/66.3 = 1.19 (not taking account of interest rates).

Finally, it was pointed out that the benefit was considerably undervalued because it was not taken into account that the seriousness of accidents at skid black spots had been considerably reduced after treatment (0.19 deaths per accident before treatment, 0.11 after). In addition, the costs of victims used dated from 1970 and should have been updated - deaths Frs.320,000 in 1973 against 230,000 in 1970, serious injury Frs.14,000 in 1973 as against 10,000 in 1970.
<table>
<thead>
<tr>
<th></th>
<th>Accidents</th>
<th>Victims</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total number</td>
<td>Number on wet road</td>
</tr>
<tr>
<td>Before improvement (base 1969)</td>
<td>1.67</td>
<td>1.25</td>
</tr>
<tr>
<td>After improvement (base 1972)</td>
<td>0.68</td>
<td>0.13</td>
</tr>
<tr>
<td>Percentage reduction</td>
<td>59%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Table

EFFECTIVENESS OF NON SKID TREATMENT FOR 51 BLACK SPOTS
3.1.2.2. Winter skidding

At the time of the PRDA study a very detailed cost-benefit analysis was carried out regarding measures to combat skidding in winter.

The data for this study had been collected for different years: accidents in 1966, traffic in 1965, cost in 1970, drop in traffic during the winter of 1966-67. For the cost-benefit analysis all these figures were brought to the base year 1966:

\[
1966 \text{ traffic} = 1965 \text{ traffic} \times 1.08
\]

\[
1966 \text{ cost} = 1970 \text{ cost} (1 + 0.1)^4
\]

3.1.2.2.1. Safety benefits

The SETRA (Services d'Etudes Techniques des Routes et Autoroutes) statistics gave the number of accidents in snow and ice conditions for the years 1963 to 1966.

By taking the total number of accidents, deaths and injuries for these years, it was a simple matter to calculate the number of deaths and injuries per bodily-harm accident.

An ONSER (Organisme National de Sécurité Routière) study in 1963 found that accidents caused by ice cost 12 per cent more than the average. Applying this 12 per cent increase to the average rates of deaths and injuries, the number of victims in bodily-harm accidents due to winter skidding was recalculated. The results are given in the table below:

<table>
<thead>
<tr>
<th></th>
<th>1963</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodily harm accidents</td>
<td>7,650</td>
<td>4,143</td>
<td>3,938</td>
<td>2,976</td>
</tr>
<tr>
<td>Deaths</td>
<td>489</td>
<td>265</td>
<td>252</td>
<td>193</td>
</tr>
<tr>
<td>Injuries</td>
<td>11,704</td>
<td>6,347</td>
<td>6,072</td>
<td>4,607</td>
</tr>
</tbody>
</table>

In addition, SETRA had estimated the average effectiveness of treating winter roads at 75 per cent, taking into account the different levels of service.
according to climatic zone(6). It was assumed that this effectiveness also applied to the reduction in the number of accidents. The proper level of treatment in 1976 ought to have been Frs. 80 million, while in fact only Frs. 55 million were spent. Supposing the effectiveness to be proportional to expenditure, the additional expenditure of Frs. 25 million would have brought about a reduction in accidents of 1,440, or, applying the average rates of seriousness discussed above, 2,229 injuries and 94 deaths, hence a gain in safety of:

\[
\begin{align*}
\text{Deaths} & \quad 94 \times 230,000 \text{ F} = 21,620,000 \text{ F} \\
\text{Injuries} & \quad 2229 \times 10,000 \text{ F} = 22,290,000 \text{ F} \\
\text{Accidents} & \quad 1440 \times 3,500 \text{ F} = 5,040,000 \text{ F} \\
\text{Total} & \quad = 48,950,000 \text{ F}
\end{align*}
\]

To estimate the total gain due to increased safety, it is necessary to add the cost of damage-only accidents, reckoned at 70 per cent of the cost of bodily-harm accidents - i.e. Frs. 34,265,000.

Hence a total safety benefit of Frs. 83,215,000.

3.1.2.2.2. Traffic volume benefits

The average daily traffic volume for the months of November, December, January and February has been estimated at 80 per cent of the daily average for the whole year. In addition, vehicle counts carried out by SETRA gave a figure of 20 per cent for the drop in traffic volume on snowy or icy days.

Thus the traffic volume \( V \) on a snowy or icy day as compared with an average day \( J \) was:

\[
V = J \times \frac{80}{100} \times \frac{80}{100}
\]

This traffic was broken down into 85 per cent light vehicles and 15 per cent heavy vehicles.

3.1.2.2.2.1. Time savings

The drop in speed in snowy or icy conditions was estimated at 30 per cent.

6. The whole of France being divided into four zones: mild (less than five days of snow or ice), not very harsh (5 to 20 days), fairly harsh (20 to 40 days), harsh or very harsh (over 40 days).
The result was a reduction from 65 to 45 kmh for light vehicles, i.e. a loss of 24 seconds per kilometre and for heavy vehicles a reduction from 45 to 30 kmh or 40 seconds per kilometre. Taking the value of time for the user at Frs.11 per hour for light vehicles and Frs.20 for heavy vehicles, the losses per vehicle-kilometre are:

Heavy vehicles: \[
\frac{40}{3600} \times 20 = \text{Frs.0.22}
\]

Light vehicles: \[
\frac{24}{3600} \times 11 = \text{Frs.0.073}
\]

To measure the annual benefit resulting from elimination of these losses, the above amounts have to be multiplied by the number of kilometres covered by heavy and light vehicles respectively on snowy or icy days (0.15 V and 0.85 V, V having been defined above) by the average number of days with snow and ice according to climatic zone.

The overall benefit calculated for the whole of France was Frs.207,900,000.

3.1.2.2.2. Benefit for induced traffic

The fact that 20 per cent more vehicles should be on the road when the snow or ice is eliminated shows that the loss previously caused by the lower speed was too great for some users. It was thus assumed that for these 20 per cent of users the benefit of driving at lower speed was only half that of the other users who drove under all circumstances.

Thus the benefit for this category is 1/8 of the above benefits (they represent 1/4 of the other category and their benefit per user was only half) i.e. 208 x 1/8 = Frs.26 million.

3.1.2.2.3. Cost of accidents due to induced traffic (whole country)

<table>
<thead>
<tr>
<th>Climatic zone</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily traffic volume (J)</td>
<td>72.10^6</td>
<td>29.10^6</td>
<td>41.10^6</td>
<td>28.10^6</td>
</tr>
<tr>
<td>Number of days of snow or ice (n)</td>
<td>3.5</td>
<td>14</td>
<td>28</td>
<td>49</td>
</tr>
<tr>
<td>Traffic concerned (T) V = J x n x 80/100</td>
<td>202.10^6</td>
<td>325.10^6</td>
<td>918.10^6</td>
<td>1098.10^6</td>
</tr>
</tbody>
</table>
Total traffic on days of snow or ice: \(2,543 \times 10^6\) vehicle-km.

Induced traffic: \(2,543 \times \frac{20}{100} = 509 \times 10^6\)

The number of accidents due to induced traffic (applying the rate of 145 accidents per 100 million vehicle-kilometres, the rate observed by SETRA for 1966):

\[509 \times 10^6 \times \frac{145}{100} = 683\]

It had previously been calculated that the cost of 1,440 accidents was Frs.83,215,000. Applying the rule of three, the cost here works out at Frs.39,500,000.

3.1.2.2.3. Calculation of the fuel tax

It was assumed that the 20 per cent of vehicles kept off the road because of ice caused a loss of budget revenue because of the non-consumption of fuel. Taking a fuel consumption of 0.09 litres per kilometre, with Frs.0.72 per litre for light vehicles, and a consumption for heavy vehicles of 0.29 litres per kilometre with a tax of Frs.0.41 per litre, the loss of tax revenue was Frs.29,400,000, hence a corresponding benefit on eliminating these losses.

3.1.2.2.4. Overall assessment of the operation

In addition to the benefits of the operation from the safety standpoint, the other benefits were calculated on the basis of traffic volume on the national road network. It thus remained to take account of traffic on the départemental level or, according to SETRA at the time, 45 per cent of the former. It was also necessary to take into account that non-skid treatment was envisaged only on the most heavily trafficked half of these local networks. It was therefore estimated that the benefits as regards time savings and fuel tax on the département network amounted to 30 per cent of the benefits calculated above.

1. Cost:

\[80,000,000 - 55,000,000 = \text{Frs.25,000,000}\]

(starting hypothesis)

2. Benefits:

- Increased safety: Frs.83,215,000, from which the losses due to induced traffic have to be subtracted,
i.e. 39,500,000 \times 1.3 (to take account of the départe ment networks) = Frs.51,350,000.

Hence a net gain due to increased safety of Frs.31,865,000.

- Time savings: still taking account of the traffic volume on the départe ment networks:

\[
207,900,000 \times 1.3 = Frs.270,270,000
\]

Total benefits: Frs.302,135,000.

3. Budgetary revenue:

Still taking account of traffic volume on the départe ment networks:

\[
29,400,000 \times 1.3 = Frs.38,220,000.
\]

3.1.2.2.5. Budgetary impact

Quite apart from the economic results of this operation discussed above, setting up and organising these measures against snow and ice required a substantial initial investment. SETRA actually estimated this cost at Frs.60 million, comprising Frs.30 million of fixed installations (radio, ice detectors, housing, sheds, salt storage, etc.) and Frs.30 million for vehicles and equipment (automatic salting machines, robot snow plough, rotating snow shifters, etc.) this investment being necessary because the Public Works Department was sadly lacking in equipment and the gap had to be bridged in time for the proposed treatment in 1970.

3.1.3. Road markings

Road marking operations are particularly appreciated by drivers, whose ease of driving is greatly improved, particularly at night.

Road markings have two main functions:

- guidance - indicating road edges and traffic lanes;
- indication of prohibitions or compulsory or authorised movements - solid lines, warning lines and turning arrows, indication of reserved lanes, special lanes and direction arrows, these markings also have a guiding function.

At first sight it might be thought that guiding lines serve ease of driving rather than safety, since they enable
speed to be increased, while indications of prohibitions and authorisations are more directly concerned with safety.

At the time of the PRDA study, however, the Roads and Road Traffic Directorate carried out an experiment involving road markings over the entire RN10 route between Trappes and Tours. The PRDA team defined the conditions necessary for the profitability of this operation from the safety standpoint.

Since accident statistics broken down by area were available, the accidents occurring on this route were known.

Two important problems arose in interpreting the results:
- definition of a reference base;
- significance of the figures obtained.

3.1.3.1. Definition of a reference base

The fact is that each year a certain amount of work is carried out on a major road like the RN10, in particular changes of road width, improvements at intersections and renewal of the surface, all such work obviously having an impact on safety. Knowledge of accidents in previous years is thus not enough to define a reference base. The PRDA team made this problem known to the Roads and Road Traffic Directorate.

3.1.3.2. Profitability of the operation

The average cost of a bodily-harm accident over the section of road concerned was:

Deaths $85 \times 230,000 = \text{Frs.}19,550,000$
Injuries $1625 \times 10,000 = \text{Frs.}16,230,000$
Accidents $618 \times 3,500 = \text{Frs.}2,163,000$

Total $= \text{Frs.}37,943,000$

Taking account of the cost of material damage accidents which amounted to 70 per cent of the cost of bodily harm; accidents average cost per accident is:

$\frac{37,943,000 \times 1.7}{618} = \text{Frs.}104,000$

Considering an expenditure of Frs.1.2 million for an investment with a life of two years over this 200 km, to balance the operation it was necessary to save Frs.0.7 million a year in accident reduction, i.e.:
on approximately 7 accidents a year.

The operation was balanced if the number of accidents fell by 7, i.e. by 1.1 per cent (7/618).

3.1.3.3. Significance of the figures obtained

The law governing accidents is a Poisson distribution which, when the average number of accidents is high, is practically the same as a normal distribution. This being valid for road accidents in general, it also applies to deaths and injuries if a constant level of seriousness is assumed before and after the road is treated.

The average number of accidents recorded outside built-up areas in 1965 and 1966 on the Trappes-Tours road and the corresponding standard deviations are:

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>σ</td>
</tr>
<tr>
<td>Accidents</td>
<td>618</td>
<td>25</td>
</tr>
<tr>
<td>Deaths</td>
<td>85</td>
<td>9.2</td>
</tr>
<tr>
<td>Injuries</td>
<td>1,123</td>
<td>33.3</td>
</tr>
</tbody>
</table>

The law governing accidents being normal for these average values, it is permissible to postulate that there is a 95 per cent chance that the number of accidents observed will lie within the confidence interval \((m + 2\sigma)\), or from another standpoint, if the accident figure recorded after treatment lie outside this confidence interval there is a 95 per cent chance that this reduction is due to the treatment. For this experiment to be significant, then, the fall in the number of accidents recorded after treatment had to be higher than the confidence intervals below:

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Confidence interval</th>
<th>Corresponding effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>618</td>
<td>100</td>
<td>(\frac{100}{618} = 16%)</td>
</tr>
<tr>
<td>Deaths</td>
<td>85</td>
<td>37</td>
<td>(\frac{37}{87} = 42%)</td>
</tr>
<tr>
<td>Injuries</td>
<td>1,123</td>
<td>133</td>
<td>(\frac{133}{1123} = 12%)</td>
</tr>
</tbody>
</table>
This corresponds to an effectiveness of the operation, as defined above, significantly higher than the effectiveness necessary to ensure the profitability of the treatment.

3.1.3.4. Proposal for extending the experiment

3.1.3.4.1. Determination of a "significant threshold"

In view of the very great profitability of such treatment, the important problem was to determine the number of kilometres over which the experiment should be carried out in order to show an effectiveness of 10 per cent (a figure that can be reasonably expected) on the number of road deaths.

Taking a route with homogeneous traffic and physical characteristics, the number of deaths can be considered proportional to the number of kilometres.

On the 196 km studied, there had been 170 deaths in two years. On N x 196 km, there would therefore have been N x 170.

To say that treatment over this latter kilometrage is 10 per cent effective, then with T the number of accidents avoided thanks to the treatment, this means that:

$$\frac{T}{N \times 170} = \frac{10}{100}$$

For the experiment to be significant, a necessary condition would be that the number of deaths T avoided should be greater than the confidence interval of the measurements, i.e. T > $4 \sqrt{170 \times N}$.

These two conditions mean:

$$\frac{4 \sqrt{170 \times N}}{N \times 170} = \frac{10}{100}, \text{ i.e. } N = 9.5$$

Therefore, to demonstrate an effectiveness on the number of deaths of 10 per cent for treatment of a stretch of road similar to the RN10 between Trappes and Tours, the road would have to be 1,900 kilometres long, the observations being made over two years.

3.1.3.4.2. Significance of the forecast results

The PRDA team therefore considered a hypothetical road marking operation over 1,900 km of roads with similar characteristics to the RN10 between Trappes and Tours. The
Overall effectiveness of this operation was estimated at 10 per cent and its cost at Frs.11.5 million.

The results are shown in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Forecast without treatment</th>
<th>Avoided with an effectiveness of 10%</th>
<th>Confidence Interval</th>
<th>Corresponding effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>11,700</td>
<td>1,170</td>
<td>432</td>
<td>3.7%</td>
</tr>
<tr>
<td>Deaths</td>
<td>1,620</td>
<td>162</td>
<td>162</td>
<td>10%</td>
</tr>
<tr>
<td>Injuries</td>
<td>21,400</td>
<td>2,140</td>
<td>584</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

The table shows that if the rate of reduction is not achieved with regard to deaths, it is still possible to demonstrate the effectiveness of the marking from the safety standpoint with the reductions of 3.7 and 2.7 per cent in the number of accidents and injuries respectively.

3.1.4. Safety fences

The analyses made during the PRDA study showed the seriousness of accidents involving collision with fixed obstacles. The study recommended in the first place a consolidation of the studies already carried out on accidents aggravated by the presence of road side obstacles (trees in particular), to be followed by cost-benefit analyses on the measure which was tending to be employed, i.e. the erection of safety fences. Such fences were erected to provide protection against three types of obstacle:

- individual obstacles (in particular bridge piers);
- the central reserves of motorways;
- road-side trees.

3.1.4.1. Safety fencing for individual obstacles

The only study was carried out after the event in the early 70s for the A6 and A7 motorways. It found a profitability of 500 per cent, provided that it was possible to correctly locate the fencing.

3.1.4.2. Safety fencing on the central reserves of motorways

A study was carried out in 1974 by the National Road Safety Organisation (ONSER) at the request of the Ministry for Equipment (SETRA).
The study was intended to test the hypotheses regarding the effect of safety fences along the central reserves of motorways, i.e.:

- the seriousness of accidents is reduced;
- the number of accidents increases as the result of the creation of additional obstacles.

61 km of central reserves, generally 5 m wide, were fenced on the A1 (North), A2 and A6 motorways. The average traffic volume on these sections was about 17,000 vehicle-kilometres per day. The same kilometrage of equivalent sections of unfenced central reserves, matched as regards number of lanes, traffic flow, width of reserve and accident rates was used for control.

The observation period lasted a year, the results on the experimental network being compared with those observed before the erection of safety fences, taking account of trends on the control network.

The main findings of the study are as follows:

- no case of crossing the central reserve was observed on the fenced zones;
- the seriousness of accidents was reduced on these zones (35 per cent less bodily-harm accidents) while the number of material damage accidents recorded by the motorway services increased by a total of 46 per cent, thus very much confirming the hypotheses of the study,

The first calculations indicate an immediate profitability rate of 30 per cent for a period of one year, with a confidence interval of (16 per cent; 43 per cent). The bases used for calculation were: Frs. 320,000 for a death, Frs.14,000 for an injury, Frs.5,600 for the material damage part of a bodily-harm accident and Frs.830 for a purely damage accident (this last cost being determined by the average cost of accidents in 1971 for the Association Générale des Sociétés d'Assurances contre les Accidents).

3.1.4.3. Safety fences to isolate road side trees

3.1.4.3.1. 1974 ONSER study

The Road and Road Traffic Directorate installed safety fences along 200 km of roads bordered by trees over 2.50 m from the road and ONSER was requested by SETRA to assess the effectiveness of this measure.

The sole aim was to test the effectiveness of fencing off the trees and not the effect of other
possible measures. Its conclusions do not therefore exclude the fact that there could be solutions which are even better from the safety standpoint.

The study covered 185 km of road on which the distance from a carriageway to the trees was over 2.50 m. The observation periods after erection of the fencing were relatively short, generally between six and nine months. The difficulty of finding sufficiently long control sections meant that the comparison had to be between accident trends before and after fencing with the general trend observed over the whole of the open country network.

The study showed that fencing off the trees reduced the number of fatal accidents by 46 per cent, serious injury accidents by 17 per cent and slight injury accidents by 44 per cent.

The number of deaths fell by 51 per cent, serious injuries by 26 per cent and slight injuries by 37 per cent. The benefit on the sections observed in terms of the cost of accidents to the community was 47 per cent (of the costs used above in a discussion of central reserve safety fences).

Using the usual Roads Directorate criteria, the operation was profitable within one year, this period having a confidence interval of (8 months to 18 months). The immediate profitability rate was 103 per cent with a confidence interval of (65-140 per cent).

The authors of the study pointed out that this profitability applied only to the sections observed as a whole and that extension of fencing to sections where the distance between the carriageway and the trees was less than 2.50 m could have quite a different profitability.

3.1.4.3.2. Safety costs and benefits of the elimination of road side trees

This more general study also requested from ONSER was to assess the safety impact of road side trees and also if possible to assess the differential effect due to the position of the trees with respect to the carriageway, this being characterised by two parameters - distance from carriageway to tree and distance between trees.

Samples of treelined and treeless sections with a total length of 888 and 912 km respectively, distributed over 21 departments, were finally constructed.

On these samples, the frequency and seriousness of accidents was significantly higher on the treelined than
on the treeless sections for the two observation periods.

In addition, this differentiation of the frequency and seriousness of accidents was found not only spatially between treelined and treeless sections also temporally between the two periods. The fact is that the expected benefit of turning a treelined road into a treeless one, taking the accident rate as indicator, increased from 15 per cent for the first period to 28 per cent for the second.

Safety measures such as seat belts and speed limits had less effect on treelined than on treeless sections. This could be due to the fact that even before these measures were introduced the effect of having a wall of trees along the road already led to more careful driving and the effectiveness of a seat belt is in any case limited in the case of collision with a tree.

FREQUENCY AND SERIOUSNESS OF ACCIDENTS - FIRST PERIOD
(rates per 10^8 vehicle-kilometre)

<table>
<thead>
<tr>
<th></th>
<th>Accident rate</th>
<th>Death rate</th>
<th>Injury rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treelined roads ( \tau_p )</td>
<td>38.8</td>
<td>9.0</td>
<td>67.6</td>
</tr>
<tr>
<td>Treeless roads ( \tau_{NP} )</td>
<td>31.9</td>
<td>6.3</td>
<td>57.7</td>
</tr>
<tr>
<td>Relative difference ( (\tau_p - \tau_{NP})/\tau_p )</td>
<td>+ 18%</td>
<td>+ 32%</td>
<td>+ 15%</td>
</tr>
</tbody>
</table>

FREQUENCY AND SERIOUSNESS OF ACCIDENTS - SECOND PERIOD
(rates per 10^8 vehicle-kilometre)

<table>
<thead>
<tr>
<th></th>
<th>Accident rate</th>
<th>Death rate</th>
<th>Injury rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treelined roads ( \tau_p )</td>
<td>32.1</td>
<td>8.1</td>
<td>55.5</td>
</tr>
<tr>
<td>Treeless roads ( \tau_{NP} )</td>
<td>23.2</td>
<td>4.6</td>
<td>41.5</td>
</tr>
<tr>
<td>Relative difference ( (\tau_p - \tau_{NP})/\tau_p )</td>
<td>+ 28%</td>
<td>+ 45%</td>
<td>+ 25%</td>
</tr>
</tbody>
</table>

Between the two periods accident rates had fallen more on the treeless roads, which resulted in a relative increase in accident risk on treelined roads after implementation of the safety measures mentioned. In the second period the relative risk of accident had increased by 1.4 on treelined roads and the risk of death by 1.76 (1.2 and 1.4 respectively in the first period).
It can be seen that accident rates on treeless roads in the first period and treelined roads in the second period are very close, so that the effects of the factors concerned (trees and speed limits) are of the same order of magnitude in terms of primary safety.

The safety benefit in money terms(7) of eliminating the trees from a treelined road is in the order of Frs.33,000 per kilometre per year, for an average daily traffic volume of 5,600 vehicles.

After breaking down the sample of treelined roads into six classes according to the distance between carriageway and the trees, the study was able to demonstrate a significant influence of this distance on the frequency and seriousness of accidents, both of which increase as distance decreases. This effect became even more marked after the introduction of new safety measures—speed limits and seat belts.

The study led to the conclusion that only roads where the distance between the carriageway and trees was less than or equal to 2 metres had a significantly greater number of accidents and more serious accidents. The hypothesis according to which the presence of trees at a distance greater than 2 metres from the carriageway had no effect on the frequency of accidents was consistent with the results, i.e. it can be accepted for the moment, but other experiments will be necessary to confirm it and to assess the effect on secondary safety. The regular forms of the curves showing the fall in the accident rate as a function of carriageway-tree distance nevertheless gave ground to think that if the samples of stretches of road with trees at a distance of greater than 2 metres were big enough, the above conclusions could be extended to them.

As for the distance between trees, the study showed that this variable had no significant influence on the frequency of accidents.

3.1.5. Infrastructure improvements in urban areas

In built-up areas of a certain size, two types of measure can increase road safety:

- ad hoc improvements (e.g. at dangerous intersections). The principle of analysis is the same as for accident blackspots outside built-up areas, so will not be discussed further here.

7. Cf. the costs given above.
- co-ordinated projects involving traffic engineering plans which are subsidised by the central government. These are aimed at improving both traffic flow and safety in town centres.

As part of the preparatory work for the VIIth Plan (1974-1975), a balance sheet of the first cost-benefit studies was drawn up. The findings are summarised in the table on the following page.

Details of the results for Rouen are given below.

Cost-benefit study of the Rouen traffic engineering project

This project was implemented in April 1967. The accident statistics given below cover only two North-South routes which were made one-way (from Place St. Sever to Place Beauvoisine) crossing the Corneille and Boildieu bridges:

<table>
<thead>
<tr>
<th>Statistics from April 65 to April 67</th>
<th>Statistics from April 67 to April 69</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>Deaths</td>
</tr>
<tr>
<td>316</td>
<td>4</td>
</tr>
</tbody>
</table>

126 injuries/100 accidents 115 injuries/100 accidents

The recorded traffic increased by 18 per cent in two years.

The benefits were as follows:

- reduction in accidents
  \[
  \frac{316 \times 1.18 - 263}{4,000} = 439,520
  \]

- reduction in deaths
  \[
  \frac{4 \times 1.18 - 2}{230,000} = 625,600
  \]

- reduction in injuries
  \[
  \frac{397 \times 1.18 - 302}{10,000} = \frac{1,664,600}{2,729,720}
  \]

The estimated planning, investment and operating cost was Frs.1,150,000.

Immediate profitability from the safety standpoint was:

\[
\frac{2,729,720}{1,150,000} = 237\%
\]
### Effectiveness of Traffic Engineering Projects

<table>
<thead>
<tr>
<th>Town</th>
<th>Date of implementation of the project</th>
<th>Effectiveness from the safety standpoint</th>
<th>Observation period</th>
<th>Apparent profitability from the safety standpoint</th>
<th>Apparent profitability from the traffic flow standpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rouen</td>
<td>April 1967</td>
<td>Reduction in the number of accidents: 16.8%</td>
<td>2 years before/2 years after</td>
<td>240%</td>
<td>260%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduction in the seriousness of accidents (deaths per 100 accidents): 8.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belfort</td>
<td>November 1972</td>
<td>Reduction in the number of accidents: 50%</td>
<td>1 year before/9 months after</td>
<td>40%</td>
<td>not estimated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduction in the seriousness of accidents (deaths per 100 accidents): 6.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cherbourg</td>
<td>June 1972</td>
<td>Reduction in the number of accidents: 14.3%</td>
<td>1 year before/6 months after</td>
<td>80%</td>
<td>not estimated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduction in the seriousness of accidents (deaths per 100 accidents): -9.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From the traffic flow standpoint, estimated time saved was 300,000 hours a year for the peak hours alone and a further 300,000 hours a year for off-peak hours.

The hourly cost of lost time was taken at Frs. 5 at that time, giving a profitability from the traffic flow standpoint of:

\[
\frac{3,000,000}{1,150,000} = 261\%
\]

3.1.6. Other infrastructure improvements

Many other studies have been concerned with infrastructural road safety measures, but they are generally concerned only with the effectiveness of the measures or are very fragmentary and poorly documented as regards statistics. They are thus not true cost-benefit studies. It is also easy to list a number of subjects which have been more or less neglected: road signs, where there has been much innovation and rationalisation, but few economic studies (priority roads in the open country or built-up areas, direction signs, warning and prohibition signs, etc.) a particular type of marking, delineators, motorway or road lighting, grooving of motorway pavements to prevent aquaplaning, impact absorbing devices, pull-ins, etc.

3.2. VEHICLE

3.2.1. General

The annex to the PRDA study has a section on the vehicle and road safety which lists the factors to be taken into account in road safety cost-benefit studies. It deals with four categories of effects:

3.2.1.1. Monetary effects

3.2.1.1.1. Budgetary:

Increased budgetary expenditure on bodies responsible for information, control and enforcement.

3.2.1.1.2. For users

Algebraic increase in total user expenditure on the purchase, maintenance and running of vehicles:
- increase in the total user expenditure on public transport;
- decrease in total user expenditure on the repair and accident-damaged vehicles and medical care for road victims.

3.2.1.1.3. For other agents

- algebraic increase in production due to an increase in the manufacture, maintenance and use of vehicles;
- increase in production due to the increased activity of public transport. This is not equal to the increase of user expenditure on public transport mentioned above unless the public transport multiplier is equal to one and this mode of transport is not state subsidised;
- decrease in production due to reduction in accident damage repairs and the number of people requiring medical treatment.

3.2.1.2. Bodily effects

The death, invalidity or incapacity of productive individuals (actual or potential) is harmful to the economy.

3.2.1.3. Effects on the service quality of the road system

Only time losses for users are taken into account.

3.2.1.4. Psychological and social effects

The four factors taken into account are:
- reduction in pain and suffering due to bereavement;
- reduction in physical suffering;
- restrictions on individual freedom;
- restrictions on the use of private vehicles.

On the basis of these data, the authors of the study develop a method inspired by road investment profitability calculations. The various independent effects of any measure M are considered as satisfactions of the State. These satisfactions, expressed in money units, may be positive or negative. Effects appearing at different dates are compared by applying a discounting rate. It is thus possible to sum the costs and benefits and judge a measure according to its discounted value of future returns.
Not all the data necessary for these calculations was available, however. In a first stage, tables were drawn up for about 20 possible operations, the spaces corresponding to the different costs and benefits being filled in as far as the available information allowed. This enabled an initial judgement, showing in particular the operations where evaluation studies appeared particularly urgent.

In addition, in order to get an idea of the order of magnitude of admissible increases in vehicle prices, the authors calculated the average cost per private vehicle of the discounted cost to the community of accidents where at least one private vehicle was involved. Details of this calculation are as follows:

Number of bodily-harm accidents involving a private vehicle (1966)

1 vehicle accidents: 46,994
2 vehicles (or agents): 108,265
Total: 155,000

Number of deaths (1966) in accidents involving a private vehicle:

1 vehicle accidents: 2,460
2 vehicles (or agents): 6,288
Total: 8,750

Number of injuries (1966) in accidents involving a private vehicle:

1 vehicle accidents: 34,640
2 vehicles (or agents): 180,688
Total: 215,000

The costs used by the Ministry for Equipment in 1966 were:

death = Frs.230,000
injury = Frs. 10,000
material damage in a bodily-harm accident = Frs. 3,500

Giving a total cost for bodily-harm accidents involving private vehicles of:

\[230,000 \times 8,750 + 10,000 \times 215,000 + 3,500 \times 155,000 = 4,700 \text{ millions}\]

The cost per vehicle, knowing that the total number of cars as at 30th June, 1966 was 11.3 million:

\[4,700/11.3 = \text{Frs.415.}\]
This gives the mathematical expectation of the annual cost per car of accidents involving less than three vehicles, supposing that the probability of accidents is the same for all and that it remains constant during the life of the vehicle, average 10 years) which as a first approximation seemed to emerge from an ONSER study on bodily-harm accidents in 1961.

The mathematical expectation of the discounted cost (discounting rate 10 per cent) is \( 415 \times 6.14 = \text{Fr}\.2,550 \).

To take into account the 11,000 accidents involving 3 or more vehicles where the nature of the vehicles is not known, but where it could be assumed that the majority involve at least one car, the authors increased the result by the arbitrary figure of 5 per cent, giving a cost of \( \text{Fr}\.2,700 \).

In 1966, then, the maximum sum to invest per vehicle to avoid accidents and their consequences was \( \text{Fr}\.2,700 \).

3.2.2. The main studies carried out in this field

3.2.2.1. General - technical inspection

France being one of the very few industrialised countries where there is no technical inspection of light vehicles, the national road safety organisation (ONSER) was given the task in 1970 of carrying out a cost-benefit analysis of this problem. This was the 1970-1971 "Véhitest" study.

In order to compare the expected annual benefits and the cost to the community of technical inspection, this study considered 40 possible combinations: 4 levels of thoroughness; 5 possible lower age limits for the vehicles subject to inspection; the number of registrations of the vehicles subject to inspection (2 possibilities were considered: vehicles having changed the registration certificate at least once and all vehicles).

Estimating annual benefits on the basis of the type of link between technical faults and accidents involved a certain number of assumptions. The calculations were made for four cases, according to the impact of technical inspection on the mechanical state of the vehicle (3 assumptions) and the reduction in seriousness of accidents (2 assumptions).

Annual inspections only were envisaged. The influence of an inspection on the state of maintenance of a vehicle one year later is in fact very slight. A system involving inspection once every n years would cost
n times less but mean n times less benefit. The cost-benefit ratio would therefore remain unchanged.

3.2.2.1.1. Cost components

3.2.2.1.1.1. Unit cost

In addition to the actual price of the inspection, this cost includes the value of the time lost for the user, estimated at Frs. 12 per hour, and the cost of the journey, estimated at Frs. 0.30 per hour.

The final result was:

- **1st level of inspection**: cost to the community - Frs. 10
- **2nd level of inspection**: cost to the community for 5 million inspections a year - Frs. 25
- **3rd level of inspection**: cost to the community for 5 million inspections a year - Frs. 38
- **4th level of inspection**: cost to the community - Frs. 50

3.2.2.1.1.2. Number of inspections as a function of vehicle age

The proportion of reinspections necessary is estimated at 25 per cent. The following table shows the number of inspections (in millions) on the basis of the estimated number of vehicles for 1971.

<table>
<thead>
<tr>
<th>Vehicles aged over</th>
<th>All vehicles</th>
<th>Vehicles having changed registration at least once</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year</td>
<td>19.7</td>
<td>10</td>
</tr>
<tr>
<td>3 years</td>
<td>14.7</td>
<td>9.4</td>
</tr>
<tr>
<td>5 years</td>
<td>9.8</td>
<td>7</td>
</tr>
<tr>
<td>8 years</td>
<td>5.6</td>
<td>4.4</td>
</tr>
<tr>
<td>10 years</td>
<td>3.9</td>
<td>3.1</td>
</tr>
</tbody>
</table>

The estimate by age category of the number of vehicles having changed registration at least once was made on the basis of the results of a survey covering about 2,000 vehicles carried out by ONSER in 1968.
3.2.2.1.2. Effectiveness

3.2.2.1.2.1. Estimation of co-efficients for determining effectiveness

(a) Technical inspection of vehicles would bring about a reduction in the seriousness of certain accidents, but whenever a mechanical defect is identified as an aggravating factor it is difficult to estimate what this reduction would have been without the defect. The study of accident records led to the following assumptions being made:

- for the reduction in the number of deaths:
  . low assumption: a reduction of 50 per cent in the number of deaths for those accidents whose seriousness would be reduced by the elimination of mechanical faults;
  . high assumption: 70 per cent;

- for the reduction in the number of injured:
  . low assumption: 40 per cent
  . high assumption: 60 per cent.

(b) technical inspection would not ensure that vehicles remained in a perfect mechanical state throughout the period between two inspections, as the frequency of inspection and the number of kilometres covered need to be taken into account. Since foreign experience provided little information, ONSER made three assumptions regarding the influence of an annual inspection on the mechanical state of the vehicle, i.e.

. low assumption: the number of defects existing at any one time in inspected vehicles is 70 per cent of the number which would exist without inspection;
. medium assumption: this proportion is 50 per cent;
. high assumption: this proportion is 30 per cent.

3.2.2.1.2.2. Annual savings in accidents, deaths and injuries

These calculations are made on the basis of the following formulae:

- annual saving on accidents: KA
- annual saving on deaths: K(B + k1b)
- annual saving on injuries: K(C +k2c)
where:

A = number of accidents avoided;
B = number of deaths in the accidents avoided;
C = number of injuries in the accidents avoided;
b = number of deaths in accidents whose seriousness is reduced;
c = number of injuries in accidents whose seriousness is reduced;
K = co-efficient of influence of technical inspection on the mechanical state of vehicles (0.3, 0.5 or 0.7 according to the assumption made);
k_1 = co-efficient of reduction of seriousness of accidents for deaths;
k_2 = co-efficient of reduction of seriousness of accidents for injuries.

3.2.2.1.3. Annual benefit-cost ratio

The numbers of victims "saved" were given the values used by the Ministry for Equipment in 1970(8) and the benefit-cost ratios were obtained. An example is given in the following table (for the 3rd level of inspection, which gives the highest ratios, and the optimistic assumption for the impact of technical inspection on the mechanical state of vehicles, i.e. K = 0.7, the only one which gives advantage-cost ratios greater than unity).

It can be seen that:

- inspections of vehicles having changed registration at least once give consistently higher benefit-cost ratios than the figures for all vehicles;
- cost benefit ratios increase with the lower age limit of vehicles subject to inspection (the exception for vehicles over ten years old is not significant).

3.2.2.2. Safety fittings and components

The following sections present a cost-benefit study of the seat belt, the effect on costs and benefits of measures to increase seat belt use and lastly an assessment of head rests. There is no discussion of helmets, for which there have been mainly effectiveness studies without the cost standpoint being considered.

8. Death - Frs.230,000; injury - Frs.10,000;
material damage in bodily harm accident - Frs.4,000.
<table>
<thead>
<tr>
<th>Lower age limit for vehicles subject to inspection</th>
<th>All vehicles</th>
<th>Vehicles having changed registration at least once</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low assumption of reduction in seriousness</td>
<td>High assumption of reduction in seriousness</td>
</tr>
<tr>
<td>3 years</td>
<td>0.54</td>
<td>0.70</td>
</tr>
<tr>
<td>5 years</td>
<td>0.75</td>
<td>0.97</td>
</tr>
<tr>
<td>8 years</td>
<td>0.90</td>
<td>1.16</td>
</tr>
<tr>
<td>10 years</td>
<td>0.88</td>
<td>1.11</td>
</tr>
</tbody>
</table>
There is, however, the interesting but as yet little-studied question of the impact of compulsory wearing of helmets on the sales of light motorcycles.

3.2.2.2.1. The seat belt

This being considered a relatively cheap fitting, the studies are mainly concerned with the effectiveness of different sorts of belts or their effectiveness for different categories of vehicle occupant (front seat, back seat, children, etc.) or different types of vehicle (front wheel drive, rear engine etc.) rather than being economic cost-benefit studies.

As part of the PRDA pilot study, however, a safety cost-benefit study was carried to determine from what rate of seat belt wearing it was profitable to fit all cars with seat belts.

The methodology of this study is as follows:

1. Estimation of the number of front seat passenger victims in 1966

ACCIDENTS IN 1966:

Number of car drivers killed : 2,853
Number of car drivers injured : 68,413
Number of car passengers killed : 2,685
Number of car passengers injured : 80,472

SAMPLES USED IN THE 1960 ONSER SURVEY:

Drivers killed : 46
Front seat passengers killed : 34
Back seat passengers killed : 16
Drivers injured : 248
Front seat passengers injured : 210
Back seat passengers injured : 177

ESTIMATE IN 1966 OF:

Number of front seat passengers killed:

\[
0.5 \left( \frac{34 \times 2853 + 34 \times 2685}{46} \right) = 0.5 \left( \frac{2110 + 1830}{50} \right) = 1970
\]

Number of front seat passengers injured:

\[
0.5 \left( \frac{210 \times 68413 + 210 \times 80472}{248} \right) = 0.5 \left( \frac{58000 + 44000}{387} \right) = 51000
\]
This estimate is somewhat biased by the fact that the ONSER sample was concerned with accidents which were more serious than the average.

2. Annual cost per vehicle of bodily-harm accidents involving private cars

Number of cars on the road as at 1st June, 1966:
- 11,300,000

Number of front seat deaths per vehicle on the road:
- \( \frac{2853 + 1970}{11,300,000} = 4.3 \times 10^{-4} \)

Number of front seat injuries per car on the road:
- \( \frac{68,413 + 51,000}{11,300,000} = 1.05 \times 10^{-2} \)

Average annual cost per vehicle of front seat victims:
\[
230,000 \times 4.3 \times 10^{-4} + 10,000 \times 1.05 \times 10^{-2} = \text{Fr. 203}
\]

This assumes that the probability of death or injury for a front seat occupant is the same for all vehicles.

3. Cost of death or injury per vehicle capitalised over ten years and comparative cost of seat belts

Assuming constancy over the whole ten years of average vehicle life, the expected capitalised cost of death or injury to front seat occupants at a discounting rate of 10 per cent is:
\[
203 \times 6.14 = \text{Fr. 1,250}
\]

The estimated additional price per car for fitting front seat belts as standard: Frs.50 (excluding taxes).

Estimated discounted cost of changing the straps after five years: Frs.20.

Assuming that the belts are always worn and that

9. At that time the Ministry for Equipment assessed the cost of a road death at Frs.230,000 and an injury at Frs.10,000
wearing them reduces the probability of bodily harm by half, the benefit/cost ratio is:

\[
\frac{625}{70} = 9
\]

In order for the discounted benefit to equal the cost, the level of actual use must be 11 per cent.

3.2.2.2.2. Safety costs and benefits of measures to increase the wearing of seat belts

Details of the calculation are as follows (ONSER Study):

Starting from the basic fact that wearing a seat belt reduces the bodily harm suffered during an accident, this means that in particular a certain number of people killed not wearing seat belts could have been saved (i.e. would have been only injured or even come out unscathed) if they had been wearing a belt.

The fact is that despite the wearing of seat belts being compulsory for front seat occupants outside towns, the actual rate of belt wearing is far from 100 per cent. It thus appeared reasonable to expect to be able to save a significant number of human lives by significantly increasing the rate of seat belt wearing. In addition to tightening the regulations it is possible to install devices to encourage or even force the driver or front seat passenger to attach his seat belt. We give below a method for calculating the costs and benefits resulting from the initial expenditure of fitting such a device to vehicles (either gradually or across the board) and the saving in human lives to be expected. The outcome obviously depends on the type of device fitted, both as regards its cost on the one hand and its effect on actual levels of seat belt wearing on the other.

The calculations necessitated a certain number of initial simplifying assumptions.

The symbols used are as follows:

\[
N = \text{total number of cars}
\]

\[
P = \text{unit cost of a device fitted to a car}
\]

\[
n = \text{number of drivers and front seat passengers involved in accidents outside built-up areas in a year}
\]

\[
x = \text{rate of seat belt wearing outside built-up areas, defined as the ratio:}
\]
number of belted front seat occupants in accidents
\[ t = \frac{\text{total number of front seat occupants in accidents}}{\text{number of unbelted front seat victims}} \]

ASSUMPTION 1: the rate of involvement of occupants (i.e. the number of accidents with respect to the number of km covered) is the same for "belted" and "unbelted" populations. In practice this means that the drivers or passenger's decision to fasten his belt has no effect on his probability of being involved in an accident.

ASSUMPTION 2: the difference observed between seriousness rates for the belted and unbelted populations depends entirely on wearing a belt or not. The coefficient k could be considered the "belted" factor.

Let us now assess the consequences of installing a device on N cars, supposing that this operation increases the level of seat belt wearing by \( \Delta x \).

<table>
<thead>
<tr>
<th>Base line situation year 0</th>
<th>Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of wearing x</td>
<td>x + ( \Delta x )</td>
</tr>
<tr>
<td>Number involved in accidents n</td>
<td>n</td>
</tr>
<tr>
<td>Number involved belted x n</td>
<td>(x + ( \Delta x )) n</td>
</tr>
<tr>
<td>Number involved unbelted (1 - x) n</td>
<td>(1 - x - ( \Delta x )) n</td>
</tr>
<tr>
<td>Number of deaths unbelted t (1 - x) n</td>
<td>t (1 - x - ( \Delta x )) n</td>
</tr>
<tr>
<td>Number of deaths belted kt x n</td>
<td>kt (x + ( \Delta x )) n</td>
</tr>
<tr>
<td>Number of deaths tn (kx + 1 - x)</td>
<td>tn (kx + 1 - x - (1-k) ( \Delta x ))</td>
</tr>
</tbody>
</table>

There is thus a saving in deaths of:

\[ tn (kx + 1 - x) - tn (kx + 1 - x - (1-k) \Delta x) = tn (1 - k) \Delta x \]
who move into the category of injured or simply of people involved in accidents.

Taking $P$ as the cost of a death (neglecting the cost of injury), the benefit over one year is:

$$G = t_n (1 - k) A x P$$

to be compared with an initial expenditure in year 0 of $D = Np$ (the cost of fitting the device to all cars).

The ratio $r = \frac{G}{D} \frac{t_n (1 - k) A x P}{Np}$
is the immediate profitability rate.

If the device works on average over a period of five years with a discounting rate of 10 per cent the total capitalised return will be:

$$G^* = 3.8 G$$

The criterion of "intrinsic profitability" of the initial investment $D$ will be:

$$\frac{G}{D} > 1 \quad \text{or} \quad \frac{r}{3.8} > 0.26$$

Let us make a numerical calculation to determine the orders of magnitude.

Taking: $N = 14$ million cars fitted with seat belts

$P = \text{cost of a death} = \text{Frs.}380,000 \ (1974)$

In addition (1976 statistics) (11).

$n \approx 127 \times 10^3$ front seat occupants involved in accidents outside towns, of which:

- 100,500 belted, i.e. $x \approx 79$ per cent
- 2,325 belted deaths i.e. $kt = 2,325 \approx 2.3$ per cent

10. According to the road traffic safety directorate scale in 1974: death - Frs.380,000; injury - Frs.17,000

- 26,150 unbelted occupants involved in accidents
- 1,590 unbelted deaths, i.e. \( t = \frac{1,590}{26,150} \approx 6.1 \) per cent

hence \( k \approx 0.38 \)

and consequently \( r = \frac{0.061 \times 127 \times 10^3 \times (1 - 0.38) \times \Delta x \times 380 \times 10^3}{14 \times 10^6 \times p} \)

The profitability condition becomes:

\[ \frac{\Delta x}{p} \geq 0.26 \approx 0.2 \times 10^{-2} \]

The following correspondence table can now be drawn up to determine, as a function of a given price of the device the minimal level of seat belt wearing to be expected.

<table>
<thead>
<tr>
<th>Cost of device in 1974 Francs</th>
<th>( \Delta x \geq )</th>
<th>( x + \Delta x )</th>
<th>Annual savings in deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2%</td>
<td>79.2%</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>1%</td>
<td>80%</td>
<td>47</td>
</tr>
<tr>
<td>10</td>
<td>2%</td>
<td>81%</td>
<td>95</td>
</tr>
<tr>
<td>50</td>
<td>10%</td>
<td>89%</td>
<td>475</td>
</tr>
<tr>
<td>100</td>
<td>20%</td>
<td>99%</td>
<td>950</td>
</tr>
</tbody>
</table>

CONCLUSIONS

This preliminary calculation gives some idea of the cost-benefit balance which seems, on the face of it, to be very unfavourable as regards the possible fitting of a seat belt fastening indicator to cars. It can be seen, for example, that a device of the indicator lamp type which would cost about Frs.10 would need, to be profitable, to increase the level of seat belt wearing by 2 per cent. Such an increase is in practice difficult to detect as a significant change. In any event, it can be seen that the cost of such a device must not be higher than about Frs.100 (1974 prices) or about Frs.130-140 at 1978 prices, and it seems difficult to be able to produce a device of this price which would increase actual seat belt wearing by over 10 per cent.

3.2.2.2.3. Head rests

In 1975, ONSER carried out a rapid safety cost-benefit analysis of head rests. This is summarised below.
3.2.2.2.3.1. The problem

Fitting head rests to car front seats as standard throughout Europe was envisaged. To judge the value of this measure from the safety standpoint ONSER carried out a rapid cost-benefit evaluation.

A study by the United Kingdom Delegation to the European Conference of Ministers of Transport provided the basic assumptions for these calculations. The United Kingdom Delegation in fact came to the conclusion that this measure was not very profitable if it was envisaged to retrofit all cars. In its summary note, ONSER studied the case of making the backs of front seats higher at the manufacturing stage, an improvement of much lower cost.

3.2.2.2.3.2. Assumptions for the study

(a) Assumptions regarding the frequency of cervical injury to front seat occupants caused by rear-end collision

1. Assumptions taken from the United Kingdom study
   - 25 per cent of the deaths;
   - 50 per cent of the injuries.

2. Minimum assumptions (based on comments by the ONSER crash laboratory
   - 0 per cent of the deaths;
   - 25 per cent of the injuries.

(b) Effectiveness of headrests
The two United Kingdom assumptions were retained:
   - pessimistic assumption: reduction of 55 per cent in victims;
   - optimistic assumption: reduction of 100 per cent in victims

(c) Assumed additional cost of seats with higher backs
   - Frs.10 per seat, i.e. Frs.20 per vehicle

(d) Assumed number of cars to be fitted and the implications of this in bodily-harm accidents
ONSER assumed 1.2 million new cars a year to be fitted, these new vehicles being involved in 10 per cent
of the bodily-harm accidents and thus representing 10 per cent of the victims (10 per cent of deaths and 10 per cent of injuries).

(e) Cost of victims (using the costs used by DSCR since 1974)
- death = Frs. 0.38 million;
- injury = Frs. 0.0165 million.

3.2.2.2.3.3. Data from SETRA records - bodily-harm road accidents in 1973

(a) Cars suffering rear end collisions accounted for:
- as regards the number of vehicles involved in accidents: 41,717 or 14.2 per cent of the total (72.5 per cent frontal collision and 13.3 lateral or other);
- as regards death: 367 or 4.6 per cent of the total;
- as regards serious injuries: 2,892;
- as regards all injuries: 20,370
- as regards occupants involved: 61,953

The seriousness of rear-end collisions (ratio of victims to number involved) is the lowest:
- deaths: 0.59 per cent (as compared with 1.74 per cent for frontal collisions and 2.63 per cent for lateral and other);
- serious injuries: 4.7 per cent (as compared with 11.29 per cent for frontal and 12.29 per cent for lateral and other collisions).

(b) Victims among front seat occupants in rear-end collisions
- deaths: 256 (plus 111 in the rear seat);
- injuries: 16,422 (plus 3,948 in the rear seats).

3.2.2.2.3.4. Results

(a) Annual cost of fitting new cars
- 1.2 million cars;
- Frs. 10 per seat or 20 per car;
- hence a total cost of Frs. 24 million.

(b) Effects of the measure
1. **Cervical injury victims**

United Kingdom assumptions:
- deaths: 25 per cent of 256 = 64;
- injuries: 50 per cent of 16,422 = 8,211

**Minimum assumption**
- injuries: 25 per cent of 16,422 = 4,105

2. **Victims occupying fitted vehicles** (current year's cars)

Assumed to be 10 per cent of the total, i.e.:

**First case** (United Kingdom assumptions):
- deaths: 10 per cent of 64 or approximately 6
- injuries: 10 per cent of 8,211, or approximately 820.

**Second case** (Optimistic assumption):
- injuries: 10 per cent of 4,105 or approximately 410.

(c) **Effectiveness**

1. **With the low assumption of 55 per cent**

First case:

\[ 6 \times 0.55 \times 0.38 + 820 \times 0.55 \times 0.0165 = \text{approximately Frs.} 8.7 \text{ million, with a total of 6 deaths and 820 injuries.} \]

0.55: effectiveness rate
0.38 and 0.0165: cost in millions of francs of one death and one injury respectively.

Second case:

\[ 410 \times 0.55 \times 0.0165 = 3.72 \]

2. **With the optimistic hypothesis of 100 per cent**

First case:

\[ 6 \times 0.38 + 820 \times 0.0165 = 15.8 \]
Second case:
410 \times 0.0165 = 6.76

(d) Immediate profitability

1. With the pessimistic assumption

First case:
8.7/24 = 36 per cent

Second case:
3.72/24 = 15.5 per cent

2. With the optimistic assumption

First case:
15.8/24 = 66 per cent

Second case:
6.76/24 = 28 per cent

(e) Cumulated profitability over 5 years
(pessimistic assumption)

Assuming a discounting rate of 10 per cent and a reduction of 5 per cent a year in the number of victims (new cars in year "n" representing a diminishing proportion of the total number of cars as time goes on):

First case:
the present value (1975) of the annual benefit of Frs. 8.7 million cumulated over 5 years with an annual depreciation rate of 15 per cent (10 per cent + 5 per cent) is Frs. 32.3 million, i.e. 35 per cent higher than the cost of fitting (Frs. 24 million).

Second case:
Similarly, the present value of the annual benefit of Frs. 3.72 million cumulated over 5 years is Frs. 13.8 million, or 57.5 per cent of the cost of fitting (Frs. 24 million).
## Summary Table

### Comparing the Effectiveness of Headrests Using United Kingdom and French Data

<table>
<thead>
<tr>
<th>Item</th>
<th>United Kingdom</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency of rear-end accidents:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- occupants involved</td>
<td>11.2%</td>
<td>13.4%</td>
</tr>
<tr>
<td>- deaths</td>
<td>5.5%</td>
<td>4.6%</td>
</tr>
<tr>
<td>- serious injuries</td>
<td>7.2%</td>
<td>5.9%</td>
</tr>
<tr>
<td>- slight injuries</td>
<td>12.8%</td>
<td>12.0%</td>
</tr>
<tr>
<td><strong>Frequency of cervical injury among front seat occupants in rear-end collisions:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- deaths</td>
<td>25%</td>
<td>50% + 95.5%(*)</td>
</tr>
<tr>
<td>- injuries</td>
<td>50% + 95.5%(*)</td>
<td></td>
</tr>
<tr>
<td><strong>Effectiveness of the headrest:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- assumption 1</td>
<td>55%</td>
<td>55%</td>
</tr>
<tr>
<td>- assumption 2</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td><strong>Cost of victims:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- deaths</td>
<td>£22,000</td>
<td>380,000F</td>
</tr>
<tr>
<td>- injuries</td>
<td>£245 and £35(*)</td>
<td>16,500F</td>
</tr>
<tr>
<td><strong>Nature and cost of fitting per car</strong></td>
<td>£8.5</td>
<td>20F (extended backseat)</td>
</tr>
<tr>
<td><strong>Immediate profitability</strong></td>
<td>a) 1.6%</td>
<td>15.5%</td>
</tr>
<tr>
<td>(fitting cars produced in the current year)</td>
<td>b) 3.0%</td>
<td></td>
</tr>
<tr>
<td><strong>Profitability of investment in year &quot;n&quot;</strong></td>
<td>a) 6.0%</td>
<td>57.5%</td>
</tr>
<tr>
<td>cumulated over 5 years</td>
<td>b) 11.0%</td>
<td></td>
</tr>
</tbody>
</table>

* Number of injuries in accidents considered mainly as material damage accidents.
COMMENTS ON THE TABLE: Explanation of the divergences between the United Kingdom and French cases.

1. The United Kingdom study is based on:

135 deaths and 15,889 injuries among front seat occupants in rear-end collisions, while in France there were 256 deaths and 16,422 injuries.

2. However,

in the ONSER optimistic assumption there are no deaths due to cervical injury while the United Kingdom study assumes 3 (10 per cent of 34).

ONSER assumes 410 injuries while the United Kingdom study assumes 795, to which must be added almost 1,600 very slight injuries in accidents considered mainly as material damage accidents.

Assessing all these United Kingdom victims at the average injury cost:

795 + 225 (equivalent of the very slight injuries) + 300 (equivalent of the deaths) - 1,320 injuries, i.e. 3.2 times the French figure.

3. But,

cost of average injury in the United Kingdom: £245
in France: Frs.16,500

Thus a cost 6.5 times as high in France.

4. In addition,

the cost of fitting in the United Kingdom is £8.5 as compared with Frs.20, i.e. 4.4 times the French cost.

5. Finally,

United Kingdom profitability =
French profitability

\[
\frac{3.2}{6.5 \times 4.4} = \frac{1.6}{15.5} = 11 \text{ per cent}
\]

3.2.2.2.3.6. Conclusions

While the United Kingdom study tended to unconditionally reject seat belts, the French study based on a low-cost built-in headrest showed that the profitability should be better than that obtained in the United Kingdom study.
This comparison shows the importance of the basic assumptions, which are unfortunately often far too shaky.

3.2.2.3. Vehicle components

This section discusses two studies carried out by the National Road Safety Organisation (ONSER): anti-blocking devices for brakes and laminated windscreens.

3.2.2.3.1. Anti-blocking devices for brakes (ONSER 1973)

A non-locking braking system presents numerous advantages:

- it eliminates uneven braking and in particular veering;
- it gives a better distribution of braking and makes it optimal with respect to the distribution of the load;
- it eliminates braking defects;
- it makes it possible to brake without particular danger in certain driving situations such as on bends or in wet, snowy or icy conditions;
- in particular it maintains steerability stability during braking without significantly increasing braking distance (possible improvements in braking distances are not taken into account).

1. METHODOLOGY

The initial stage is to find cases where an accident would more or less probably have been avoided had such a device been fitted. The different cases in which the wheels of the vehicle locked were selected. The researchers tried to assess whether evasive action made possible by using a non-locking braking system would have been likely to succeed or whether the cause of the accident was due to pulling to one side or loss of control through braking too violently. The subjective probability coefficient for eliminating each accident was determined on the assumption that the driver kept cool and was in fact capable of taking the evasive action which was physically possible in a given situation.

The safety benefits were then estimated through applying the subjective accident elimination probability coefficient and corrective coefficients relating to the appropriateness of manoeuvres to accidents in which an anti-locking device appeared necessary.
For the cost of the device, the researchers updated the calculation made during the PRDA study, which considered Frs.2,700 to be the maximum sum to invest per vehicle to eliminate all accidents and their consequences (cf. above at the end of section 3.2.1.). This sum therefore increased from Frs.2,700 to Frs.4,900.

Hence a measure which eliminates 1 per cent of accidents without modifying their seriousness must, to be profitable, bring about a pre-tax price increase per vehicle of less than Frs.49.

The maximum admissible cost for an anti-locking device, for a given benefit-cost ratio, is therefore:

\[
\text{benefit-cost ratio} = \frac{\text{percentage reduction} \times \text{Frs.49}}{\text{Frs.49}}
\]

2. RESULTS

-Frequency of accidents in which the anti-locking device could have been useful:

of 1,121 accident records studied, in 391 cases or 35 per cent of the accidents* the anti-locking system could have been useful and would have provided a greater or lesser probability of avoiding the accident.

-appropriateness of evasive action:

- in 16 per cent of the accidents the manoeuvres were appropriate;
- in 20 per cent of the accidents the manoeuvres were inappropriate;
- in 50 per cent of accidents no manoeuvre was made;
- in 11 per cent of the accidents no evasive manoeuvre was necessary.

The method of studying these accidents reports was such that the subjective coefficient of probability of eliminating the accident was determined on the assumption that the manoeuvres made were appropriate to the circumstances and therefore needs to be corrected by a coefficient for the appropriateness of the manoeuvre.

Assumptions relating to this correction coefficient can be made because of their approximate nature even though the preceding results are not homogeneous.

Pessimistic assumption

In 30 per cent of the accidents where an anti-locking device could have been useful, the possibilities opened up by this device are correctly used
by the driver and bring about the reduction in accidents predicted during the study of the records.

This assumption stems directly from the observed facts: avoiding manoeuvres are appropriate, or no manoeuvre is necessary, in 27 per cent of cases.

Optimistic assumption

The predicted reduction in accidents is achieved in 60 per cent of cases. Here it is assumed that some of the passive or inappropriate behaviour is brought about by driver panic caused by the unexpected behaviour of the vehicle with its wheels locked or by a kind of defeatism which might be mitigated by having confidence in an anti-locking device.

- frequency of accidents avoided:

Pessimistic assumption

6.7 per cent of the accidents could be avoided by fitting anti-locking devices to all vehicles on the road. The symmetric confidence interval having a probability of 0.95 of covering the actual value of the frequency is (5.2 - 8.2 per cent):

Optimistic assumption

13.4 per cent of the accidents could be avoided. Confidence interval (11.3 - 15.5 per cent).

It is in fact observed that the frequency of avoidable accidents varies according to the type of accident, the state of the road surface and the category of vehicle fitted.

- costs and benefits of the anti-locking system.

For the different assumptions regarding the appropriateness of manoeuvres, the maximum admissible costs of the anti-locking system are as summarised in the following table:

<table>
<thead>
<tr>
<th>Assumptions regarding the appropriateness of manoeuvres</th>
<th>Pessimistic assumption</th>
<th>Optimistic assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>All vehicles</td>
<td>340 F</td>
<td>660 F</td>
</tr>
<tr>
<td>High-performance vehicles</td>
<td>450 F</td>
<td>890 F</td>
</tr>
<tr>
<td>Low-performance vehicles</td>
<td>185 F</td>
<td>370 F</td>
</tr>
</tbody>
</table>
It can be seen from this table that:

- the benefits of the anti-locking are greatest when it is fitted to high-performance vehicles. For this category of vehicle the percentage of avoidable accidents and the coefficient of relative risk are the greatest;
- for low-performance vehicles the percentage reduction in accidents and the relative risk coefficient are low;
- for the benefit-cost ratio to approach 1, it would be necessary, assuming that all vehicles were fitted, that the pre-tax price of the anti-locking system should be between Frs.340 and Frs.660, (excluding taxes), which assumes mass production and more economical systems than are available at present.

3.2.2.3.2. Laminated windscreens

This cost-benefit analysis was another ONSER study.

1. Aims of the study:

- to estimate the nature and seriousness and average socio-economic cost of eye injuries caused by windscreens on the basis of clinical surveys. This phase of the study was carried out in 1975-1976;
- evaluation of the frequency of eye injuries by means of an extensive survey among ophthalmological services. This study was carried out in 1976-1977 and led to the main findings set out below.

2. Field covered by the survey:

The survey was carried out between the 1st June and 30th November, 1976 in the following five programme areas:

. Nord - Pas-de-Calais;
. Rhône - Alpes;
. Languedoc-Roussillon (plus the département of Ariège);
. Provence - Côte d'Azur (excluding Corsica);
. the Paris area.

1,324 practicing ophthalmologists were surveyed.

3. Main findings:

The number of cars fitted with laminated windscreens was low so that it was not possible to collect sufficient
data to compare the frequency of eye injuries caused by toughened glass and laminated windscreens.

In addition, the large number of data sources meant that it was not possible to record all injuries to the eyelids alone so that in what follows only injuries to the eyeball itself are considered.

The authors estimate the annual number of car front seat occupants suffering injuries to the eyeball due to toughened glass windscreens at 813 (+15 per cent) (base year 1975).

They estimate the proportion of front seat car occupants suffering injuries to the eyeball due to toughened glass windscreens at 0.5 per cent.

In the extensive 1976 survey there is no case of eyeball damage caused by laminated windscreens.

The risk of eye injury to non-belted front seat occupants is about 1.4 times greater than that of belted occupants.

The authors made no estimates regarding back seat passengers since there was only one eye injury in their sample.

4. Conclusion

From the two phases of this study the authors derive the parameters necessary for a comparative profitability study of toughened glass and laminated glass windscreens.

While the average extra cost of the laminated windscreen can be estimated at Frs.120 (1974) to the manufacturer - and this value is probably a lower limit - it can be estimated that fitting new vehicles to a number equalling that of cars on the road in 1974(12) would mean an increased cost of Frs.1.8 billion (1974 prices) or, at least, Frs.180 million a year.

The socio-economic benefits of the reduction in injuries to the eyeball brought about by the laminated windscreen would probably be in the order of Frs.54 million (1974 prices)(13) assuming that the socio-economic cost of eye injuries is negligible with laminated windscreen.

12. 14.9 million.
13. 75 million at most.
The cost of the laminated windscreen is 3.3 times the benefit in reduced eyeball injuries so that the risk of such injury due to toughened glass windscreens does not in itself justify the extra cost.

3.2.2.4. Heavy vehicles

3.2.2.4.1. Maximum safety investment for a heavy vehicle

At the end of section 3.2.1. we described the calculation of the maximum sum to invest per vehicle to avoid accidents and their consequences.

This calculation was made by the PRDA team for the year 1966 and was taken up again by ONSER in 1973, using 1972 data, for the study of anti-locking devices for brakes. In early 1975, ONSER again reworked these calculations on the basis of 1973 data, distinguishing between cars and vans on the one hand and heavy vehicles on the other. At this time, the maximum sum to be invested for a light vehicle amounted to Frs. 5,200 and for a heavy vehicle Frs. 10,600, or roughly double (using the same assumptions of a discounting rate of 10 per cent and a vehicle life of ten years).

3.2.2.4.2. Risk cost associated with the presence of heavy vehicles on motorways and other heavily trafficked roads.

This is not exactly a cost-benefit study, but resembles one in that it determined the risk cost resulting from different categories of heavy vehicle operating on different types of road in order to decide the regulations to be applied to such vehicles (speed limits, calculations of axle taxes, etc.). The fact is that the constraints, and hence the costs, were chosen on the basis of the potential safety benefits.

1. Methodology

The analysis can be broken down into three parts:

a) determination of the frequency and seriousness of accidents involving heavy vehicles by tonnage class, vehicle type, and type of road, over a year.

b) calculation of the kilometres covered by these categories of heavy vehicle over the same period.

14. 2.4 at the minimum.
c) calculation of the risk and seriousness of accidents by comparing the frequency and cost of accidents with the distance covered by different categories of heavy vehicle over different networks.

2. Main findings

A. Risk cost on heavily trafficked roads (1974 prices)

<table>
<thead>
<tr>
<th></th>
<th>1975 records(1)</th>
<th>SETRA(2)</th>
<th></th>
<th>95 per cent confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Vehicle-kilometres (10^8)</td>
<td>Average annual cost vehicle-kilometre (Fr.10^6)</td>
<td>Cost per vehicle-kilometre (C = centimes)</td>
</tr>
<tr>
<td>Trucks &lt;10t max. all-up wt</td>
<td>20.3</td>
<td>25.8</td>
<td>71.35</td>
<td>2.8 C/VK</td>
</tr>
<tr>
<td>Trucks &gt;10t max. all-up wt</td>
<td>33.6</td>
<td>42.7</td>
<td>191.26</td>
<td>4.5 C/VK</td>
</tr>
<tr>
<td>Tractors and semi-trailors</td>
<td>40.1</td>
<td>50.9</td>
<td>232.71</td>
<td>4.6 C/VK</td>
</tr>
<tr>
<td>Motor coaches</td>
<td>6.0</td>
<td>7.6</td>
<td>40.69</td>
<td>5.4 C/VK</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>127</td>
<td>536</td>
<td>4.2 C/VK</td>
</tr>
</tbody>
</table>
### B. Risk cost on motorways (1974 prices)

<table>
<thead>
<tr>
<th></th>
<th>1975 records(1)</th>
<th>SETRA(2)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Vehicle-kilometres (10^8)</td>
<td>Average annual cost vehicle-kilometre (Fr.10^6)</td>
<td>Cost per vehicle-kilometre (C = centimes)</td>
<td>95 per cent confidence interval</td>
</tr>
<tr>
<td>Trucks &lt;10t max. all-up wt</td>
<td>16.5</td>
<td>4.6</td>
<td>5.94</td>
<td>1.3 C/VK</td>
<td>1.0 - 1.6</td>
</tr>
<tr>
<td>Trucks &gt;10t max. all-up wt</td>
<td>26.9</td>
<td>7.5</td>
<td>20.03</td>
<td>2.7 C/VK</td>
<td>2.2 - 3.2</td>
</tr>
<tr>
<td>Tractors and semi-trailors</td>
<td>51.2</td>
<td>14.3</td>
<td>34.22</td>
<td>2.4 C/VK</td>
<td>2.4 - 2.8</td>
</tr>
<tr>
<td>Motor coaches</td>
<td>5.4</td>
<td>1.5</td>
<td>2.11</td>
<td>1.4 C/VK</td>
<td>1.0 - 1.8</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>27.9</td>
<td>62.30</td>
<td>2.2 C/VK</td>
<td>1.9 - 2.5</td>
</tr>
</tbody>
</table>

1. Kilometrage at night is estimated on the basis of a night vehicle count on heavily trafficked roads in 1974. It is also assumed that the frequency observed during the day is valid for the whole day.

2. The cost is calculated on the basis of victims recorded on the exhaustive SETRA files (average for the years 1974 and 1975). The DSCR 1974 scale was used for the cost of death or injury (Fr.380,000 and 17,000 respectively).
It can be seen that there is a significant improvement in safety for heavy vehicles of all categories, and in particular for motor coaches, on motorways as compared with other main roads. The overall improvement in the risk cost for heavy vehicles is in the order of 50 per cent.

Taking both categories of road together, the average cost risk of a heavy vehicle in 1974 was 3.9 centimes/vkm, ± 10 per cent.

C. Costs according to accident circumstances on heavily trafficked roads

Analysis of the effect of circumstances - night, work-day or other day - shows that:

- The risk cost at night is in the order of 20 per cent higher than during the day - this difference is significant;

- At night there is no significant difference in the risk cost between articulated and other trucks, but motor coaches are significantly more dangerous than other heavy vehicles at night;

- The risk cost of heavy vehicles is significantly higher on work days.

D. Risk costs of heavy vehicles operating by day on heavily trafficked roads broken down by weight class:

- The risk cost increases with the authorised all-up weight. Thus, for example, trucks of 19 to 26 tonnes have a risk cost three times greater than trucks of 10 to 15 tonnes;

- Heavy vehicles with two disks are more dangerous than those with one disk (although the differences are not significant). This could be explained by the fact that the average speed of heavy vehicles with two disks are in the order of 5 km/h higher than those with one disk. (It should be recalled that heavy vehicles with a single disk are those dating from before 1966).

3.3. DRIVER TRAINING

Being allowed to drive a motor vehicle depends on obtaining a driving licence which has for some years been
mainly a matter for young people. The great majority of the licences issued each year go to young people under 23 who make up approximately two-thirds of the women and 83 per cent of the men receiving licences. The official statistics show that this young population is over-represented in road accidents. For this reason, driver training has appeared as a preventive and educative measure to improve road safety.

It is frequently found however, that those who recommend educative measures find it repugnant that such proposals should be considered from the profitability aspect. They consider that the improvement of human knowledge and competence legitimises the action, without any need for no economic justification.

As regards road safety, however, training and educational measures are but part of a whole set of measures which may be recommended and it is important to determine what ranking they should be given and to justify this decision. Otherwise there is considerable risk of them being under estimated with respect to other proposals which seem to be more immediately profitable or simply whose profitability is easier to demonstrate because it is based on factors which can easily be quantified.

3.3.1. Methods of obtaining a driving licence

1,288,751 licences were issued in France in 1981, broken down as follows:

- Licences issued by the SNEPC (National Driving Test Service)

This service examines candidates who have learnt to drive either through attending a private driving school or by driving accompanied by a licence-holder. 87 per cent of the licences issued in 1981 (i.e. 1,131,362) were issued by SNEPC. The number of candidates who do not attend a driving school is generally reckoned at 2 or 3 per cent, but this figure has never been checked.

- Conversion of military licences

The army trains and selects several thousand drivers each year according to its own criteria.

Holders of military licences can subsequently request the FNPC (Body responsible for national driving licence records) for their conversion to civil licences.
In 1981, 123,309 military licences were converted to civil licences, this representing 10 per cent of total licences issued.

- Conversion of foreign licences

A licence obtained in a foreign country can be validated through the FNPC. In 1981, 34,088 such licences, or 3 per cent of the total, were issued.

3.3.2. Economic aspects of driving

- Instruction

85 per cent of driving licence candidates attend a driving school. The cost of this training is borne mainly by the candidate himself. There are at present 11,500 driving schools offering instruction for all classes of licence. The cost of this training is not high - in the order of Frs.3,000. The annual turnover of all driving schools amounts to about Frs.3,000 million.

The driver training budget for the army is not known because it is included in the motor fuel budget.

- Examination service

This Service comes under the Ministry of Transport and the Ministry of the Interior.

The examination fee is Frs.50, which meant a revenue of Frs.142 million in 1982.

Driving licence stamp duty averages Frs.100, but varies according to region, ranging from Frs.75 in Bourgogne to Frs.200 in Alsace. This regional tax brings in a revenue of Frs.124 million, but this is not counted as part of central government resources.

The budget appropriation for the Examination Service was Frs.187 million in 1982 and Frs.207 million in 1983.

Comparing this income and expenditure of this Service between 1968-69 and the present day, it can be seen that it is no longer profitable to the State as it once was (PRDA 1969).

3.3.3. Evaluation of training within the overall system

This evaluation is made using the latest criteria.
This is the most commonly studied aspect. It is a matter of measuring the effect of the training system on safety, using such criteria as number of accidents, number of infringements, etc., but since safety is the resultant of many other measures in addition to training (user information, advanced training, infrastructure improvements, regulation, enforcement), this evaluation can be made only at the level of the overall road traffic system, i.e. through experimentally controlling all the other factors.

In these studies the most usual approach is to record by various methods the accidents and infringements during the period (from one to four) after passing the driving test.

All these studies are foreign and no evaluation of training in terms of road safety effectiveness has been carried out in France. The fact is that the findings of these various studies sometimes appear significant and sometimes non-significant and frequently contradictory. This can be explained by a number of factors:

The comparison is simply between the overall effect of systematic training as compared with no training at all. The findings in terms of accidents or infringements thus give no direct information about the effectiveness of the particular pedagogical principles used. It is thus not possible to make point by point comparisons of these different studies.

In addition, the different circumstances in which driver training takes place (recruitment of candidates, situations encountered by learner drivers, specific content of training courses, etc.) being different from one study to another, the extreme diversity of these factors makes comparison difficult or even impossible.

Furthermore, as regards our own concern, no cost-benefit studies have yet been undertaken.

3.4. INFORMATION AND PUBLICITY

The aim of road safety information policy is to bring about a reduction in the harmful effects of accidents. In order to ensure the rationality of the administrative decisions to be made in this field it is necessary to try to evaluate the measures envisaged by means of cost-benefit analyses.

Thus in order to design a road safety publicity campaign, an attempt is made to establish the relationships between programme indicators (for example
the number of road side posters), impact indicators (the number of drivers influenced by the posters in question) and outcome indicators (for example the number of accidents on routes where the posters have been put up).

Such analysis is often difficult partly because of the lack of data and partly because of the interdependence of different measures.

By way of example, we shall describe the evaluation of a publicity campaign concerning seat belts. This analysis was made in 1969 as part of the PRDA study, hence before the wearing of seat belts was made compulsory in France.

If \( x \) per cent of users wear their seat belts before the campaign, after an intensive campaign \( (x + \Delta x) \) per cent of road users will do so.

In 1970, over 2 million vehicles had been fitted with seat belts.

If \( \Delta x = 1 \) per cent, the capitalised benefits (with a discounting rate of 10 per cent) over 10 years for these vehicles will be:

\[
\frac{1}{100} \times 625(10) \times 2,000,000 = \text{Fr.12.5 million}
\]

The publicity campaign cost about Frs.3 million in 1970 and 1 million in subsequent years.

The corresponding capitalised cost is:

\[
\sum_{k=1}^{10} \frac{1}{(1.1)^k} = \text{Fr.9.14 million}
\]

Under these circumstances, it suffices for the campaign to induce something under one per cent of additional users to wear their seat belts for it to have a positive benefit-cost ratio with regard to safety.

3.5. REGULATION AND CONTROL

This is an area where cost-benefit studies are particularly useful. The fact is that while it appears

10. The expected discounted cost of injury to front seat passengers is Frs.1,250. Assuming that the seat belt reduces such injuries by half, the capitalised benefit over 10 years will be Frs.625 per vehicle. See above under 3.2.2.2.1. for a discussion of seat belts.
very simple and inexpensive to take a regulatory decision, this decision involves constraints and hence costs for the road user and also for the authorities who have to enforce the regulations and hence provide an adequate level of control, which also costs money.

A particularly striking case is that of speed limits. The PRDA team studied this subject and we summarise this work under four headings below.

3.5.1. Impacts which cannot really be judged good or bad

3.5.1.1. Long-term effects on the road network

It would appear that if the aim is optimal utilisation of road infrastructures with the best possible safety conditions, rational operation will be achieved through strict enforcement of speed limits which vary with time and place according to the density of traffic.

3.5.1.2. Long-term effects on car manufacture

The problem here is the question of whether speed limits threaten to harm the car industry. This is a very controversial question. There are other arguments for promoting sales and Japan, where this industry is expanding at an unprecedented rate, imposes speed limits, etc. This is the type of argument to put up against manufacturers, motor journalists and others obsessed by speed.

3.5.1.3. The psycho-sociological problems raised by regulation

Speed limits reduce driver fatigue but make driving more monotonous. If the outlet for aggressiveness is reduced on the roads will it not reappear somewhere else?

3.5.1.4. The problem of overtaking

One disadvantage of uniform speed limits is serious problems with overtaking in the neighbourhood of the maximum authorised speed.

Vehicles bunch together and traffic becomes congested causing additional cost (lost time, higher fuel consumption, increased engine wear through overheating).

It is possible to introduce a certain relaxation of the speed limit to allow a single vehicle to be overtaken.
3.5.2. Implementation costs and the associated disadvantages

3.5.2.1. Cost of a publicity campaign

The adoption of new regulations requires a broad publicity campaign to make them accepted and an effort to inform users so that they know the rules and respect them. On the face of it the costs of publicity campaigns and the new road signs required are independent of the level of speed limit imposed.

3.5.2.2. Cost of enforcement and penalties

These costs depend much more on the way the measures are applied than on the theoretical cost of the new regulations.

3.5.2.3. Loss of time for the user

It is easy to see that the increased journey time over short or medium distances is negligible.

3.5.3. The benefits of speed limits

3.5.3.1. Reduction in the harmful consequences of road accidents

Speed limits reduce both the number of accidents and their seriousness.

On this subject the PRDA team pointed out that according to insurance statistics, the bodily harm costs per accident are about three times higher for fast cars (over 140 kmh) than slow ones (less than 110 kmh).

3.5.3.2. Reduced transport costs

The cost per kilometre as a function of annual kilometrage and length of use of the vehicle increases with vehicle speed.

The reduction in fuel consumption can be calculated from the difference in speed before and after limitation. The savings in oil and tyres can be reckoned at one third of the fuel saving (convention adopted by the United States and the United Kingdom).
3.5.3.3. Reinforcement of the effectiveness of other safety measures

For example, speed limitation makes the seat belt more effective.

3.5.3.4. Reduction of excessive speeds

This is the case in particular where main roads go through villages.

3.5.4. Example of a cost-benefit analysis for a speed limit

The PRDA team made the following assumptions to simplify the analysis: the authorities decide to limit speeds to 100 kmh on all roads outside built-up areas with the exception of motorways. They carry out a publicity campaign and buy control instruments. There is no change in the numbers of police or gendarmes.

In this simplified analysis the long-term effects are not taken into account. The calculation is limited to the benefits and costs in the first year in which the measure is applied. For expenditure whose effects go beyond this first year, the equivalent annuity is calculated at a discounting rate of 10 per cent (the rate then recommended by the General Commission for the Plan).

3.5.4.1. Analysis of costs

3.5.4.1.1. Costs associated with the publicity campaign

The cost was to be Frs.3 million in the first year and 1 million a year thereafter.

With a discounting rate of 10 per cent, the equivalent annuity is Frs.1.2 million.

3.5.4.1.2. Cost of control

At the end of 1968, the Ministry of the Interior possessed 25 cars fitted with an automatic speed checking system. The PRDA team considered that it would be necessary to multiply this figure by 10 to cover the whole of France, which would mean approximately three vehicles per département.

The equipment cost Frs.30,000 per car, with an annual maintenance cost of Frs.3,000. Although designed
to be written off over 10 years, a life of six years only was assumed, to take account of technical progress. Hence an equivalent annuity of:

$$250 \left( \frac{3,00 + 30,00 \times 22.96}{100} \right) = 2,474,500$$
or almost Frs.2.5 million.

### 3.5.4.1.3. Cost of users' loss of time

On the basis of a certain number of assumptions, the PRDA team calculated an annual time loss, supposing that the speed limit was strictly observed, of 15 million hours.

Taking the figure of Frs.11 per hour lost per vehicle, they obtained a money value of Frs.165 million a year for lost time.

### 3.5.4.2. Analysis of the benefits

#### 3.5.4.2.1. Evaluation of the reduction in fuel consumption

The calculations show a saving of 156 million litres a year if all vehicles respect the speed limit. At that time, Frs.0.8 of the average price of a litre of fuel went to tax revenue and Frs.0.3 to the production and distribution services; hence:

- benefit to users:
  $$1.1 \times 156 \times 10^6 = \text{Frs.172 million}$$
- benefit to the community:
  $$0.3 \times 156 \times 10^6 = \text{Frs.47 million}$$
- loss of tax revenue for the State:
  $$0.8 \times 156 \times 10^6 = \text{Frs.125 million}.$$

#### 3.5.4.2.2. Evaluation of the reduction in vehicle maintenance costs

As mentioned above, studies carried out in the United Kingdom and the United States have estimated the reduction in vehicle maintenance costs (lubricants, tyres, brakes, general wear and tear) at one third of the reduction in fuel consumption.
In the absence of any comparable studies in France, the reduction in these costs was taken as one quarter of the reduction in fuel consumption to take account of the difference in the tax component of the fuel price between the United Kingdom and France.

The resulting saving is therefore \( 0.25 \times 172 = \text{Fr. 43 million} \).

3.5.4.2.3. Reduction in the number of accidents and their seriousness

The PRDA team did not have any forecasts available regarding the effectiveness of the speed limit. It was therefore not possible for them to calculate the benefits resulting from this measure. Foreign experience led them to think that the reduction would be in the order of 10 to 20 per cent that it would be more marked in terms of road deaths than the number of accidents.

Finally, the PRDA team limited itself to calculating the benefits resulting from a 1 per cent reduction in accidents, with no change in the degree of seriousness, in order to obtain a figure which could be compared with above costs.

Thus the benefit obtained by a reduction of 1 per cent in the number of accidents with no change in seriousness could be estimated at about Frs.90 million.

3.5.4.3. Comments on these findings

In the first place the authors stressed the uncertainty of results obtained on the basis of such fragmentary data. They hoped that experience with speed limits would provide reliable data for the future.

Secondly, they pointed out that quite apart from the time factor, users seem to attach importance to the mere fact of being able to drive fast. It was thus necessary to make a distinction between the satisfaction provided by speed for its own sake and the time saving it permits.

3.5.4.4. Summary

The authors present a summary in the form of a table, pointing out that the results have been rounded down to considerably lower value to take account of non-respect of the speed limits by certain users. The figures should in any event be considered as no more than orders of magnitude for the directly measurable impact of speed limitation.
<table>
<thead>
<tr>
<th>Categories</th>
<th>Deaths</th>
<th>Injuries</th>
<th>Damage costs of bodily harm accidents</th>
<th>Damage only accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit cost per category (in Francs)</td>
<td>230,000</td>
<td>10,000</td>
<td>2,500</td>
<td>600</td>
</tr>
<tr>
<td>Reduction of 1% per category (physical units)</td>
<td>130</td>
<td>3,000</td>
<td>2,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Benefit per category of a 1% reduction (Frs. million)</td>
<td>29.9</td>
<td>30</td>
<td>5</td>
<td>24</td>
</tr>
</tbody>
</table>

The indirect effects have not been quantified except for the loss of revenue to the State. It was assumed that the Frs. 150 million saved on fuel would be spent by users on other consumption subject to VAT, thus limiting the loss of tax revenue due to the measure to Frs. 80 million.
### 3.5.4.4.1. Direct effects

#### A. Measurable costs and benefits (Frs. millions)

<table>
<thead>
<tr>
<th></th>
<th>Real value - 1st year</th>
<th>Annual costs (at constant prices)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Budget</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>publicity campaign</td>
<td>3</td>
<td>1.2</td>
</tr>
<tr>
<td>enforcement</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>loss of tax revenue</td>
<td>≈ 80</td>
<td>fines ≈ 80</td>
</tr>
<tr>
<td><strong>Users</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>loss of time</td>
<td>≈ 150</td>
<td>150</td>
</tr>
<tr>
<td>reduced fuel</td>
<td>≈ 150</td>
<td></td>
</tr>
<tr>
<td>consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reduced wear and</td>
<td>≈ 40</td>
<td></td>
</tr>
<tr>
<td>tear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>other effects</td>
<td>fines</td>
<td></td>
</tr>
<tr>
<td><strong>&quot;Community&quot;</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>publicity and</td>
<td>5.5</td>
<td>1.7</td>
</tr>
<tr>
<td>enforcement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>loss of time</td>
<td>≈ 150</td>
<td></td>
</tr>
<tr>
<td>reduction in fuel</td>
<td>≈ 80</td>
<td></td>
</tr>
<tr>
<td>consumption and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wear and tear</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### B. Direct effectiveness: reduction of accidents

The reduction of 1 per cent in the number of accidents results in a benefit of about Frs.90 million to the community. The measure is thus very profitable if it reduces the number of accidents by something over 2 or 3 per cent.
C. Other direct effects

- delays - short
- popularity - rather low ...
- ease of implementation - good, but a precise study of enforcement measures needs to be carried out.

3.5.4.4.2. Indirect or external effects

- transport - possible switch to other modes (rail, air)
- production - domestic market - bad in the short term
- export market - adjustment in the medium term depending on the coherence of international regulations
- economy as a whole (growth) negligible influence
- international coherence: favours the generalisation of the measure (United Kingdom, Germany, Scandinavia).

3.5.4.4.3. Interdependence
- Makes other safety measures more effective.
- alcohol test,
- safety belt, etc.
- Reduces excessive speeds.

3.6. EMERGENCY SERVICES

So far as we know this area has not been the subject of systematic cost-benefit studies at the national level.

The fact is that studies have above all been concerned with cutting down the time taken for help to arrive and having doctors aboard emergency vehicles. While any improvement in this time is easy to measure, its effects on the survival of victims are more difficult to quantify. However, the work carried out under
Professor Serre of Montpellier provides a certain amount of data both about costs (cost per hour of a helicopter with a doctor aboard as compared with an ambulance) and the survival of victims (comparison of the two systems mentioned for accidents occurring over 10 km from the nearest SAMU), which should now make it possible to carry out a cost-benefit analysis on this subject.

In other sub-fields it can be reported that an economic study on the provision of emergency telephones along major links was to be carried out by the ONSER, but came to nothing because of a lack of financing.

Lastly, the cost-benefit aspect as regards first-aid instruction is scarcely any different from the general problem of evaluating the effects of training measures, a problem discussed above.

3.7. STUDY AND RESEARCH

In this field, costs and benefits are particularly difficult to measure because, by definition, it cannot be known in advance whether a research project will be successful, and even if it is, the results are not necessarily easily measurable.

For this reason, in accordance with the practice of firms which devote an empirically determined percentage of their turnover to advertising, an arbitrary target has been set for study and research on road safety - 0.2 per thousand of the total cost of road accidents, a figure which has been achieved by Sweden.
4. PRESENT ORIENTATIONS AND FUTURE POSSIBILITIES

4.1. PRESENT ORIENTATIONS

The preceding sections surveyed the main cost-benefit studies carried out in France in the different sectors of road safety. It can be seen that almost all these studies were carried out between 1969 and 1975, i.e. starting with the PRDA study and going up to the preparation of the VIIth Plan. Since then, cost-benefit studies have practically been abandoned in France. Why? This is no doubt due to a number of reasons.

A first indication of the lack of interest was the fact that the Ministry of Transport ceased to update the cost of road victims after 1974. It was not until 1980, after the studies carried out by ONSER, that the official figures began to be published again - meanwhile the official index of retail prices in France had increased by over 75 per cent!

The PRDA study had prepared the targeted road safety programme for the VIIth Plan. In preparing the VIIth Plan, a posteriori effectiveness studies were carried out on the measures introduced by the VIIth Plan, but subsequently the road safety Priority Action Plan (PAP) contented itself with re-adopting the basic outline of the VIIth Plan, though of course modifying measures in accordance with the experience gained thanks to analyses of previously implemented measures. There was no significant subsequent action regarding road safety in the VIIIthe Plan, whose fate is well known. In the field of road safety, therefore, since detailed objectives were no longer laid down there was no need for preliminary economic studies and in particular cost-benefit studies.

It may perhaps also have been more or less realised that although a good many cost-benefit studies had been carried out, some of them were based on such shaky and uncertain foundations that the results could easily be invalidated (cf. the differences between the conclusions regarding head rests in France and the United Kingdom in paragraph 3.2.2.2.3). Under these circumstances, it no doubt appeared wiser to direct efforts towards serious studies of the effectiveness of measures taken and thus
obtain data which would subsequently enable cost-benefit studies to be taken up again on a sounder basis.

These explanatory factors cannot in fact hide the obvious fact that there still remains much to be done before perfect economic rationality can be applied in the field of road safety investment. There follows a survey of the situation in the different sectors.

4.1.1. Infrastructure

This field is a fairly good illustration of what has just been said. In many cases the effectiveness studies are not sufficiently general to serve as a basis for cost-benefit calculations. This is so in particular as regards road signs, lighting, pull-ins, concrete barriers, delineators, speed regulating signs on the approaches to individual danger spots, etc.

However, in the last case cited, speed regulation approaching danger spots, there can be no general doctrine since each spot is more or less an individual case and depends on local study. This is also true for accident black spots outside built-up areas, danger spots in urban areas, road markings, urban traffic engineering plans, etc. In practice, these cost-benefit studies are generally carried out locally in order to decide the allocation of resources, but in most cases the study is rapid and very summary, not to say simplistic.

Lastly, there is a third category of subject area which is ignored for complex reasons of a somewhat political nature. As regards roadside obstacles, this is the case of trees, the most murderous obstacle of all. The subject was admittedly studied by ONSER at the request of the Roads Directorate (see above, paragraphs 3.1.4.3.1. and 3.1.4.3.2.), but the study was continued to the extent of being able to provide the best solution from the safety angle in terms of cost and benefits. There would appear to be a preference to remain in ignorance rather than risk being forced into action!

In the same category, another measure for which there has been no cost-benefit study is the installation of roadside emergency telephones. Such a study was in fact planned, but came to nothing for financial reasons, the Ministries of Transport and Health being unable to reach agreement on the joint financing of the work.

4.1.2. The vehicle

In this field too, cost-benefit studies are extremely rare. The main reason is no doubt that the
most important ones have already been carried out. For the rest, the difficulties are very often upstream, since it is first of all necessary to find an appropriate solution to a problem, for example, water spraying up behind vehicles on wet roads, improvements to night visibility, protection against fire, etc. The cost is not so much of a problem for the authorities, since it is borne by the manufacturer and hence finally the user. What is more, an individual country is not entirely free to make certain devices compulsory, to the extent that there is a considerable degree of concerted action at the European level, this being essential since vehicles go beyond national frontiers. The cost has sometimes appeared sufficiently minor not to need studies, such as in the case of helmets for motor cyclists or warning signs. It is true that mass production brings about a very substantial cost reductions.

### 4.1.3. Training and education

Making an existing system of road safety training and education more efficient requires a certain number of measures. It is therefore necessary to decide which are the most profitable and with which it would be best to start.

In any training system the three key points which cover the basic factors which need to be considered if the effectiveness of driver training is to be improved are:

- the objectives of the instruction;
- the pedagogical principles and methods;
- evaluation of the results.

If it is desired to take action to resolve these three basic problems, indicators have to be developed, for example, to measure the extent to which the instruction achieves the desired objectives; to measure the effectiveness of the teaching methods used, which have already been subject to a preliminary evaluation; evaluation of the training on the basis of intermediate criteria allowing the level of acquisition to be measured.

In order to implement such action, the content of which already exists (cf. ONSER research since 1972) it is necessary to define a target group (e.g. a département) and evaluate the relationships between the different criteria studied and general road safety objectives which aim at an overall reduction in accidents.

At the same time, on the basis of a cost-benefit analysis of such action on a limited scale, it would be necessary to extrapolate to the national level on the basis of estimating the present costs of training and
examination. The main difficulty is in defining a target group which can be monitored and serve as the basis for the cost-benefit studies which have never yet been carried out in France in this field. However, to help make such a project successful, there are the results of United States and, above all, German studies.

4.1.4. Publicity

Generally speaking, publicity is an area poorly suited to cost-benefit calculations. It is in fact not at all easy to measure the real effectiveness of a campaign in terms of changes in attitudes or behaviour. Very often, the public is aware of the campaign and understands the message but is nevertheless unconvinced and therefore does not follow the recommendations of the message. Professionals in the publicity field thus generally limit themselves to the first two stages - checking whether the message has been perceived and has been understood.

The PRDA study, intended to clear the ground and get down to basics, studied the cost-benefit aspect of a publicity campaign using the example of the seat belt. This was described in section 3.4. It was an a priori evaluation of the minimum increase in the percentage of people wearing seat belts which would have given a favourable balance to cost-benefit calculation. But the difficulty of making a follow-up evaluation was already recognised since it is not easy to single out the exact role of the publicity campaign in any increase in the proportion of people wearing seat belts. It is already difficult to measure any change in the rate of wearing and if this change is fairly small it is virtually impossible to detect what share is due to the campaign and what is due to all the other factors.

This is why cost-benefit studies have not developed in this area.

4.1.5. Regulation and control

It is perhaps in this area that the present lack of interest in cost-benefit studies is the most striking.

The research which preceded implementation of the major road safety measures of speed limitation and compulsory wearing of seat belts has been discussed above. More recently, however, the decision to make the use of dipped headlights in built-up areas compulsory was taken on the basis of foreign examples without any cost-benefit study, even though it is a subject which seems eminently suited for such a study since on the
positive side there is increased road safety and on the negative side the extra energy expenditure.

This example speaks for itself and there is no point in pursuing the argument.

4.1.6. Emergency services

Embryo cost-benefit studies have been carried out at the local level to justify the use of helicopters in emergencies, as was done in Strasbourg (see above, section 3.6).

4.1.7. Study and research

It was seen above (section 3.7) that study and research is a field rather ill-suited to cost-benefit analysis. There is, however, a sub-field where such analysis appears desirable - data collection. The fact is that collecting and processing data is very expensive, while the resources available are obviously limited. In order to make a rational choice it is necessary to know in advance the cost-benefit ratio for each case.

4.2. POSSIBILITIES FOR A NEW LEASE OF LIFE

We have just noted the lack of cost-benefit studies in recent years. It should not be over-hastily assumed, however, that this means that road safety cost-benefit studies have been given up for good. There are in fact signs that a revival may not be far away.

4.2.1. Analysis of the effectiveness of road safety measures

An internal document from the Safety and Road Traffic Directorate to the Ministry of Transport has for the first time attempted to draw up a complete balance sheet of what has been done in the different fields to improve road safety. This report has already given rise to much discussion within government departments.

4.2.1.1. Aims of the study

The author, Mr. Orselli, proceeds from the observation that sectoral approaches to the effectiveness of each measure being subject to large margins of error, it is necessary to try another approach, this being a global model:
- based on breakdowns;
- checked by an aggregated return to the global level.

This model gives an idea of the real effectiveness of each measure implemented in the past. The real effectiveness can be extrapolated - for example, the real effectiveness of the seat belt can be combined with the future improvement in the percentage of people wearing them.

The aim of the model is thus:

- analysis of the value of measures implemented in the past;
- extrapolation of the effects of these measures into the future.

It is considered essential to direct studies and resources to the most effective measures and possibly to seek others.

The value of this model is that it puts the various past measures in their true positions with respect to one another.

For the present, it explains the change in trend seen since 1978 - stagnation then renewed growth in the number of deaths.

For the future, it allows extrapolation, this being dependent on many outside factors like any other extrapolation.

The breakdown-reaggregation approach is self-correcting vis-à-vis extrapolation. The fact is that the combination of a first order error on each component will give a second order error on the whole and this remains in the extrapolation despite the inevitable distortions.

4.2.1.2. Methodology

In the first place, for the choice of the time series on which the evolutionary model was to be based, the author preferred to exclude injury accidents (slight or serious) on which the statistics are more or less incomplete.

The number of deaths was more or less taken as a basis. It was assumed that the time series were reliable in that the definition of a road death and the standard of data collection were assumed to be constant over time.
In addition, the number of deaths is the most visible indicator in road safety from the political standpoint.

The model used is very simple:

- breakdown into 8 independent categories:
  pedestrian, cycle, light motorcycle, motorcycle,
  light vehicle on motorways, other roads outside
  built-up areas and in towns, and other;
- breakdown within the 3 categories of light vehicle
  on the basis of 8 multipliers: traffic, vehicle,
  emergency services, seat belt, speed, alcohol,
  infrastructure, driving style.

The author had intended to make the model more complex by applying coefficients differentiated according to the two main population categories involved - low risk and high risk, but had to give up owing to a lack of data. He nevertheless stresses the fact that since the impact of past measures has been very different according to the type of population, measures differentiated according to the type of population (low or high risk) would perhaps be very effective with regard to certain types of accident unaffected by past measures.

4.2.1.3. "Provisional" conclusions

The author considers his conclusions provisional to the extent that he had to rely on experts' estimates which may sometimes be questionable or open to dispute.

Subject to this proviso, the findings can be summarised as follows:

1. The majority of measures appear to be of limited effectiveness:
   - the active and passive safety of vehicles
     (including two-wheelers);
   - improved emergency services;
   - continuing education for drivers to improve their "driving style";
   - infrastructural improvements (roads or traffic engineering).

2. Three measures stand out from the rest:
   - speed limits;
   - seat belts;
   - motorways.
3. One measure seems to have had a very different impact on different populations: the campaign against drink and driving, which had a significant effect on occasional drinkers and very little effect on confirmed alcoholics.

4. The future does not look very rosy:

- the two categories - pedestrians and light motor cycles - which together accounted for 30 per cent of the improvement included internal mechanisms contributing to the reduction in the number of deaths. These mechanisms are becoming exhausted and the absolute numbers of deaths still occurring are now very low;
- traffic volume is still growing;
- the return to two-wheelers seems to be accelerating;
- the programme of bringing motorways into service within 10 years is falling off.

5. Contrary to popular belief, the author states that France's ranking as regards road safety is very good. The differences noted at the overall level depend much more on geographical factors (the density, distribution and physical nature of the different networks) than on people's behaviour. This observation has its gloomy side in that it makes the limit to the future effects of safety measures look fairly close.

4.2.2. The REAGIR programme

The REAGIR (Réagir par des Enquêtes sur les Accidents Graves et des Initiatives pour y Remédier)(16) programme is at the focus of a new road safety policy which, in the context of decentralisation, is trying to ensure that local authorities, regional institutions (in particular the press and other media) and the man in the street are more involved.

This kind of inquiry is already opened when there is a disaster in other transport sectors such as rail, air or even telepherics. In this case it is a matter of systematically carrying out a technical inquiry at the level of the département, under the authority of the Commissaire for the Republic, intended to:

- improve our knowledge:

16. "React by inquiries into serious accidents and initiatives to remedy them".
On the basis of the reports by the Police and Gendarmerie, and additional information concerning in particular the human factors, it is a matter of building the most likely hypotheses on the sequence of causes of the accident and any possible aggravating factors.

- To propose remedial action:

These deeper analyses should enable more diversified and appropriate action taking account in particular of secondary factors which favoured the appearance of an accident situation.

4.2.3. The potential offered by these new measures

We are thus in the presence of two initiatives which are very important for our knowledge of the effectiveness of road safety measures:

- one at the central government level tends to measure a posteriori the effectiveness achieved in each of the broad fields of road safety in order to pinpoint those where the potential for further improvement is the greatest;
- the other at local (département) level enables the men in the field to seek, on the bases of actual cases, the most appropriate measures to prevent a repetition of actual accidents in the future. They can subsequently judge for themselves the adequacy of the solutions adopted. Thus they can gradually and empirically form their own guide to the effectiveness of road safety measures.
GENERAL CONCLUSION

In France, the period 1968-1975 was the golden age of road safety cost-benefit studies. This golden age started with the introduction of RCB (Rationalisation of Budgetary Choice) throughout the Administration and in particular in the field of road safety. Subsequently, however, a kind of disenchantment followed this period of euphoria, during which there had perhaps been an attempt to go too fast and too far without sufficiently solid foundations. In any event, the fact is that cost-benefit studies were practically abandoned in road safety after 1975.

With 1982, however, hope was reborn. New instruments are being forged to measure the effectiveness of road safety measures, one at the central level, the other at local level. This better understanding of the effectiveness of measures will also require a knowledge of the costs in view of the budgetary constraints. These costs in fact appear easier to estimate. In order to compare costs and effectiveness, it is necessary to translate this effectiveness into monetary benefits and then, in order to justify the always heavy cost, not only the benefits in the field of safety should be considered, but also those in other areas. This brings us back to road safety cost-benefit analyses which thus reassume the role they should never have lost - that of being an indispensable guide for action.
NORWAY

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INTRODUCTION

Traffic safety is a topic of high political priority. Consequently substantial resources are spent on measures to improve traffic safety. In times of increasing competition for public funds an effective use of these resources is a requirement. Various methods for evaluation of traffic safety measures are being used in order to decide which measures should have priority.

Cost-benefit analysis is a method which may be helpful in the decision-making process. However, it necessitates more detailed knowledge of the various measures than we have today. The net benefits of a particular measure depend heavily on local conditions and will therefore most likely vary from place to place in the road network as well as from country to country.

Consequently it would seem to be of little value in this report to refer to the benefits and costs of particular projects as an indication of their general economic feasibility. In other words, it is impossible to generalise the conclusions drawn from particular projects regarding profitability. The conclusions will only be relevant to a particular project at a particular place and at a certain time. A more appropriate way would be to analyse the relationship between benefits and costs in light of the factors which influence these parameters. It is necessary to make such an analysis macroscopic in order to fit into the scope of this report.

The different traffic safety measures have, however, their particular traits and there are special conditions which have to be regarded. Through a few examples I hope to demonstrate what an important role such parameters may play in an economic analysis of benefits and costs.
1. PROBLEM STATEMENT

The international road accident statistics give a coarse measure of the problem at hand which we are trying to solve. The number of fatalities and injured persons in road traffic accidents is the starting point for any nation's traffic safety work. Table 1 shows the accident statistics for a selection of European countries. These are not completely comparable however, because of differences in the accident reporting accuracy and comprehensiveness.

Table 1

NUMBER OF PERSONS INJURED AND KILLED (*)
IN ROAD TRAFFIC ACCIDENTS IN 1976 AND 1980

<table>
<thead>
<tr>
<th>Country</th>
<th>1976</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
<td>Killed</td>
</tr>
<tr>
<td>Norway</td>
<td>10,394</td>
<td>471</td>
</tr>
<tr>
<td>Denmark</td>
<td>20,456</td>
<td>857</td>
</tr>
<tr>
<td>Finland</td>
<td>11,766</td>
<td>804</td>
</tr>
<tr>
<td>Sweden</td>
<td>21,843</td>
<td>1,168</td>
</tr>
<tr>
<td>Austria(2)</td>
<td>62,771</td>
<td>1,903</td>
</tr>
<tr>
<td>Belgium</td>
<td>84,955</td>
<td>2,486</td>
</tr>
<tr>
<td>France(3)</td>
<td>357,351</td>
<td>13,787</td>
</tr>
<tr>
<td>West Germany</td>
<td>480,581</td>
<td>14,920</td>
</tr>
<tr>
<td>Great Britain</td>
<td>333,103</td>
<td>6,570</td>
</tr>
<tr>
<td>Italy(4)</td>
<td>217,979</td>
<td>4,927</td>
</tr>
<tr>
<td>Netherlands</td>
<td>62,304</td>
<td>2,432</td>
</tr>
</tbody>
</table>

1) Dead within 30 days after accident.
2) " " 3 " " "
3) " " 6 " " "
4) " " 7 " " "

Source: IRF World Road Statistics 1976-1980
The table shows that the number of persons killed in traffic accidents was decreasing by the end of the seventies. The number of injured persons was decreasing in some countries but increasing in others.

The clear positive tendency of a decreasing number of fatalities cannot alone be ascribed to the traffic safety work in these countries without reservations. There are many other factors which may have had their effect on this development. There may for instance have been a general reduction in the level of risk, due to a higher share of better drivers in the population for example. The positive tendency is, however, even more striking when we compare the reduction in the number of persons killed or injured to the increase in the number of vehicles registered or the number of vehicle miles travelled.

Table 2

NUMBER OF PERSONS KILLED(1) OR INJURED IN ROAD TRAFFIC ACCIDENTS PER 100,000 VEHICLES IN 1976 AND 1980

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>888</td>
<td>40</td>
<td>733</td>
<td>26</td>
</tr>
<tr>
<td>Denmark</td>
<td>1,283</td>
<td>54</td>
<td>916</td>
<td>42</td>
</tr>
<tr>
<td>Finland</td>
<td>997</td>
<td>68</td>
<td>610</td>
<td>40</td>
</tr>
<tr>
<td>Austria(2)</td>
<td>3,140</td>
<td>95</td>
<td>2,622</td>
<td>71</td>
</tr>
<tr>
<td>Sweden</td>
<td>714</td>
<td>38</td>
<td>625</td>
<td>28</td>
</tr>
<tr>
<td>Belgium</td>
<td>2,744</td>
<td>81</td>
<td>2,343</td>
<td>68</td>
</tr>
<tr>
<td>France(3)</td>
<td>1,916</td>
<td>74</td>
<td>1,564</td>
<td>58</td>
</tr>
<tr>
<td>West Germany</td>
<td>2,329</td>
<td>72</td>
<td>2,014</td>
<td>52</td>
</tr>
<tr>
<td>Great Britain</td>
<td>2,036</td>
<td>40</td>
<td>1,945</td>
<td>35</td>
</tr>
<tr>
<td>Italy(4)</td>
<td>1,271</td>
<td>52</td>
<td>1,166</td>
<td>45</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1,508</td>
<td>59</td>
<td>1,205</td>
<td>42</td>
</tr>
</tbody>
</table>

1, 2, 3 and 4: Same remarks as in table 1.

The number of vehicles in Table 2 refers to the sum of all vehicles, passenger cars, buses and trucks. Some countries also have a great number of motorbikes and mopeds, but the data from these countries are not comprehensive enough for data reference use.

Table 2 shows a reduction in the number of persons killed or injured per 100,000 vehicles in all countries. The relative reduction in the number of injured persons per 100,000 vehicles has been greatest in Denmark (29 per cent) and smallest in Great Britain (9 per cent).
(The number of injured persons in Finland is, however, influenced by the fact that the reporting procedures have been changed.) The relative reduction in the number killed per 100,000 vehicles has been greatest in Finland (41 per cent) and smallest in Italy (13 per cent).

In order to compare the level of risk in the various countries it is necessary to have knowledge of the level of exposure as given by the number of person kilometer of travel for example. Lack of data makes it impossible for us to estimate general values of accident risk for many countries. Data relating number of persons killed in road traffic accidents per 100,000 inhabitants give a more reliable statistic.

Table 3

<table>
<thead>
<tr>
<th>Country</th>
<th>1976</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Denmark</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>Finland</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>Sweden</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Austria</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>Belgium</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>France</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>West Germany</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>Great Britain</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Italy</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Netherlands</td>
<td>18</td>
<td>14</td>
</tr>
</tbody>
</table>

The risk of death or injury in road traffic accidents varies widely between the different European countries but was in general lower in 1980 than in 1976. I will not discuss the reasons for these differences but point out that this is of great importance regarding the benefits one may obtain from the various traffic safety measures undertaken in these countries. A high accident risk would normally mean a relative great potential for the traffic safety work and a good return on the investment in traffic safety measures. In countries where the level of risk is low it will be much harder to obtain a further reduction of this level.

The level of accident risk for the different groups of road users is varying widely. Motorbike drivers and their passengers have an extraordinary high level of
accident risk. The Norwegian data in Table 4 may deviate from similar data in other countries. The numbers of person-kilometre travel and travelling time are used as a measure of exposure to accident risk.

Table 4

LEVEL OF ACCIDENT RISK IN ROAD TRAFFIC FOR VARIOUS ROAD USER GROUPS IN NORWAY

<table>
<thead>
<tr>
<th>Road user group</th>
<th>Number of persons injured and killed per 100 mill. person km</th>
<th>Number of persons killed per 100 mill. hours in road traffic</th>
<th>Number of persons injured or killed 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
<td>Killed</td>
<td></td>
</tr>
<tr>
<td>Car Drivers</td>
<td>22</td>
<td>0.8</td>
<td>38</td>
</tr>
<tr>
<td>Car Passengers</td>
<td>23</td>
<td>0.6</td>
<td>28</td>
</tr>
<tr>
<td>Moped Drivers</td>
<td>130</td>
<td>4.2</td>
<td>117</td>
</tr>
<tr>
<td>Light motorcyclists</td>
<td>500</td>
<td>10.6</td>
<td>420</td>
</tr>
<tr>
<td>Heavy motorcyclists</td>
<td>530</td>
<td>26.7</td>
<td>1,060</td>
</tr>
<tr>
<td>Cyclists</td>
<td>70</td>
<td>2.2</td>
<td>22</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>115</td>
<td>8.1</td>
<td>31</td>
</tr>
</tbody>
</table>


The numbers are chiefly based on data from the end of the 1970s and express the big differences in the level of risk for the various road user categories. The largest number of injured and killed, however, are found among car drivers and passengers when we look at the volumes. From that point of view we find that the road user groups with the highest level of risk do not represent any sizeable problem.

The primary goal is to reduce the number of persons injured and killed regardless of category. It is, however, also politically desirable to even out the differences in the level of risk.

The risk of death in road traffic can be compared to the death risk involved with other activities. The values for risk of death connected with various activities shown in Table 5 are collected from several different sources and are therefore not completely comparable but give an impression of the order of magnitude of risk levels.
Table 5
DEATH RATES CONNECTED WITH VARIOUS ACTIVITIES IN NORWAY. NUMBER OF DEATHS PER 100 MILL. PERSON HOURS OF WORK

<table>
<thead>
<tr>
<th>Activity</th>
<th>Deaths per 100 mill. person hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing industry</td>
<td>67</td>
</tr>
<tr>
<td>Oil industry on the Norwegian continental shelf</td>
<td>205</td>
</tr>
<tr>
<td>Mining</td>
<td>18</td>
</tr>
<tr>
<td>Agriculture</td>
<td>11</td>
</tr>
<tr>
<td>Forestry</td>
<td>54</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2.4</td>
</tr>
<tr>
<td>Helicopter pilots in the oil industry on the Norwegian continental shelf</td>
<td>1,655</td>
</tr>
</tbody>
</table>

Most risk rates in traffic are high compared to other activities. The level of risk regardless of category is higher than the one found for the manufacturing industry. Even the risk level for the oil industry is lower than the highest risk level for the road users.
2. COSTS AND BENEFITS OF TRAFFIC SAFETY MEASURES

2.1. Introduction

It is most instructive to divide the impacts of traffic safety measures into two categories:

1. Direct impacts
   - Direct costs
   - Direct benefits

2. Indirect impacts
   - Indirect costs
   - Indirect benefits

The direct costs of a measure are the actual cost of an action to promote traffic safety and are always positive. The direct benefits are expressed as the reduction in the number of accidents or as a reduction in the accident costs when a cost-benefit analysis is to be performed. The direct benefits of a traffic safety measure will also be positive as far as the effects of the measure are positive. A reduction in the degree of severity of the traffic accidents would thus yield direct positive benefits.

The indirect impacts of a traffic safety measure can be positive or negative depending on the type of measure. These impacts consist of changes in the road user costs such as time costs and vehicle operating costs and also of environmental costs. In addition to these costs we must also consider the indirect impacts of an action when the capital resources are limited. The latter will be discussed at a later stage.

2.2. Direct costs

As mentioned before, it is of little value to give general recommendations with regard to the direct costs of traffic safety measures by listing the actual or calculated costs from individual projects. It would be of greater interest to look at factors which are decisive for the costs and how they vary with the different types of measures.
There are two factors in particular which are decisive with regard to the direct costs for a project. These are the design of the measure and the conditions at the location of the project. I am here primarily thinking of projects where changes in road design and environment are affecting the accident level.

The standard of a traffic safety measure can be defined as the qualitative or quantitative level of a variable which may describe the measure. Table 6 shows some measures and the variable which best describes the project standard.

Table 6

<table>
<thead>
<tr>
<th>Measure</th>
<th>Standard expressed in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road lighting</td>
<td>Luminance, cd/m²</td>
</tr>
<tr>
<td>Curve straightening</td>
<td>Curve radius, m</td>
</tr>
<tr>
<td>Police surveillance of drunken driving</td>
<td>Number of police controls per year</td>
</tr>
<tr>
<td>Speed limits</td>
<td>Reduction of running speed</td>
</tr>
<tr>
<td>Sanding of roadway</td>
<td>Quantity of sand per m² roadway</td>
</tr>
</tbody>
</table>

The relationship between costs and standard will vary from project to project. Generally speaking the costs will increase with increasing standard, the relationship can be linear or curved with a progressive increase. A regressive increase in the costs is hardly possible. Local conditions will often determine how fast the costs increase with increasing standard. Typical of this are projects involving curve straightening in mountainous terrain where increasing the curve radius gives a progressive increase in the costs.

Reduced speed limits on the other hand represent the other extreme in the relationship between costs and standard. When introducing a speed limit it does not matter what this limit is where costs are concerned, the signs have to be put up all the same. The marginal costs are in other words zero. On the other hand, the lower limits the greater is the need for enforcement by the police, implying that the marginal cost will be positive, either constant or increasing.

Many projects will not have a clear relationship between the costs and the standard of the improvement. This is due to the fact that the standard may not always
be expressed either quantitatively or qualitatively. Improving the safety for pedestrians when crossing the road is often done by:

1. Marking the crossing.
2. Installing pedestrian signals.
3. Building a grade separation.

None of these improvements is easily defined by any particular standard measure. Other examples are improvements such as mandatory seat belt use and limits for the intake of alcohol when driving. Such measures result in discontinuous cost functions.

The potential of a traffic safety improvement is normally expressed as the number of accidents it will affect or the number of injured or killed. It will in this way determine the costs of an improvement. The optimum standard of an improvement will increase with an increase in the potential and thus result in increased costs. This depends however on whether the accident potential is the result of high risk or high exposure. The indirect impacts are mostly related to exposure and will in that respect be of importance.

The direct costs have different characteristics and size depending on the type of improvement or measure. Some improvements have big investment costs and low operating costs. Others have only running costs through the period of instalment. This can be illustrated by listing traffic safety improvements in a number of categories:

1. Primary or high level measures or policies which affect the exposure or the amount of travel (person kilometres) and its distribution to the various types of transportation vehicles.
2. Physical improvements which affect the accident frequency through changes in road design or environment.
3. Traffic regulations which affect the accident frequency through changes in the individual's behaviour or use of the road network.
4. Traffic safety improvements related to the vehicle or driver/passenger which affect the accident frequency or the severity of the accidents.
5. Enforcement of traffic rules and regulations which affect the accidents with high level risks in particular.
6. Other actions or improvements.

Primary or high level measures or policies which reduce the number of accidents through a reduction in travel (person/kilometre per year) are often motivated by other reasons than concern with traffic safety. An example is the tax on vehicle fuel which is motivated by financial
reasons since this is a source of income for the public administration. Measures which are intended to help transferring people and travel from the private automobile to mass transit are often motivated from the need to reduce noise and air pollution in urban areas and not from the need to improve traffic safety.

The direct costs from using high level measures or policies (expressed as changes in the use of resources) which affect traffic safety directly or indirectly are relatively low in general. The effects on the public finances can sometimes be great, however. Indirect costs from such policies can be large, particularly with regard to measures which are intended to reduce the exposure.

Physical improvements usually involve large direct costs but there are considerable variations in the costs from project to project. Most of the improvements are motivated by concern for traffic safety; in some cases, however, the transportation function of the road may also play a significant role. This is particularly true with respect to the maintenance of the road network which may be defined as part of physical improvements.

Changes in the road curvature (straightening or enlarging curves) is an example of a relatively expensive improvement, especially in mountainous terrain. Construction of motorways is also very expensive and can hardly be defended from the traffic safety point of view alone unless the traffic volume is very high. Simple improvements at road intersections and junctions such as channelling the approaches is an example of an inexpensive improvement.

Traffic regulations which are intended to improve traffic safety are usually inexpensive for the public administration to introduce (direct costs). The introduction of speed limits is an example of such an inexpensive measure where the costs for the traffic signs are relatively low. Even less costly is the introduction of right-of-way regulations at an intersection where the money spent for signposts is negligible.

Types of traffic regulatory measures which increase traffic safety to the detriment of the transportation function or travel speed usually result in high indirect costs, however.

Traffic safety improvements related to the vehicle or driver/passenger conditions are usually inexpensive from the view of the public agencies. The costs for the road users can, however, become quite considerable i.e. the requirement for anti-blocking brakes. They may also be relatively small, such as the requirement to
have a signal arm on a bicycle. In Norway the vehicle owner's expenses for traffic safety improvements on vehicles do not reflect the economic costs because of the high taxes paid for their import and use.

**Enforcement of legal traffic rules and regulations** is necessary to ensure that they are followed or to reduce the relatively high number of traffic violations in society. The direct costs for enforcement are to a great extent dependent on the degree of surveillance (defined as a standard) and on the type of methods used. Surveillance performed automatically is most likely to be less expensive per violation than a similar manual method.

If measures in this category are to produce a real reduction in the number of accidents, enforcement has to be comparatively rigid and the legal repercussions have to be severe. This results in relatively large direct costs.

On the basis of these considerations I conclude that the direct costs for safety improvements vary from measure to measure, from improvement to improvement and from project to project. There seems to be a tendency, however, that measures involving small direct costs can result in high indirect costs. This is very important to remember when calculating the profitability of a particular measure.

The experience in Norway regarding traffic safety measures probably may be valid also in other countries. A direct comparison of the costs between the different countries is difficult, however, because of differences in the average wage levels, degree of mechanisation within the highway agencies and, last if not least, differences in the technical solutions.

2.3. Direct benefits

Fewer accidents and/or lower degree of severity are the direct benefits of traffic safety work. In order to estimate the benefits from various improvements or measures, the benefits are usually expressed in terms of reduced accident costs. The direct benefits of a traffic safety improvement are dependant on several conditions. The two most important are:

a) The accident potential at which the improvement is aimed.

b) The effect of the improvement or measure.

The benefits of the improvement are the product of the number of accidents which the improvement aims to reduce (accident potentiality) and the effect of the improvement.
The direct benefits of an improvement will in most cases increase in proportion to its potentiality. Differences in the potentiality between countries are therefore the most important cause of the difference between the countries regarding benefits from various improvements. In Norway and in countries with similar accident records the benefits of a particular improvement are relatively modest.

The effect of an improvement or a measure is dependant on several conditions. Local conditions will undoubtedly influence the effects. Generally there are two factors of great influence:

a) The accumulated use of resources.

b) The standard of a particular measure which in this case means the costs of implementation.

Today there are several traffic safety improvements which have been implemented in one form or another and to varying degrees. They may have been given priority according to a decreasing benefit-cost ratio. It must be decided whether to increase the expenditures to improve the standard of a particular measure or to increase the number of places where a particular measure may be implemented. In this case it is also important to know whether other improvements have been implemented earlier at particular locations to reduce traffic accidents. The benefits of a particular improvement are therefore dependent on the accumulated use of resources for the total traffic safety work and the particular improvement.

As pointed out previously an explicit relationship exists between the costs of a measure or improvement and its standard. This relationship also connects the effect of an improvement to the amount of resources which are allocated to it. If the use of resources is considerable, a greater effect is to be expected than if the expenditures are small.

These conclusions are summed up in Figure 1 where the costs of implementing a traffic safety measure are represented by values along the x-axis and the benefits (reduced accident costs) are represented by y-axis values. Both variables are calculated at present values.

The accident potentiality which the measure is aimed at is represented by the shape of the curves. Curve A represents a great potential and curve B a lesser potential. If the existing use of resources is $K_1$, and the use increases with $\Delta K$, this will result in an increase of $\Delta N_1$, in the benefits on curve B which are less than the increase $\Delta N_2$ on curve A.
Considering curve B, we see that an increase in the costs of $\Delta K$ yields an increase in benefits of $\Delta N_1$, when the accumulated costs are $K_1$. Similarly the increase in benefits is $\Delta N_3$ when the accumulated costs are $K_2$. We also observe that $\Delta N_3$ is considerably smaller than $\Delta N_1$.

The last case can be illustrated by looking at two different increases in costs from the basic level of $K_1$. A cost increase $\Delta K$ yields an increase in benefits $\Delta N_1$, while an increase in costs of $2 \cdot \Delta K$ yields an increase in benefits of $\Delta N_1 + \Delta N_4$. When $\Delta N_4$ is greater than zero the effect of a $2 \cdot \Delta K$ use of resources for a measure is greater than when using only $\Delta K$.

In the literature there is ample proof of the effects of traffic safety improvements but information on the direct costs of such improvements is lacking. In addition, the estimated or calculated effects are often full of uncertainty, which in its turn makes the calculated benefits questionable or uncertain. It is therefore necessary to point out some of the most common problems encountered when calculating the effect of an improvement on accident reduction and which may explain why an improvement may show positive benefits in one place and negative results in another.
The random variation of accidents. The number of accidents varies over time. When studying the accident statistics of a relatively limited area such as an intersection, this randomness can have a great impact on the yearly accident statistics. If a local traffic safety improvement is implemented while the number of accidents is high, a decrease in accidents may well be mainly due to this random variation. This is an important source of error when estimating effects if no proper corrections and adjustments are made to allow for this.

Limited or biased accident statistics often present problems for the estimation of the effects of local physical improvements on accident volumes. In Norway the accident volume in many cases is simply too small to permit reasonably good estimates of the safety effects of an improvement. The accuracy of reporting also varies from year to year and thus makes the basis for the estimation even more uncertain. The most reliable statistic is the number of persons killed, but this number is in most cases too small to draw statistically significant conclusions.

Correlated variables. To directly evaluate the reduction in accidents is not always possible. The effect of an improvement can in some cases be evaluated for one or more variables which are thought to be related to the accident risk. Examples of such variables are speed, friction factors, and conflicts between road users in the traffic stream. It is difficult to determine if the effect of the improvement for these variables will yield the same results as a direct evaluation of accident reduction. This then leads to uncertainty in the evaluation of the benefits.

Effects of other factors. During the observation time of the effects of an improvement, there are other factors which may affect the development of accidents. It may often prove to be very difficult to control and correct the effects of these factors. The limited possibility of making controlled experiments results in additional uncertainty in the estimation of the effects.

The considerations regarding uncertainty connected with the estimation of the effects of traffic safety improvements are also valid regarding the calculated benefits since they are directly related. Depending on the extent to which the uncertainties can be eliminated, the same improvement will give different benefits from project to project even though the potential may be the same.
2.4. Accident costs as inputs in cost-benefit analyses

Loss of life, personal injuries and property damage caused by traffic accidents represent a loss of resources in economic terms. Partly there is a loss of productivity, i.e. reduced amount of manpower or work capacity and partly there are resources spent on repairs and treatment of injuries to persons and property caused by traffic accidents.

The calculation of a loss of income does not express the total loss the society suffers from the traffic accidents. The costs only illustrate the changes in the economic costs or in the material goods being shared.

The accident costs involved in the calculations consist of four main components:

1. Loss of manpower. This cost component is an expression of the loss to society of the productive manpower, be it permanent or temporary.
2. Medical costs. These are in principle all costs connected with the medical treatment of injured persons. Medical costs include both medical treatment and costs of hospitalisation.
3. Cost of repairs. These ideally include all repairs to damaged property and the replacement of irreparable property.
4. Institutional costs consist of the cost of police work, legal costs, insurance costs and medicare or medical security costs which include the costs of handling the accident cases.

The economic costs only represent minimum costs. The loss to society from traffic accidents will therefore always be greater than what is expressed by the economic costs.

In Norway the average accident cost of a personal injury is calculated at about Norwegian kroner 118,000 and, for property damage accidents at Norwegian kroner 17,000 (as at 1st January, 1983).

Accidents involving property damage only are much more numerous than personal injury accidents. The reporting of property damage accidents is, however, very incomplete and the exact number of such accidents is unknown. On average it is nevertheless estimated that there are about 15 property damage accidents for each personal injury accident. This fact constitutes the basis for calculating the average total accident cost per personal injury as the combined costs of one personal injury and of 15 property damage accidents. This makes a total cost of Norwegian kroner 370,000.
If required, the costs can be specified for different accident categories within or outside built-up areas. The accident categories will represent different costs due to differences in accident severity (the proportion of number of killed to number of injured) and differences between the proportion of personal injuries to property damage only.

On the basis of Norwegian accident statistics, it is possible to estimate factors which, multiplied with the accident costs of a personal injury (118,000 Norwegian kroners), will yield the average cost of different accident categories when the degree of severity and various numbers of property damages per personal injury are considered.

Table 7

FACTORS TO BE USED FOR ESTIMATION OF ACCIDENT COSTS FOR DIFFERENT ACCIDENT CATEGORIES AND LOCATION

<table>
<thead>
<tr>
<th>Accident Category</th>
<th>Urban Area</th>
<th>Rural Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Rear</td>
<td>5.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Opposite Direction</td>
<td>1.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Intersection</td>
<td>3.0</td>
<td>4.9</td>
</tr>
<tr>
<td>Pedestrian accident</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Single Vehicle</td>
<td>2.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Others</td>
<td>2.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>3.2</td>
</tr>
</tbody>
</table>

The factors are calculated on the assumption that a safety improvement has the same effect on personal injury accidents as on accidents causing only property damage. An improvement which reduces the number of rear-end accidents with personal injury will at the same time produce a considerable reduction in the number of property damage-only accidents. The reduction of accident costs for one personal injury will on this basis amount to Norwegian kroner 600,000 (118,000 • 5.1) if the rear-end accident occurs in an urban area.

Accident costs are closely connected to the level of income in a society. Costs therefore differ from country to country. This is also one of the reasons for the difference in benefits found from various improvements since they are related to the reduction in accident costs.
2.5. Optimum benefits of traffic safety improvements

Both costs and benefits will depend on the standard of the improvement we have shown previously. When considering the effective use of resources the standard should be such that the sum of the accident costs and the cost of implementing the improvement are minimised. This is equivalent to demanding that the net benefits of the improvement should be maximised.

Figure 2 illustrates how the different cost elements and the criteria for standard are related.

The optimum standard is found in principle as the derivative of the total costs $t(s)$ with respect to $s$ and by equalling the derivative to zero.

$$\frac{dt(s)}{ds} = \frac{dk(s)}{ds} + \frac{du(s)}{ds} = 0$$

$$\frac{du(s)}{ds} = -\frac{dk(s)}{ds} ; \quad \frac{du(s)}{ds} = -1$$

This expression shows that the optimum standard is reached at the point where the tangents to the accident cost curve and the implementation cost curve have equal slopes but different directions.
The benefits from a safety improvement as given by reduced accident costs and implementation costs can in principle be represented as in Figure 3.

**Figure 3. BENEFITS FROM TRAFFIC SAFETY IMPROVEMENTS AS A FUNCTION OF IMPLEMENTATION COSTS**

The line L represents a benefit-cost-ratio of a magnitude equal to 1. The tangent to the curve at point P has the same slope as the line L and this point determines benefits and costs by optimum standard \((N_{\text{opt}}, K_{\text{opt}})\). At this point the marginal benefits are equal to the marginal cost and the marginal benefit-cost-ratio is equal to 1. The benefit-cost ratio is represented by \(N_{\text{opt}}/K_{\text{opt}}\), however.

The mathematical relationship between benefits, costs and standard are unknown for most of the improvements. Because of this the resources are seldom efficiently used and this non-optimum use results in a waste of resources. Also, there are improvements which are not carried out because the benefit-cost-ratio is less than one while a reduction of the improvement standard may have resulted in an acceptable benefit-cost-ratio and implementation of the improvement.

Figure 3 represents an improvement which may be implemented at a particular location and at a particular time. The curve may also represent an improvement executed at different locations and at different times but which has a given standard and is implemented according to falling values of the benefit-cost-ratio.
The total resources which ought to be allocated to this improvement are given by \( K_{opt} \) because the marginal benefit-cost-ratio is one (1) at this location.

2.6. **Indirect impacts of traffic safety improvements**

The indirect impacts have previously been labelled as changes in the road user time costs, vehicle operation costs and environmental costs. A limitation of resources will also affect the indirect impacts of traffic safety improvements.

**Time costs**

As long as travel time is looked upon as a nuisance the road users are willing to pay to reduce it. The willingness to pay is dependent on travel purpose and, if calculated per vehicle, on the number of occupants.

The time costs are directly related to the speed of travel, the average operating speed. Traffic safety improvements which consist of physical measures and traffic regulations, will normally influence the average operating speed. Typical examples of this are speed limits which may yield big differences, and enlargement or straightening of curves if the existing curves are relatively small (less than 250 m).

The road user's estimation of travel time in Norway is put at about Norwegian kroner 38 per hour when travelling in a passenger car.

**Vehicle operating costs**

Vehicle operating costs are normally divided into two parts: fixed costs and variable costs. The fixed costs consist of costs which are not influenced by the operation of the vehicle as opposed to the variable costs. Where safety improvements are concerned it is the variable costs which are primarily influenced.

The variable costs are dependent on a number of factors. It is primarily changes in travel speed which influence the costs. Figure 4 illustrates the relationship between operating speed and the variable costs.

Certain traffic safety measures also change the operational smoothness in such a way that a constant level of speed cannot be maintained, which in turn affects fuel consumption. Examples of such measures are road humps and roadway-narrowing.
Environmental costs

Traffic safety improvements affect both noise and air pollution caused by the automobile traffic. In Norway all private cars use studded tyres in the Winter and the noise level in this season is significantly higher (3-5db A), than in the Summer. If the consequent increased need for sound barriers were known, we could calculate the costs of the increased noise level.

The use of studded tyres also incurs other costs. It is estimated that the use of such tyres causes damage to the roads which requires 240,000 tons of pavement material each year to repair. This contributes greatly to the pollution of the environment - not to mention the costs of the added maintenance.

The air pollution caused by motor vehicles is, among other factors, dependent on fuel consumption. This means that as fuel consumption increases so will air pollutants. As the number of accelerations and brakings increases so does the incomplete combustion of fuel, resulting in more air pollutants.

Traffic safety improvements also can result in barrière effects where traffic is restricted from using certain roads and is rerouted to avoid through movements, for example. Such effects may be difficult to assess, especially where pedestrians and cyclists are concerned.
Travel demand

Traffic safety measures which aim at reducing the exposure to traffic accident risks through reductions in the amount of personal travel will reduce the consumer's surplus. A measure of this kind could be the introduction of added taxes on vehicle fuel to reduce travel demand. The result of such an action is illustrated in Figure 5 where the loss in consumers' surplus due to reduction in travel demand is represented by the shaded area.

Figure 5 CHANGE IN TRAVEL DEMAND AS A FUNCTION OF TAX INCREASE

The travel demand before the tax increase is \( X \) and the tax dependent travel cost \( P_0 \). After the tax increase the travel demand is reduced to \( X_1 \), as the travel cost increases to \( P_1 \). The loss in the consumer's surplus as represented by the shaded area \( A \) can be approximated using the expression:

\[
A = \frac{1}{2} (X_0 - X_1) (P_1 - P_0).
\]

The increased income to public administration from the tax increase is represented by the rectangle \( I \) which area is represented by \( I = (P_1 - P_0)(X_1) \). This area also
represents a change in the consumer's surplus but the tax income will mean a redistribution of the total wealth in society, the effects of which will depend on how the benefits for the society of the marginal value compares with the individual consumer's marginal benefits.

Traffic safety improvements which reduce the accident risk can under certain conditions increase travel activity. Referring to Figure 5 this increase is illustrated by a shift of the travel demand curve to the right. This means an increase in the consumer's surplus which in turn is an indirect benefit of the improvement. The increase in travel demand will on the other hand result in an increased number of accidents through increased exposure. The total effect may therefore be somewhat reduced.

An example in kind of such effects of a traffic safety measure was the introduction of studded tyres in Norway in the middle of the 1960s. The use of studded tyres has increased over the years and today almost all passenger cars use such tyres in Winter. At the same time the amount of travel in the Winter season has increased from 37 per cent to 45 per cent of the yearly amount. This increase may be due to the public's increased feeling of safety using the studded tyres. Whatever the safety effects may have been from the use of these tyres these effects have, however, been reduced by the increase in travel.

Opportunity cost

If the potential benefits from traffic safety improvements are great there will be more profitable projects than resources available for their implementation. In such cases we may introduce the concept called "opportunity cost of capital", which should also be considered in the cost-benefit analysis.

The opportunity cost of capital of an improvement is defined as the net benefits which could be achieved by alternate uses of the resources. These net benefits are mirrored in the "limited resources factor" which expresses the probable net benefits per invested kroner obtained if investing in the marginal safety improvement.

The limited resources factor may also be used as the internal rate of return in the marginal traffic safety improvement. Figure 6 illustrates the relationship between the limited resources factor and the internal rate of return. In cases without limited resources (i.e. the total number of all profitable projects is less than the available resources) the internal rate of return will equal the social rate of discount for a particular improvement.

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Referring to Figure 6 we see that when the limited resources factor is equal to one (1) it is reasonable to assume that the supply of resources is moderate, i.e. the internal rate of return for the marginal traffic safety improvement is about 17 per cent when the social discount rate is 7 per cent.

Figure 6  THE INTERNAL RATE OF RETURN FOR THE MARGINAL TRAFFIC SAFETY IMPROVEMENT AS A FUNCTION OF THE LIMITED-RESOURCES-FACTOR AND THE SOCIAL RATE OF DISCOUNT

Limited resources will influence the optimum standard of the traffic safety improvement. The cost function as shown on pages 17-18 will in this case be expressed as:

\[ t(s) = u(s) + k(s) + \lambda k(s) \]

where \( \lambda = \) limited-resources-factor and \( \lambda k(s) = \) net benefits of alternate use of resources

The optimum standard can be found as the derivative of the above equation and equalling the derivative to zero:

\[ \frac{dt(s)}{ds} = \frac{du(s)}{ds} + (1 + \lambda) \frac{dk(s)}{ds} = 0 \]
This will yield a lower optimum standard than when resources are unlimited. Figure 7 which is based on Figure 3 illustrates this situation.

Figure 7 THE EFFECT OF LIMITED RESOURCES ON THE BENEFITS AND COSTS OF AN IMPROVEMENT

The optimum benefit is labelled $N_{\text{opt}}^x$ and the optimum cost is labelled $K_{\text{opt}}^x$ in the case of limited resources.

2.7. The benefits of improvements which apply to the same accident potential

In the previous analysis the fact that several measures are implemented at the same time and thus affect the same number of potential accidents is not considered. The benefits of improvements which influence the same accident potential are less than the sum of the benefits of the improvements when they do not affect the same accident potential.

In order to calculate the total benefits the number of accidents after the safety improvement can serve as the basis. This accident volume is equal to the accident potential less the benefits of the improvement.
\[ R = P - P'\cdot E \]

where \( P = \text{potential} \)

\( E = \text{effect of improvement} \)

\( R = \text{number of accidents after the implementation of the improvement (remaining accident volume)} \)

The benefits of the improvement are the same as given before (page 119), \( P'\cdot E \).

The relative remaining accident volume, \( R/P \), is expressed by:

\[ \frac{R}{P} = 1 - E \]

The number of accidents after two or more improvements have been implemented is the product of their relative remaining accident volume multiplied by the potential. The total effect of \( n \) improvements is then:

\[ E(n) = 1 - \prod_{i=1}^{n} (1 - E_i) \]

The total benefits of \( n \) improvements is given by:

\[ N(n) = PE(n) \]

The total implementation costs is the sum of the individual improvement's implementation costs:

\[ K(n) = \sum_{i=1}^{n} K_i \]

The benefit-cost ratio will be lower than if the improvements had influenced separate accident volumes or potential.
3. A PRACTICAL APPROACH

The preceding analysis has illustrated that the benefits and costs of traffic safety measures are dependent on a number of factors. These factors vary from project to project as well as between different countries.

As a supplement to the theoretical approach the benefits and costs of some improvements are given on the following pages where some economic analysis has also been made. The improvements which are considered are:

1. Establishment of roadway illumination.
2. Speed limits.
3. Withdrawal of pedestrians' present right to cross against red signal.
4. Instalment and mandatory use of seat safety belts.

The analysis of these measures is based on data from Norway as far as costs of implementation and the accident potential are concerned. The effects of the improvements have in some cases been estimated in other countries, however.

3.1. Roadway illumination

Road illumination is one of several improvements which reduces the number of accidents which take place after nightfall. The experience from most countries is that the accident-reducing effect is greatest on roads where a relatively high proportion of the accidents took place after dark.

Direct benefits

The direct benefits expressed as the reduction of accidents per kilometre are the product of accident density (accident per kilometre per year) the share of accidents after dark and the effect of the improvement. In Norway the proportion of night-time accidents is on the average 35 per cent. The effect of the improvement is defined as $E = (M - M_B)/M$, where:
E = the effect of road illumination expressed as a part of the night-time accidents

M = number of accidents before illumination

MB = number of accidents after illumination

The effect is dependent on the standard of illumination given by the luminance (cd/m²) and the proportion of night-time accidents (L1):

\[ E = \left(1 - \frac{0.66 \cdot e^{-0.42 \cdot L}}{m/(1 - m)}\right) \]

where

m = proportion of accidents after dark
L = average level of illumination
e = basis for the natural logarithms (2.7183)

On a road section where illumination would be required the proportion of night-time accidents would be about 50 per cent.

Direct costs

The direct costs of illumination consist of construction costs and operating costs. On the basis of experience gained from Norwegian projects we have established a relationship between construction costs, a(L) and the standard of illumination:

\[ a(L) = 130,000 \cdot e^{0.11 \cdot L} \text{ (kroner per kilometre)} \]

This cost function is valid for \( L \geq 0.5 \text{ cd/m}^2 \) and road lighting with open air cables.

The relationship between the operating costs, d(L) and the standard of illumination is expressed as:

\[ d(L) = 4500 + 3300 \cdot L \text{ (kroner per km per year)} \]

All costs are in 1983 kroner.

Indirect impacts

Illumination of roadways has a number of indirect impacts which are difficult to quantify. Some of these impacts are:

- Operating speed: is increased and more constant.
- glare: glare from oncoming vehicles is reduced.
- Optical guidance: roadway illumination gives good optical guidance even in daylight hours when light supports are placed for this purpose.
- Capacity: road capacity may be increased.
- Driving comfort: stress from night driving is reduced.
Security: the general feeling of security is increased for the drivers and other road users as well as for people residing in the vicinity of the road.

Roadway lighting will generally only give positive indirect impacts in addition to the direct benefits from the installation.

Comparison of benefits and costs

The analysis is based on recommendations from the Commission Internationale de l'Eclairage (CIE) which uses present values in the calculations (L2).

The average life of a roadway lighting installation in Norway is about 25 years. This period is used as the time basis for the analysis. The social rate of discount is about 7 per cent per annum in Norway and this is the real(1) interest rate.

Norwegian accident statistics show that the accident severity is greater in darkness than in day light. This is the reason for using an accident cost of kroner 177,000 per personal injury. There is no indication that illumination will reduce the number of property damage accidents.

Relative prices and costs are estimated to be constant in the time period considered. The general reduction in risk is expected to be evened out by the increase in exposure. The yearly costs and benefits are discounted to present values by multiplication with a factor $D = 11.65(2)$.

The benefits of roadway illumination expressed as the present value of reduced accident costs are hence:

$$N(L) = 177,000 \cdot UT \cdot m \cdot D \cdot \left(1 - \frac{0.66 \cdot e^{-0.42 \cdot L}}{m/(1 - m)}\right)$$

kroner per kilometre where $UT = \text{accident density (accidents/km/year)}$

The present value of the costs, $k(L)$ is given by:

$$k(L) = 130,000 \cdot e^{0.11 \cdot L} +$$
$$D(4500 + 3300 \cdot L) \text{ (kr/km)}$$

1. Real interest rate = interest rate after the inflationary rate has been subtracted from the nominal interest rate.
2. $D = 25 \cdot 1.07^{-i}$
On the basis of these expressions the benefits may be expressed as a function of the costs of different accident potential as given by the accident density. Night time accidents account for about 50 per cent of the total (Figure 8).

The net benefits of the measure are given by:

\[
1(L) = 177,000 \cdot UT \cdot m \cdot D \cdot \left(1 - \frac{0.66 \cdot e^{-0.42 \cdot L}}{m/(1 - m)}\right) \\
- 130,000 \cdot e^{0.11 \cdot L} - D(4500 + 3300 \cdot L)
\]

By finding the derivative of this expression for net benefits with \( L \) as the variable and setting the derivative equal to zero it is possible to find what level of luminance maximises the net benefits of the measure (called optimum standard). In Figure 9 the derivative is shown as a function of \( L \) for different values of the accident density (potential).
Figure 9: Relationship between level of luminance and the derivative of the function of net benefits $dI(L)/dL$ for different values of accident potential.

Figure 10: Level of luminance corresponding to different values of net benefits and different accident potential.
The optimum level of luminance is given by the points where the curves cross the horizontal axis. This optimum can also be found by drawing curves for the net benefits function for different values of accident potential as shown in Figure 10.

Figure 11 RELATIONSHIP BETWEEN COSTS AND BENEFITS AT DIFFERENT POTENTIALS

The figures illustrate the conclusion from the theoretical analysis, that the optimum standard to be used for a measure is dependent on the accident potential, given as accident density in this example. Benefits and costs are dependent on choice of standard as well. Figure 11 illustrates the optimum benefits and cost levels at different accident potentials.
The curve, Q, showing the optimum ratio at the various accident potentials expresses the maximisation of the net benefits of the installation. At the points where the slope of the tangent to the curve is less than one (1) the net benefits are negative.

In the paragraph about opportunity cost it was shown that limited resources will result in a lower optimum standard. The net benefits resulting from an alternate use of the resources are in this case given by $\lambda \cdot a(L)$ where $\lambda = "\text{limited-resources-factor}"$. The function for net benefits $l(L)$, when resources are limited is given by:

$$l(L) = 177,000 \cdot UT \cdot m \cdot D \cdot \left(1 - \frac{0.66 \cdot e^{-0.42 \cdot L}}{m/(1 - m)}\right) - (1 + \lambda) \cdot 130,000 \cdot e^{0.11} \cdot L - D(4500 + 3300 \cdot L)$$

As previously shown we find the derivative of this function with respect to $L$ and equal it to zero to find the optimum level of luminance. Figure 12 illustrates the relationship between the derivative and luminance when the accident potential is 0.8 accidents/km/yr and the resources are either limited, $\lambda = 1$, or unlimited, $\lambda = 0$.

---

**Figure 12. RELATIONSHIP BETWEEN THE DERIVATIVE OF THE FUNCTION OF NET BENEFITS $d(l(L))/dL$ AND THE LUMINANCE AT VARIOUS DEGREES OF LIMITATION OF RESOURCES ($\lambda$) AND WHEN ACCIDENT POTENTIAL IS 0.8 ACCIDENTS/KM/YEAR**
The optimum level of luminance defined as the points of intersection of the curves with the x-axis, is reduced from 3.2 cd/m² to 2.6 cd/m² when the resources become limited as opposed to unlimited. The net benefits of the measure are also reduced by more than 50 per cent. The benefits are, however, still greater than the costs (direct + indirect) after the resources have become limited.

The importance of limited resources for the benefits and direct costs under the variable circumstances described is illustrated in Figure 13. The opportunity costs of capital are not included in the cost values given on the horizontal axis in the figure.

*Figure 13. ILLUSTRATION OF THE IMPACT OF LIMITED RESOURCES ON THE BENEFITS AND COSTS*

![Graph showing benefits and costs](image)

Point "m" corresponds to $\lambda = 0$, i.e. the available resources are great enough to realise all profitable traffic safety measures.
Point "n" corresponds to \( \lambda = 1 \), i.e. the limitation of resources is effective and the optimum combination of benefits and costs is smaller than at point "m".

The basis for these calculations is the demand for maximisation of the net benefits of the measure. As mentioned before this demand is equivalent to a demand for minimisation of the total costs.

3.2. Speed limit reductions

Introduction

Our desire for short travel times may lead to high travel speeds. Higher speeds are, however, often associated with an increased number of accidents. Higher speeds increase driver reaction distance as well as the braking distance which increase with the square of the speed, and these factors in turn increase the probability for an accident to happen and its degree of severity. A reduction of speed through lower speed limits therefore seems justified from a traffic safety point of view.

In Norway the general maximum speed limit is 80 km/h and in addition there are several special speed limits. Table 8 shows the total length of the national primary roads and the relationship between speed limits, accidents per year and average daily traffic (ADT).

Table 8

<table>
<thead>
<tr>
<th>Speed limit km/h</th>
<th>Length km</th>
<th>Number of accidents/year</th>
<th>Average daily traffic (ADT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>560</td>
<td>40</td>
<td>2,100</td>
</tr>
<tr>
<td>80</td>
<td>18,800</td>
<td>1,500</td>
<td>1,050</td>
</tr>
<tr>
<td>70</td>
<td>665</td>
<td>250</td>
<td>3,400</td>
</tr>
<tr>
<td>60</td>
<td>3,595</td>
<td>1,500</td>
<td>2,700</td>
</tr>
<tr>
<td>50</td>
<td>1,380</td>
<td>1,150</td>
<td>3,200</td>
</tr>
<tr>
<td>Sum total</td>
<td>25,000</td>
<td>4,440</td>
<td>1,500 (1)</td>
</tr>
</tbody>
</table>

1. Average daily traffic for total road length.
It is not considered feasible to reduce the general speed limit on rural roads in Norway. Instead there is an increasing interest in introducing special speed limits on parts of the national primary network in order to reduce the number of accidents. As an example I shall estimate the benefits and costs involved by reducing the speed limit on 20 per cent of road lengths from 80 km/h to 70 km/h. This would increase the proportion of length of road with 70 km/h speed limit from 3 per cent to 18 per cent.

**Direct benefits**

Direct benefits are dependent on the potential and the effect as defined in this paper. The effect is dependent on the reduction in operating speed as illustrated in Figure 14 (L3).

![CALCULATED REDUCTION IN ACCIDENTS RELATED TO REDUCTION IN OPERATING SPEED (L3)](image)

It is estimated that a reduction in the general speed limit from 80 km/h to 70 km/h will result in a 7.5 per cent reduction in the operating speed. This results in a 25 per cent reduction in the number of accidents as illustrated in Figure 14.

The benefits are dependent on the accident density (acc/km/yr) on that part (20 per cent) of the road network which will have the speed limit reduced. It seems
logical to reduce the speed limit on the sections which have the highest accident density. About 40 per cent of the accidents are associated with these sections which represent 20 per cent of the roads with an 80 km/h speed limit. The benefits of such a measure, expressed as a reduction in accident costs, are about 56 million Norwegian kroner per year. It is then presumed that the measure will have the same effect on property damage accidents as on personal injury accidents.

**Direct costs**

The direct costs consist of costs for signs and their installation.

The basis for the cost estimation of the signposting is three signs per km at a cost of Norwegian kroner 1,000 per sign. The direct costs are thus calculated to be about 11 million kroner.

In addition the yearly costs for maintenance and replacement of signs will increase by about 1 million kroner per year.

**Indirect impacts**

The reduction in operating speed increases the road users time costs and reduces the vehicle operating costs. The calculation is based on a traffic composition of 90 per cent private cars and 10 per cent trucks.

A reduction in the speed limit from 80 km/h to 70 km/h results in an increase in travel time of 0.00116 h/km. The amount of vehicle travel may be estimated from Table 8. The increase will amount to about 154 million kroner per year.

The reduction in operating speed means a reduction in variable costs of about 4 per cent for private cars and 10 per cent for trucks or heavy vehicles. The introduction of a lower speed limit would hence reduce the vehicle operating costs by about 60 million kroner per year.

**Comparison of benefits and costs**

Reduced speed limits result in relative low direct costs but high indirect costs. Table 9 shows a comparison between the different benefit and cost factors where positive values indicate benefits and negative values indicate costs.
Table 9

BENEFIT AND COST FACTORS PERTAINING TO THE USE OF SPEED LIMITS AS A TRAFFIC SAFETY MEASURE

<table>
<thead>
<tr>
<th>Factor</th>
<th>Costs and benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct benefits, reduced accident costs, mill. kroner/yr</td>
<td>56</td>
</tr>
<tr>
<td>Direct costs, maintenance of signs, mill. kroner/yr</td>
<td>-1</td>
</tr>
<tr>
<td>Indirect benefits, reduced vehicle operation costs, mill. kroner/yr</td>
<td>60</td>
</tr>
<tr>
<td>Indirect costs, increased time costs, mill. kroner/yr</td>
<td>-154</td>
</tr>
<tr>
<td>Sum total, mill. kroner/yr</td>
<td>-39</td>
</tr>
<tr>
<td>Direct costs, investment costs, mill. kroner</td>
<td>-11</td>
</tr>
</tbody>
</table>

The yearly benefits and costs are summed and result in a negative value. This means that the costs are greater than the expected benefits. Also there are other direct costs such as investment costs which make the negative net benefit even greater.

The direct benefits are coupled to the accident potential which is expressed as the product of risk and exposure. If the measure is to give positive net benefits the accident potential has to be considerably greater. If the greater potential is caused by greater exposure it will not have any positive effect because the indirect impacts will also increase in the same way. The accident risk on a rural road network with a speed limit of 80 km/h is generally low because of relatively high geometric standard and little or no strip development, etc. A general conclusion in this case must be that the costs incurred due to a speed reduction on the primary network will be greater than the benefits.

3.3. Prohibition of crossing against a red signal indication

Introduction

In Norway pedestrians are allowed under the rules of law regulating traffic to cross the roadway against a red traffic signal indication when this action does not hinder the vehicle traffic or present any danger to themselves or the vehicle traffic.
Presently this rule is subject to a critical review and faces a possible change to prohibition of crossing against a red traffic signal indication. Traffic regulation by traffic signals as a traffic safety measure is supposed to:

- reduce conflicts and accident risk related to intersecting traffic flows;
- regulate and give priority to motorised or non-motorised road users at intersections or at other road crossings thus affecting capacity;
- provide crossing opportunities for pedestrians and add a degree of security for them on roads with heavy traffic volumes.

Direct benefits

About 110 pedestrians were injured or killed in Norway in 1980 when crossing the roadway at intersections or at pedestrian crossings regulated by signals; 65 per cent of these accidents happened when the pedestrian crossed against a red indication. Hence the potential for a measure which prohibits walking against red lights would be 72 personal injury accidents per year (110 \cdot 0.65).

The effect of the measure is dependent on how many of the pedestrians know if their action is permissible or not and act accordingly.

A Norwegian study showed that 16 per cent of the pedestrians at signal-regulated intersections cross against a red indication. About 20 per cent of these do so knowing that the rules allow it. However, the great majority cross against the red light thinking they are infringing the law. The change of rules will hence only affect 2.0 per cent of potential at the most.

An accident cost of Norwegian kroner 118,000 can be used when calculating the benefits from a change of rules. This cost is found in Table 7. The maximum benefits are calculated to be 1.7 million Norwegian kroner per year total.

Direct costs

The direct costs will consist of implementation costs such as costs for information, enforcement and administration of fines. These costs will greatly depend on the level of enforcement.

Experience from earlier information campaigns indicates that the cost for this item will be about 2 million kroner. Because the benefits of the measure are
relatively modest and the enforcement can be implemented in existing procedures, a moderate increase of about 1 million kroner for enforcement is calculated.

Indirect costs

The pedestrians who cease crossing against a red light will in general encounter greater delays at signalled crossings. The amount of delay time and the cost of this time is, however, unknown.

Comparison of benefits and costs

The benefits and costs from this measure are relatively small. A yearly profit of 0.7 million kroner will cover the costs of the information campaign. The present value of the benefits for a four-year period is higher than the costs of implementation (the social rate of discount is put at 7 per cent per annum).

The effect of the action will be less than 20 per cent. Some pedestrians will continue to cross against red lights regardless of the prohibition. This will reduce the benefits of the measure. If in addition studies show that the effect of the new rules is small, the enforcement will probably be increased. This in turn will mean an increase in the yearly costs and a reduction in the net benefits.

3.4. Mandatory safety belts in the rear seats of light vehicles

Introduction

Installation of safety seat belts is an accident-counter-measure which reduces the severity of injuries suffered in collisions and other accidents where the vehicle's occupants are subject to strong forces of retardation.

In Norway the installation of safety belts in the front seats of private cars and the use of these is mandatory and non-compliance is punishable by fines. It is therefore of interest in this country to investigate the probable benefits and costs by extending the scope of the law to include safety belts in the rear seats of the vehicles. I shall estimate the benefits and costs regarding such a law concerning light vehicles, i.e. vehicles of gross weights less than 3.5 tons. Such vehicles perform 90 per cent of all the vehicle travel in Norway.
Direct benefits

As a yearly average in recent years, about 1,200 persons seated in the rear of the vehicles are injured (fatalities and bodily injuries) in traffic accidents. This is what will be defined as the accident potential on which the law will have influence. There are two measures which warrant closer attention in this connection:

1. Mandatory installation in all new cars;
2. Mandatory installation and mandatory use in all new cars.

About one-third of all light vehicles are today delivered with rear safety belts as standard equipment, and about 12 per cent of today's registered vehicles have such belts installed. Figure 15 illustrates how the percentage of vehicles with rear-seat safety belts will change through the coming years if the law is put into effect. It also illustrates the development of vehicle-kilometres of travel. It is worth noting that the portion of vehicle travel performed with vehicles with rear seat belts will be somewhat larger than the portion of number of vehicles with rear seat belts because new cars have a greater yearly driven mileage than older ones.

In Figure 16 the use of rear seat safety belts is related to the person-kilometres of travel of passengers in the rear seats. It is estimated that with voluntary use of the belts about 25 per cent of the passengers will use them and with mandatory use about 85 per cent will obey the law. It is further estimated that these percentages can be transferred to the person kilometre of travel for the passengers in the rear seat.

The reduction in severity of injury in a collision is dependent on the speed of the vehicles. A survey of different studies has shown that an injury-reducing effect of about 40 per cent can be attributed to the use of seat belts (L3). This will give benefits of the measure in the period covered by Figure 16 of about 102 million Norwegian kroner by voluntary use and about 409 million kroner by mandatory use (present values).

Direct costs

The direct costs consist of costs for installing belts in new cars. It is calculated that this will cost 1,000 Norwegian kroner per vehicle. Today about one-third of the new vehicles have rear seat belts mounted as standard equipment and this will probably increase independently of any legal requirement.
The direct costs therefore include only those vehicles which are not already equipped with rear seat belts. On this basis the present value of the costs has been calculated over the period shown in the figures which amounts to about 730 million Norwegian kroner.

**Comparison of benefit and cost**

The direct costs of this traffic safety measure are relatively high and surpass the benefits even if the use were made mandatory. The benefits are dependant on the actual percentage of use or compliance, but there is little to gain by trying to increase the use to 100 per cent by increasing the enforcement.
Figure 16 USE OF REAR-SEAT SAFETY BELTS EXPRESSED AS THE AMOUNT OF TRAVEL DONE BY THE REAR-SEAT PASSENGERS.

The mandatory use of rear safety belts would, however, prove very beneficial if the greater part of the vehicles already had them installed.
4. CONCLUSION

The intention of this document has been to show that the benefits and costs of traffic safety measures do not have a single meaning in the sense that it is possible to estimate values which have a general validity. In the theoretical approach to the problem I have analysed the factors which are of importance to the benefits and costs. In the ensuing chapters I have tried to illustrate some of the factors which determine the benefits and costs using some practical examples.

The calculations which have been made are not complete and should not be considered to have any high degree of accuracy. Simplifications made will result in different values from those obtained through more detailed analyses.

The document presupposes knowledge of the cost-benefit analysis method and some of the economic terminology associated with it. There is also a considerable amount of literature pertaining to this topic (for example L4, L5, L6).

Cost-effectiveness analyses are also useful as a tool for evaluation of traffic safety improvements. In the United States several cost-effectiveness studies have been undertaken to find the measures which would give the lowest implementation costs on a national level per accident which is prevented (L7). It is difficult, however, to account for indirect impacts of traffic safety improvement by using the cost-effectiveness method.

Traditionally the totality of benefits and costs of traffic safety measures have not been given much consideration, at least not in Norway. We need to have better knowledge of the relationship between benefits, effects and costs if we want to use the available public funds or resources effectively and reasonably. Research in this area of interest should therefore be intensified in order to bring forth new knowledge.
BIBLIOGRAPHY


PRELIMINARY NOTE

Road safety is one of the major issues of our time and a Conference of policy makers adopting stances in this field has to work continuously at the interface between research and decision-making.

Safety is a scientific concept and is perceived as a political reality often only when a certain threshold is crossed. It is therefore important to ensure that there is a proper exchange of information on the appositeness of the methods and policy measures when criteria are established.

The Round Table was accordingly called upon to consider what methods might be used in the decision-making process in this connection.

The recent trend in road safety results has been somewhat at variance with the earlier long run of improvements, so it is useful to take stock of the progress made in recent years in monitoring developments in this field.

Road safety has already been the subject of analyses both in ECMT and other international bodies, especially the OECD, so the findings of these organisations were regarded as a valid point of departure for the Round Table discussion.

METHODOLOGICAL APPROACH

Aims are defined as part of the general policy aims of each individual country, so the assessment of road safety differs from one country to the next.
It may also be asked whether one should start by defining policy aims. As the criteria depend on the aims, such criteria must necessarily be sufficiently clear once they involve expenditure.

An accident has a number of dimensions, so the problem must not be restricted in such a way as to eliminate some of them, a pitfall that can be avoided by thinking more in terms of positive and negative effects in addition to the quantitative analyses. Moreover, the discussion cannot be limited to effects, still less to direct effects.

If consideration is given solely to the fall in the number of accidents one ignores the circumstances in which they occur. If the emphasis is placed on the effects of measures (e.g. speed limits), there is a tendency to overlook other causes (road design and condition, etc.).

Since policy aims are by and large established on a selective one-off basis, they will not always be compatible with planning requirements which necessarily cover longer periods. If the aims are too precise, moreover, they are less likely to produce the quick results sought by policy makers.

Furthermore, road user behaviour is not unalterable and may change as a result of measures introduced. It may not be fully realised immediately that the change has occurred and some time may be required to take note of it correctly.

Particularly sensitive issues — some even regarded as taboos — arise in connection with users. For example, the idea of having categories of driving licence based on the risk the holder represents (age, experience, eyesight, etc.) is strongly resisted.

In some cases a measure may have little effect, or its effects may be noted but not attributed to the measure. Such is the case, in particular, when drivers in general become more experienced and their behaviour therefore changes.

At policy level, institutional difficulties may also arise, first as regards inter-level communications (general/local, conceptual/executive). More broadly, the implementation of a measure will depend on the resources available, so there is a question of monitoring efficiency in budgetary terms.

Some participants took the view that priorities are to be preferred to quantified aims when it comes to recommending methods. A fundamental distinction has to be made between preventing material accidents and
preventing injuries to people. The success in recent years has been mainly with respect to the latter. The distinction is also important from the financial standpoint, since compensation for a material accident is paid by the user's insurance, whereas the costs of an accident to a person must fall largely on the public health budget.

Before defining priorities, it is desirable to identify types of problem more clearly. Here cost plays a role when a change of aim involves higher costs. If decision-makers are not sufficiently aware of the relevance of the aims, they will be too easily inclined to change them. This emphasizes the fact that errors in the assessment of aims can to some extent be avoided if the approach is in terms of problems rather than measures.

It is difficult to judge after the event, since the results will depend on what criteria have been selected. It is therefore impossible to ascertain exactly what results other choices would have given.

On the whole, general safety and environmental aims are covered by various practical measures to deal with aspects of the problem, such as stepping up education to protect beginners against specific dangers, or stricter speed limits to reduce danger in built-up areas.

Objective references can be obtained by comparing road safety aims with aims in other fields, so as to evaluate the financing of measures. Thus, a road safety target could be compared with a fire protection target.

Similarly, the road accident risk could be compared with the risk of accidents in public transport. However, unlike medicine or the railways, a lack of responsibility seems to exist in the case of the roads, primarily owing to a less acute degree of public awareness, in turn affected by a pattern of information which highlights spectacular accidents but has little to say about more common ones.

The role of research largely consists of assessing results. If it cannot do this satisfactorily, it needs to be rethought.

USE OF METHODS

Since the use of methods had been fully discussed elsewhere, the Round Table thought that it would be useful to focus the discussion on the problems of
methods likely to be of interest to the decision-maker. This involved analysing method as an instrument of communication between policy maker and researcher. It was accordingly assumed that the scientific aspects of the choice of methods were known.

Moreover, excessive reliance on any one method leads to under-estimates or over-estimates, and this may induce the decision maker to hold back because his scope for action seems too restricted. By combining a number of approaches, values can be adequately weighed up from the policy-making standpoint, although this again gives rise to the question of the possible manipulation of the decision maker or of public opinion by predetermined ideas (values established in an unduly arbitrary manner) or by pressure groups acting through information channels. While there should be no need to encroach on the policy maker's sphere of action, there should be sufficient opportunity to put forward accurate scientific information.

The decision maker often has difficulties in coping with public opinion and looks for solutions and methods of presentation. He is primarily interested in straightforward guidance and rarely concerned with developing arguments which may give formal structure to specific problems.

The expert must understand what the decision maker knows and wants and must be able to provide a pertinent response to his questions and objections, which by no means implies that the expert should cease to be objective. The policy maker's response cannot be the prime concern of the expert who is there to provide information and not to take decisions. However, since the decision maker seldom has insight into the reasoning of the technician, it is all the more essential that the information should be made available to him in a simple correct form.

Road safety is a field in which there are convincing specific instances of scientific assessment providing policy makers with reliable information, especially as regards the financial consequences and implications of measures, examples being speed limits by type of road or type of vehicle, regulations on safety belts, head rests, mirrors, etc.

In the last analysis the purpose is to increase the well-being of a community. Accordingly, the assessments are made in a wide range of fields and some provide highly accurate results while others simply give some idea of the situation. Furthermore, some of the factors involved may not always be compatible, so it is necessary to have a whole range of descriptors based on those observations whereby the effects of the action taken can be measured most accurately.
Expert opinion is essentially formed by progressive observation of the facts, which necessarily calls for resources, effort and a methodology. However, experiments cannot be carried out everywhere at the same time. It is advisable to select specific fields and implement measures only where one is really convinced that progress can be achieved.

Since every method is implicitly determined and limited by the type of measure chosen, it is desirable to establish relations (e.g. between construction and safety) during and after implementation. Local projects are often more sensitive than large-scale projects. There is at present a process of transition from large-scale measures to the decentralisation of measures and financing. Accordingly, the observation of local target groups or objectives may prove fairly effective and directly meet the needs of the public concerned.

As regards calculating the cost of controlled experiments, a discriminating approach is needed. For a well defined project, precise costs for the variables will be useful. For a broader project, a balance sheet showing the consequences of the different solutions will be required. Sometimes, too, parameters will have to be limited in accordance with policy options already established.

The decision maker often has a need or a desire for information. In providing this, it is important to consider the various dimensions of the problem, in this case the economic and human dimensions. Here the expert will have to present complex solutions simply but correctly. He should explain the reasoning behind his recommendations and quantify the effects. He should explain the techniques used, and mention those aspects of the problem which his analysis has not taken into consideration.

PROSPECTS

There has been a levelling off in resources owing to the present economic climate, while at the same time changes in social behaviour have been such that innovation is called for in social communications.

Safety measures must therefore be rethought in conjunction with construction measures. Since measures are tested individually up to a certain point it would seem possible to decide on an empirical basis whether they should be extended though with some reallocation of resources.
The era of large-scale projects and major safety measures, for which the cost-benefit approach was suitable, is coming to its end. The safety problem is now changing in scale, becoming part of social and traffic management.

The question accordingly arises as to whether there are sufficient data on which to base this new approach. Gradual improvements will probably be required as measures are applied. There are deficiencies in our information about how drivers actually use the roads, and it is not always clear what part self-discipline plays as compared with the influence of safety measures.

The most appreciable gap in our knowledge is the absence of continuous data on drivers, vehicles and accidents. Here it is important to have an accurate picture of the situation as it was when the first measures were introduced.

Some participants considered that relatively little was being invested in data and more in methods, while others thought that surveys were often more useful than data and that there was a danger of confusing analysis with data, views which no doubt reflect the different approaches adopted in their countries.

Data are sometimes inadequate simply because they are not all communicated. Surveys yield ample trip data, but these are not sufficiently adapted to safety needs. A considerable amount of computerised data is available on accidents and hospitalisation, but the two classes of data are not cross-referenced. Some data are becoming unusable through not being updated (e.g. driving licence records when deceased drivers' records are not removed). Lastly, cross-referencing for records sometimes depends on ideological or policy considerations (incompatible with privacy).

By and large participants thought that instead of trying to collect exhaustive data the aim in future should be to collect significant data for the purpose of selective observation. The effectiveness and results of the studies would then have to be adequately analysed.

COUNTRIES' EXPERIENCES

Safety measures need to be planned together with urban development measures (e.g. appropriate siting of schools and residences for the elderly). Mistakes at the outset are very difficult to correct afterwards.
In many instances, the legal machinery does not adjust quickly or flexibly enough to technological innovations.

Studies clearly show that man causes the majority of accidents while the state of the road or vehicles account for a minority. It follows that effective measures should be possible, especially along the following lines:

-- driving licences which differ according to the stage in the driver's life; here present systems are manifestly inadequate;

-- more research into measures to instil in drivers a greater sense of responsibility;

-- physical safety measures inside vehicles, e.g., shock-absorbing areas.

Certain safety measures are difficult to monitor because the reason for them is either inadequately identified or hypothetical (as when the measure assumes knowledge of a behaviour pattern where there is no factual case). Here mention was made of the debate on lighting roads and vehicles in built-up areas. Depending upon the solution adopted in this connection, the financial impact at local authority level may be appreciable since, if the vehicle lighting is less bright, the road lighting has to be better. Furthermore, public attitudes before and after the change can differ considerably, as a recent experiment in France has shown.

Experience shows that several criteria should be used, so as to leave sufficient scope for assessment from a policy standpoint. Quantified criteria seem more appropriate for internal research purposes, whereas non-quantified criteria are more suitable for use in connection with the public. If there has to be quantification, it might sometimes be better in terms of purchasing power rather than of money, thus making it easier to see how the resources might be used in another context.

Quantified observations should indicate the limits of observation, and should lead to clear and precise conclusions.

Analyses by themselves do not win over public opinion, which often needs time to mature psychologically. Before introducing some measures, time should be allowed for the public to get used to the idea, but accurate well-thought-out information might be provided at the same time.

In every approach it is important to agree on a common system of values, otherwise a set of disparate yardsticks will give rise to total effects which cannot be measured. The measures taken should help to instil
a greater sense of responsibility in individuals and not demoralise them through excessive use of automation. Instilling a sense of responsibility in the individual depends largely on the level of information at which the road user reaches a better understanding of the consequences of his behaviour.

A higher degree of responsibility might be instilled by appropriate insurance and damages arrangements. Several participants thought that much remained to be done on the penalty side (enforcement and relevance). Lastly, instilling a sense of responsibility has to be viewed in the context of protecting young people, and the attention of road users needs to be drawn to this aspect in particular.

CONCLUSIONS

The material cost of accidents is an insurance problem, while the policy issue is mainly one of human casualties, so the question of road safety will always involve a more or less unquantifiable human aspect.

Resources are no longer unlimited, so they should be allocated in priority to the human problems.

The value of methods depends largely on the situations in which they are applied. While the multi-criterion method gives rise to problems of complexity, the cost-benefit method is sometimes hard for the policy maker to accept. Its main usefulness is in clarifying cases involving budget limits. On the other hand, the cost-effectiveness method is generally more readily accepted by decision makers.

Quite aside from the (eternal) debate on methods, it is important to integrate all aspects into a comprehensible whole, including aspects which, though unquantifiable, must nevertheless be mentioned.

Proper assessment of a measure requires that it be monitored and assessed at every stage of implementation.

Lastly, public response in the different countries is determined by the particular level of safety reached. The higher the level, the greater is the need to introduce selective measures that do not detract from the results achieved.
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