A FRAMEWORK FOR A RATIONAL ANALYSIS OF ROAD SAFETY PROBLEMS

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INTRODUCTION
An analysis of road safety problems is an essential element of a system for rational safety management. The selection of road safety measures is difficult if policy makers do not know which problems to address. Yet, no standard definition of a road safety problem has been developed. In fact, it has even been argued (Pedersen, Elvik and Bérard Andersen 1982, page 29) that the lack of a commonly accepted definition of what constitutes a road safety problem prevents a rational analysis of such problems:

“What do we mean by a road safety problem? There are many answers to this question that all make sense. The risk that children run on their trip to school is a road safety problem. Drinking and driving is a road safety problem, driving in the dark is a road safety problem, and young driver risk is a road safety problem. By making such lists of problems, it is possible to cover all areas of road safety. The snag is that the various problems on such a list tend to overlap. Children are at risk when travelling to school partly because young drivers have a high risk of accident involvement, partly because there is drinking and driving, and partly because driving in the dark increases the risk of accident. Drinking and driving is a major problem partly because it takes place in the dark and on roads where there are pedestrians and cyclists. These examples show how difficult it is to define road safety problems in an orderly and logical way. This difficulty is particularly relevant when we want to give an exhaustive definition of road safety problems.”

It is obviously correct that there are very many factors that contribute to road accidents, that not all of these factors are known, that many of them interact in complex ways that are sometimes poorly understood, and that road users are not aware of all risk factors that contribute to road accidents. Notwithstanding all these limits to knowledge, this paper will argue that a rational analysis of road safety problems is in principle possible. It is, as any analysis, limited by current knowledge and the availability of data. It is nevertheless possible to develop a framework for a rational analysis of road safety problems.

The elements of a rational analysis of road safety problems depend to some extent on the level of analysis and on its objectives. Road safety problems can be analysed at the international level, the national level, or regional or local levels of government. The recently published world report on road traffic injury prevention (Peden et al 2004) provides an example of an analysis of road safety at the global level. The objective of the report is to heighten awareness of traffic injury, thereby creating stronger incentives for effective road safety programmes.

This paper will focus on the analysis of road safety problems at the national level of government, for the purpose of developing a long-term road safety programme. It will be assumed that the analysis of road safety problems has an applied objective: to understand in
order to prevent, and not merely to satisfy intellectual curiosity. The main questions to be discussed are:

1. What is a road safety problem? What do we mean by it?
2. What is a rational analysis of road safety problems? How should such an analysis be approached?
3. What are the basic dimensions of road safety problems? How can they be assessed?
4. What information is needed in order to perform a rational analysis of road safety problems?

The objective of the paper is to show by means of examples how a rational analysis of road safety problems can be performed.

**ROAD SAFETY PROBLEMS AND RATIONAL ANALYSIS OF THEM**

It is obvious that there does not exist any “right” way of defining road safety problems. However, since the current number of road accidents and accident victims is nowhere regarded as acceptable, it seems reasonable to define a road safety problem as any factor that contributes to the occurrence of accidents or the severity of injuries.

According to this definition, a road safety problem may exist even if it is not recognised. Before the recent surge in research concerning driver fatigue (see e.g. Sagberg and Bjønnskau 2004), this was not recognised as a major problem. Moreover, even if research has shown that a certain factor, such as speeding, contributes to many accidents, road users may not see it as a problem and may not want action to be taken against it. One should therefore distinguish between the statistical analysis of road safety problems and the perception of such problems.

Rationality is often defined as choice of the best means to realise an objective (Simon 1976). To explain what is meant by a rational analysis of road safety problems, one must first define what the objective the analysis should be. The following objective of an analysis of road safety problems is suggested: to identify those factors that make the greatest contribution to accidents or injuries and that are, in principle, amenable to treatment.

This objective assumes that the results of an analysis of road safety problems are to be applied in developing road safety programmes intended to reduce the number of accidents and the severity of injuries. Rational analysis can be defined as a procedure for examining factors contributing to accidents or injuries, and their amenability to treatment, that ensures the identification of the promising targets for treatment by means of safety programmes.

The concept of amenability to treatment will be elaborated below. The essential elements of a framework for a rational analysis of road safety problems are:

1. A taxonomy for categorising potential road safety problems and sorting them in main groups.
2. Methods for assessing the size or importance of road safety problems and their main dimensions.
3. A concept of the amenability of problems to treatment.
4. Access to relevant data.

Each of these elements will be briefly discussed.
TAXONOMIES OF ROAD SAFETY PROBLEMS

Several attempts have been made to develop typologies for road safety problems and their elements. One of the best-known typologies is the Haddon matrix, in which road safety phenomena are classified according to when they occur (pre-crash, crash, post-crash) and primary contributing factors (human, vehicle and equipment, environment), forming a table of nine cells (Haddon 1970). This typology is a useful starting point for analysing road safety problems. It is, however, not the only typology of road safety problems that has been proposed.

The recently published Handbook of road safety measures (Elvik and Vaa 2004) contains a taxonomy based on the following simple model (Figure 1):

\[
\text{Number of injured or killed} = \text{Exposure} \times \text{Probability of accident} \times \text{Consequence of accident}
\]

Exposure can be defined as the amount of travel. However, there are various ways in which one can travel by road: as a pedestrian, by cycling, by driving a car, by taking the bus, etc. Not all of these ways of using roads involve the same level of accident risk. The type of exposure chosen is therefore an aspect of exposure that influences the number of people who are killed or injured in road accidents. Furthermore, the risk to which one is exposed as a road user is probably not independent of the mixture of various means of transport in traffic. The risk run by each pedestrian, for example, may be lower the higher the proportion of pedestrians is in traffic. Hence, the relative proportions of the various means of transport in a traffic stream may influence the overall level of risk represented by that traffic stream.

![Figure 1: A taxonomy of factors affecting road safety](image)

The probability of accident occurrence is affected by a very large number of risk factors related to the elements of the traffic system: infrastructure and traffic control devices, vehicles, and road users. A risk factor for accidents is any factor that increases the probability of accident occurrence. The outcome of an accident in terms of injury to people
or damage to property is also affected by a very large number of factors, related to the same elements of the traffic system as the risk factors for accidents.

Any taxonomy will have an element of arbitrariness, and there is no right or wrong taxonomy. The point of any taxonomy is simply to help classify the factors that contribute to accidents or injuries and thus establish a starting point for a more detailed analysis.

**THE BASIC DIMENSIONS OF ROAD SAFETY PROBLEMS**

Some road safety problems are usually regarded as “bigger” or “more important” than others. What do we mean by such terms? A key element of a rational analysis of road safety problems is to identify the basic dimensions of such problems and develop indicators for these dimensions. It is proposed that the basic dimensions of road safety problems are:

1. **Magnitude** (importance), which denotes the size of the contribution to accidents or injuries.
2. **Severity**, which consists of two dimensions: a) Gradient with respect to injury severity, and b) Externality, that is risk imposed on other road users.
3. **Complexity**, which denotes whether a problem represents the contribution of a single risk factor, or a few easily identifiable risk factors, or the interactive effects of a large number of risk factors, each making a small contribution to the problem.
4. **Inequity**, which refers to how variations in risk relate to variations in the benefits of transport.
5. **Territoriality**, which refers to the geographical extent and distribution of a problem.
6. **Dynamics**, which refers to whether the problem is getting worse or getting better.
7. **Perception**, which refers to whether a certain problem is seen as important.
8. **Amenability to treatment**, which refers to the prospects of reducing a problem by means of road safety measures.

The next section of the paper shows how numerical indicators for each of these dimensions of road safety problems can be developed.

**NUMERICAL INDICATORS OF ROAD SAFETY PROBLEMS**

Can road safety problems be measured numerically? Can the various dimensions of problems discussed above be quantified in a meaningful sense? To some extent, road safety problems can be analysed quantitatively and thereby made comparable. One should, however, never forget that some problems are impossible to subject to any meaningful quantitative analysis.

Table 1 proposes numerical indicators for the dimensions of road safety problems. Examples of how to estimate these indicators will be given below.

**Magnitude**

The magnitude of a problem can be indicated by the risk attributable to it. In epidemiology (Rothman and Greenland 1998), several measures of attributable risk have been developed. For the purpose of comparing the magnitude of different road safety problems, population attributable risk is perhaps the best indicator. Population attributable risk can be estimated by this formula:
Population attributable risk (PAR) = \[ \frac{PE(RR-1)}{(PE(RR-1))+1} \]

In this formula, RR denotes the relative risk associated with a certain risk factor. Relative risk is usually estimated as the ratio of the accident rate when a risk factor is present to the accident rate when the risk factor is absent. PE denotes the proportion of exposure subject to the risk factor. Figure 2 gives an example of how population attributable risk can be estimated for a risk factor that takes on two values (absent or present).

In Figure 2 (Spolander 1997), the risk of accident involvement is compared for drivers who comply with certain provisions of road traffic law and drivers who violate the same provisions. 90.2 percent of drivers comply, 9.8 percent of drivers violate. Compliant drivers are involved in 82.8 percent of injury accidents, violating drivers are involved in 17.2 percent of injury accidents. Hence, the relative risk of accident involvement associated with being a violator is \((17.2/9.8)/(82.8/90.2) = 1.906\), when compliant drivers are used as reference.

To eliminate the increase in accident risk associated with violations, the accident rate for violators would have to be reduced by \(0.906/1.906 = 0.475\), corresponding to nearly 50 percent. This is the group attributable risk for violators. The population attributable risk depends on how many violators there are in traffic. In this example, population attributable risk is \((0.098 * 0.906)/((0.098 * 0.906) + 1) = 0.082\). The interpretation of this estimate is this: If violations did not exist (i.e. if this problem was solved), but violators drove the same number of kilometres as they do know (but complying with the law), the number of injury accidents would be reduced by 8.2 percent.

Table 1: Numerical indicators for road safety problems

<table>
<thead>
<tr>
<th>Dimension of road safety problem</th>
<th>Numerical indicator of dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Magnitude</td>
<td>Population attributable risk</td>
</tr>
<tr>
<td>2. Severity</td>
<td>(A) Gradient in relative risk with respect to injury severity; (B) Contribution of risk imposed to overall risk</td>
</tr>
<tr>
<td>3. Complexity</td>
<td>The relative contribution of specific risk factors to population attributable risk</td>
</tr>
<tr>
<td>4. Inequity</td>
<td>(A) Gini-index for distribution of injuries; (B) Rank correlation between shares of exposure and shares of injuries</td>
</tr>
<tr>
<td>5. Territoriality</td>
<td>The distribution of accidents or injuries across geographical units of observation</td>
</tr>
<tr>
<td>6. Dynamics</td>
<td>Annual percentage change in accident rate or attributable risk</td>
</tr>
<tr>
<td>7. Perception</td>
<td>(A) Accuracy of perceived risk; (B) Level of support for policy interventions</td>
</tr>
<tr>
<td>8. Amenability to treatment</td>
<td>A function of complexity, perception and knowledge of effective measures</td>
</tr>
</tbody>
</table>

Figure 2: An example of how to estimate attributable risk
How can attributable risk be estimated for a risk factor that is a continuous variable, like speed? It is of interest, for example, to learn what proportion of accidents or injuries that can be attributed to speeding. In the case of speeding, the procedure for estimating attributable risk is shown in Figure 3. For each speed limit, the distribution of actual driving speed needs to be known. Figure 3 shows the cumulative distribution of speed for roads in Sweden that have a speed limit of 90 km/h (Elvik and Amundsen 2000). Mean speed, which as an approximation is assumed to be identical to the 50th percentile speed, is 96 km/h. 72 percent of drivers violate the speed limit, 28 percent comply with it. To eliminate speeding, all drivers would have to drive at less than 90 km/h. In practice, however, the police allow a certain margin of tolerance. It has therefore been assumed that perfect compliance will be regarded as accomplished when 93 percent of all drivers comply with the posted speed limit and the remaining 7 percent exceed the speed limit, but stay within the margin of tolerance used by the police. The speed distribution then shifts to the left, as shown in Figure 3. The mean speed in case of perfect compliance is estimated to 84 km/h. The double arrow in Figure 3 indicates the change in mean speed. Once the change in mean speed has been estimated, the risk attributable to speeding can be estimated by applying the Power Model of the relationship between the mean speed of traffic and the number of accidents or accident victims (Nilsson 2004).

According to the Power Model, one would, as an example, expect a change in mean speed from 96 to 84 km/h to be associated with a change of $(84/96)^4 = 0.59$, i.e. a 41 percent reduction in fatal accidents. Hence the risk attributable to speeding is 0.41.
By estimating the population attributable risk for a number of road safety problems, one may compare their magnitude. Elvik and Amundsen (2000) did this for 20 road safety problems in Sweden. Speeding was found to be the largest road safety problem in Sweden, accounting (in terms of attributable risk) for 38 percent of road accident fatalities and 21 percent of road accident injuries.

**Severity**

It is widely agreed that fatalities are the most serious impact of road safety problems, serious injuries the second most serious impact and pure property damage the least serious impact of road safety problems. Hence, a road safety problem is severe if it makes a greater contribution to fatalities and serious injuries than the contribution it makes to slight injuries or property damage.

In order to assess the severity of a road safety problem, one should compare the size of its contribution across levels of injury severity or, equivalently, estimate relative risk associated with a risk factor across levels of injury severity.

Incompatibility between vehicles or groups of road users in terms of mass or crash protection is an important road safety problem. The involvement of vehicles with a large mass in accidents is very often associated with more severe outcomes. Figure 4 gives an example of this, based on Norwegian accident statistics (Elvik 2004). It shows the relative risk of fatal, serious or slight injury to car occupants in accidents involving truck-trailers, other cars or no other vehicle or road user. The overall risk of injury at a given level of severity for all road users in all accidents has been used as reference, given the value of 1.00.
Car occupants are less at risk of being killed in accidents in which the car crashes with other cars or no other vehicle or road user is involved than the average risk of being killed in a car accident, regardless of counterpart. If, however, the counterpart is a truck-trailer, fatality risk increases by a factor of 14.34. Involvement of a heavy vehicle contributes dramatically to making accidents more severe.

Another aspect of severity, closely related to inequity, is the extent to which the overall risk of injury run by a group of road users is internal to the group or imposed upon it by the involvement of other groups in accidents in which the group of interest sustains injuries. To assess this, it is useful to cross tabulate the number of injured road users by involved parties. Table 2, which is an excerpt from a much larger table, shows such a cross tabulation.

Table 2: Example of cross tabulation of parties involved in injury accidents – based on official Norwegian road accident statistics

<table>
<thead>
<tr>
<th>Counterpart in accident</th>
<th>Truck-trailer</th>
<th>Car</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured as occupant of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck-trailer</td>
<td>45</td>
<td>65</td>
<td>338</td>
</tr>
<tr>
<td>Car</td>
<td>1150</td>
<td>20523</td>
<td>12832</td>
</tr>
</tbody>
</table>

The first line of the table shows the number of injured truck occupants. The large majority of these, 338, were injured in accidents that did not involve other road users. Accidents involving cars imposed 65 injured truck occupants – this is a risk imposed on truck occupants by cars.

Trucks, however, imposed a much greater risk on car occupants. 1,150 car occupants were injured in accidents in which the counterpart was a truck.
Internal risk can be defined as the share of overall risk that is attributable to accidents with no counterpart or with a counterpart belonging to the same group. Risk imposed by others, is the share of all injured road users in group A attributable to accidents in which the counterpart belonged to groups B, C, D, etc. The share made up by imposed risk differs greatly between various types of vehicle or groups of road users. In Norway, for example, imposed risk represents only 10 percent of overall risk for occupants of truck-trailers, but fully 99 percent of the overall risk for pedestrians.

**Inequity**

The risk of injury is equitably distributed if we all face the same level of risk. Alternatively, one could argue, invoking the difference principle of Rawls (2000), that differences in risk can be regarded as fair if they favour the least advantaged group of road users.

The advantage provided by a transport system is the opportunity to travel (or transport goods). As far as personal travel is concerned, the most advantaged group is therefore the group that performs the largest amount of travel. This group is the most advantaged by making the greatest use of a transport system, which serves several groups of road users. The least advantaged group is the one that makes the least use of the system, i.e. performs the smallest number of person-kilometres of travel.

Differences in risk favour the least advantaged if that group has the lowest level of risk, and the most advantaged group has the highest level of risk.

Inequity in risk can be measured by two indicators. The first of these is the Gini-index, which is a measure of inequality. The Gini-index, sometimes also referred to as the Gini-coefficient, takes on values between 0 and 1. Figure 5 shows how to estimate the Gini-index with respect to the distribution of fatality risk in road travel in Norway.

![Figure 5: Inequality in fatality risk in road travel in Norway](image)

Gini-coefficient for income-distribution in Norway = 0.258

Gini-coefficient for distribution of fatality risk = 0.349
The share that various groups of road users represent of total travel, summing to 1, has been plotted along the abscissa (horizontal axis). The very long line segment in the middle is travel by car. The share that various groups of road users represent of road accident fatalities, summing to 1, has been plotted on the ordinate (vertical axis). Groups have been sorted from those that have the lowest fatality rate per kilometre of travel to those that have the highest fatality rate per kilometre of travel.

If all groups had the same fatality rate, the number of fatalities would be proportional to the amount of travel, and would follow the dotted straight line. Any departure from this line represents inequality. The area bounded by the abscissa and the dotted, straight line forms a triangle, the area of which is set equal to 1 when estimating the Gini-index. The Gini-index shows size of the area between the dotted straight line and the actual distribution of risk, indicated by the bold, curved line, measured as a proportion of the triangle. It can be seen that the Gini-index for traffic fatalities in Norway is 0.349, indicating that fatality risk in road traffic is more unequally distributed than income, for which the Gini-index in Norway is 0.258.

If groups of road users are sorted from the most to the least advantaged, the rank correlation between the amount of advantage and the share of injuries can be estimated. If there is proportionality, the rank correlation ought to take on the value of 1. Based on the data given in Figure 5, the rank correlation has been estimated to 0.427, indicating a lack of proportionality between exposure and injuries.

Territoriality

Some road safety problems have a geographic dimension, some do not. It is typically problems related to the quality of infrastructure – roads, traffic control devices, etc – that have a geographic dimension. Hence, network screening should be a part of any rational analysis of road safety problem at the national (or regional) level of government. The objective of network screening is to locate as accurately as possible those places or parts of the road system that have the highest expected number of accidents or the highest incidence of fatal or severe injuries.

An instructive guide to network screening has been developed by the Federal Highway Administration in the United States (Harwood et al 2002). A detailed description of network screening will not be given here, but the essential elements will be mentioned.

Network screening starts by determining whether there is systematic variation in the number of accidents across the road system. For this purpose, the road system is usually described in terms of elements that can be counted, like sections with identical length (e.g. 1-kilometre sections), intersections, curves, or other roadway elements. The empirical distribution of accidents during a given period is examined for each type of roadway element. Figure 6 shows an example. It shows the distribution of accidents on national roads in Norway during the eight years from 1993 to 2000.
A total of 21,044 1-kilometre sections were included. More than half of these, 11,761 did not record any injury accidents during the period studied. 4,665 sections had 1 accident, 1,905 had 2 accidents, and 391 sections had 10 or more accidents. The mean number of accidents per kilometre was 1.25. The variance was 10.71, indicating that most of the observed variation in accident counts (88 percent) was systematic.

A multivariate accident prediction model was fitted by means of negative binomial regression (Ragnøy, Christensen and Elvik 2002) to explain the variation in accidents. The model explained 95 percent of the systematic variation in accident counts. Based on the multivariate model, the empirical Bayes method can be applied in order to identify those parts of the road system that have the highest expected number of accidents or the highest proportion of fatal or serious injuries. This involves looking at profiles and peaks (Hauer 2001). Figure 7 gives an example.
Figure 7: Profile of 20 km of road with respect to accident count and expected injury severity density. Derived from Ragnøy, Christensen and Elvik 2002)

Figure 7 shows 20 kilometres of road. The number of accidents per kilometre varied between 0 and 15. Injury severity density is an indicator of the severity of injuries in the accidents. The figure shows expected injury severity density, which is estimated in a way that smooths random fluctuations and shows the long-term expected values. Peak values are found in the first three kilometres of the road and between the 16th and 18th kilometre. These subsections should therefore be examined more closely in order to identify local factors contributing to accidents.

**Dynamics**

The dynamics of a road safety problem can be examined in many ways. Tests have been developed to determine if there is a trend in a series of accident counts, or if there has been a sudden jump in the series (Hauer 1996A, 1996B). At the national level, a simple indicator of dynamics is the long-term trend in accident rates or injury rates for a certain group of road users. Figure 8 gives an example. It shows the injury rate (injured riders per million person km of travel) for riders of heavy motorcycles in Norway during the period from 1985 to 2003.
Figure 8: Long-term trend in injury rate for riders of heavy motorcycles in Norway

The injury rate has dropped dramatically, indicating that the problem is becoming less important. An exponential trend line has been fitted to the observations. According to the fitted trend line, injury rate declined by 7.7 percent per year, which is considerably more than the overall trend in injury rate for all groups of road users.

**Perception**

One of the factors contributing to a road safety problem may be that it is not considered to be a problem. A problem which is not seen as a problem may be less amenable to treatment than a problem that everybody sees as a problem, and for which stronger action to reduce the problem is supported.

The perception of road safety problems can be studied in many ways. In a recent Norwegian survey, a sample of the population was asked the following question (Elvik and Bjørnskau 2004): How safe do you think it is to travel by means of (airplane, train, ship, bus, car, motorcycle, bicycle or walking)? Do you think it is:

a) Very safe  
b) Safe  
c) A little unsafe  
d) Very unsafe, or are you  
e) Unable to answer (do not know)

The distribution of answers can be converted to a summary value by assigning numerical scores to the categories very safe, safe, a little unsafe and very unsafe. This can of course be done in many ways, but based on the differences in statistically estimated fatality risk between the modes compared, the following values were initially selected: very safe = 1, safe = 5, a little unsafe = 25, very unsafe = 50. Perceived safety was then compared to actual safety for the modes included, see Figure 9.

As can be seen, the differences in fatality risk between the various modes of transport are quite accurately perceived by the Norwegian public. In a similar survey (Fyhri 2002), a
sample was asked how many people they think are killed in road accidents in Norway each year. The mean number in 2002 was 292. The actual number of road accident fatalities in 2002 was 310. On the average, the Norwegian public slightly underestimates the number of people who are killed in road accidents. In 2002, 19 percent of the Norwegian public believed that the number of road accident fatalities was lower than it has been during the past 10 years. 18 percent stated a number that was within the range of the annual number of fatalities in the past 10 years, and 24 percent stated a higher number. 40 percent of the Norwegian public answered that they did not know the number of road accident fatalities.

![Figure 9: Relationship between perceived and actual fatality risk in Norway](image)

Another indicator of the perception of a problem, and also of its amenability to treatment, is the level of support for stronger policy interventions. Table 3 shows the most recent findings of a Norwegian survey regarding this (Fyhri 2002).

Table 3: Support for road safety policy interventions in Norway. N = 1,999 for all questions

<table>
<thead>
<tr>
<th>Policy intervention</th>
<th>Percentage distribution of opinions (N = 1,999)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helmet wearing law for cyclists</td>
<td>Support 84 Oppose 14 No opinion 2 Total 100</td>
</tr>
<tr>
<td>Pedestrian reflective device in darkness</td>
<td>Support 93 Oppose 6 No opinion 1 Total 100</td>
</tr>
<tr>
<td>Imprisonment for drink-driving</td>
<td>Support 79 Oppose 19 No opinion 2 Total 100</td>
</tr>
<tr>
<td>Speed limit of 30 km/h in residential areas</td>
<td>Support 82 Oppose 16 No opinion 2 Total 100</td>
</tr>
<tr>
<td>Speed limit of 30 km/h in towns in general</td>
<td>Support 36 Oppose 60 No opinion 4 Total 100</td>
</tr>
<tr>
<td>Reducing speed limits to improve safety</td>
<td>Support 46 Oppose 51 No opinion 3 Total 100</td>
</tr>
<tr>
<td>Higher fines for speeding</td>
<td>Support 43 Oppose 44 No opinion 13 Total 100</td>
</tr>
<tr>
<td>Device in cars making speeding unpleasant</td>
<td>Support 35 Oppose 62 No opinion 3 Total 100</td>
</tr>
</tbody>
</table>
Huge majorities of the Norwegian public favour a law requiring cycle helmets to be worn, pedestrians to wear a reflective device in the dark, imprisonment to be used more often to punish drinking and driving and a speed limit of 30 km/h in residential areas. When it comes to policy interventions that deal more generally with speed or speeding, however, opinions are more divided. A majority are opposed to reducing speed limits on most roads in towns to 30 km/h. There is also little support for requiring cars to have a device that will make speeding unpleasant (for example by means of an active accelerator pedal giving resistance when the driver tries to exceed the speed limit, or by means of a warning signal that gives an unpleasant sound when the speed limit is exceeded).

This suggests that at least some measures designed to curb speeding will meet with resistance and thus be difficult to implement.

**Amenability to treatment**

A road safety problem is not always easy to solve or reduce, even if it makes a major contribution to accidents or injuries. Amenability to treatment can be defined as the prospects of implementing measures that will reduce the size of a road safety problem, or, in the best of all worlds, eliminate the problem.

Amenability to treatment can be assessed at two levels. At a general level, one can try to classify the various factors contributing to road accidents in terms of their “controllability”, as done by Fridstrøm (1999). He states the following regarding various factors contributing to road accidents:

“Road accidents occur as a result of a potentially very large number of (causal) factors exerting their influence at the same location and time. It might be fruitful to distinguish between six broad categories of factors influencing accident counts.

First, accident numbers depend on a number of truly autonomous factors, determined outside the (national) social system, such as the weather, the natural resources, the state of technology, the international price of oil, the population size and structure, etc – in short, factors that can hardly be influenced (except perhaps in the very long term) by any (single) government, no matter how strong the political commitment.

Second, they depend on a number of general socio-economic conditions, some of which are, in practice or in principle, subject to political intervention, although rarely with the primary purpose of promoting road safety, nor – more generally – as an intended part of transportation policy (industrial development, (un)employment, disposable income, consumption, taxation, inflation, public education, etc).

At a third level, however, the size and structure of the transportation sector, and the policy directed towards it, obviously have a bearing on accident counts, although usually not intended as an element of road safety policy (transport infrastructure, public transportation level-of-service and fares, overall travel demand, modal choice, fuel and vehicle tax rates, size and structure of vehicle pool, driver’s license penetration rates, etc). Most importantly, many of these factors are strongly associated with aggregate exposure, i.e. with the total volume of activities exposing the members of society to road accident risk.

Fourth, the accident statistics depend, of course, on the system of data collection. Accident underreporting is the rule rather than the exception. Changes in the reporting routines are liable to produce fictitious changes in the accident counts.

Fifth, accident counts, much like the throws of a die, are strongly influenced by sheer randomness, producing literally unexplainable variation. This source of variation is particularly prominent in small accident counts. For larger accident counts, the law of large
numbers prevails, producing an astonishing degree of long-run stability, again in striking analogy with the dice game.

Finally, accident counts are susceptible to influence – and, indeed, influenced – by accident countermeasures, i.e. measures intended to reduce the risk of being involved or injured in a road accident, as reckoned per unit of exposure.

Although generally at the centre of attention among policy-makers and practitioners in the field of accident prevention, this last source of influence is far from being the only one, and may not even be the most important. To effectively combat road casualties at the societal level, it appears necessary to broaden the perspective on accident prevention, so as to – at the very least – incorporate exposure as an important intermediate variable for policy analysis and intervention.”

At a more detailed level, one can try to assess the amenability of various problems to treatment by combining information on the size of these problems with information on the level of support for stronger policy interventions. Figure 10 shows such a combination of information for four road safety problems in Norway. The four problems are speeding, drinking and driving, pedestrian accidents in the dark, and cyclist accidents. For each of these problems, the percentage of the public who support stronger policy interventions, confer Table 3, is shown on the abscissa. The higher the percentage, the more easy one would think it would be to introduce the road safety measures that can reduce the problem. Also shown in Figure 10 is the fatality risk attributable to each problem. This is an indication of the importance of the problem.

As can be seen from Figure 10, measures designed to reduce drinking and driving, pedestrian accidents in the dark and cyclist accidents enjoy wide support. Measures to curb speeding, which is the most important of the problems shown in Figure 10, are less supported. This suggests that speeding may be less amenable to treatment than the other three problems listed in Figure 10.

![Figure 10: The amenability of road safety problems to treatment](image-url)
A treatable road safety problem is one for which there exist potentially effective measures that can be taken, the measures are not strongly opposed by a majority of the population and the measures are not prohibitively expensive.

LIMITATIONS OF THE ANALYSIS OF ROAD SAFETY PROBLEMS

Although a rational analysis of road safety problems is possible, any such analysis will be incomplete and will, in general, be subject to the following limitations:

• There are many important risk factors for which no meaningful estimate of attributable risk or other dimensions of their effects is possible. Inattention on the part of road users is a case in point. There is little doubt that inattention causes many accidents. However, trying to quantify the contribution of this risk factor to accidents is very difficult, because exposure to it is virtually impossible to measure (what is the proportion of kilometres driven by inattentive drivers?).

• Risk factors tend to be correlated, but these correlations are not very well known. It is in most cases probably not correct to add the risks attributable to two risk factors in order to find their joint contributions to accidents or injuries.

• Some road safety problems are not adequately described in terms of enhanced risk. Children, for example, do not have an excessive risk of injury in traffic compared to adults. However, it is a policy objective to provide a higher level of safety for children than for other groups of road users. As long as it remains possible to reduce the risk of injury to children, this policy objective has not been fully attained, despite the fact that estimates of attributable risk will not identify children as a particularly vulnerable group.

• Accidents and injuries are not fully reported in official accident statistics. If the level of reporting is associated with a risk factor, an estimate of the risk attributable to that factor will be biased. This may apply to the risk attributable to being an unprotected road user, at least as far as injuries is concerned. Injuries to unprotected road users, especially cyclists, are known to be more incompletely reported in official statistics than injuries to car occupants. An estimate of attributable risk based on official accident statistics will then be an underestimate of the true risk attributable to being an unprotected road user.

• It is in some cases not possible to perform a complete analysis of road safety problems at a single level of government. In this paper, the focus has been on road safety problems that can be analysed at the national level. Network screening is part of such an analysis, but a detailed analysis of the parts of the road system that are identified as needing safety treatment will usually have to be made at the local level of government, as familiarity with local conditions is essential in analysing local road safety problems.

• The availability of relevant data will set limits to any analysis. If, for example, the use of seat belts is not monitored regularly, it is not possible to know if not wearing seat belts is a road safety problem. The framework presented here can only be implemented if fairly detailed and extensive data are available.

CONCLUSIONS AND GUIDELINES

A comprehensive analysis of road safety problems is needed to develop effective road safety programmes. Analysis of road safety problems must be made both at the national level and at regional and local levels of government. The analysis of road safety problems is complex,
as these problems are multidimensional and tend to be clustered. To ensure that the most important problems are identified, it is important to rely on a systematic approach to analysis. This paper has explained the main elements of such a systematic approach. These elements can be summarised as follows:

1. Analysis should start by choosing a taxonomy to help classify problems. A tentative list of problems to be subjected to analysis should be made. It is impossible to analyse every conceivable road safety problem. Analysts should therefore confine analysis to those problems that are believed to be the most important. A realistic level of ambition is probably to aim for an analysis of around 20 road safety problems that are judged to be the most important.

2. Road safety problems are multidimensional. The most important dimensions of such problems are:
   a. Magnitude
   b. Severity
   c. Complexity
   d. Inequity
   e. Territoriality
   f. Dynamics
   g. Perception
   h. Amenability to treatment

3. The most important of the dimensions listed above are magnitude, severity and amenability to treatment. It is important to try to assess amenability to treatment as part of the analysis; otherwise there is a risk that the road safety programme developed will be too idealistic or optimistic with respect to the prospects for solving the problems.

4. To be able to assess all dimensions of all road safety problems selected for analysis, very extensive data are needed. All relevant data will not always be available. In case new data need to be collected, the following guidelines are offered with respect to the data that are most important to collect:
   a. Periodic travel behaviour surveys should be made in order to estimate the amount of travel for as many groups of road users as possible.
   b. Road user behaviour should be monitored regularly with respect to speed, drinking and driving and seat belt wearing.
   c. Surveys should be made to assess risk perception and the level of support for various road safety measures.

5. Analyses of road safety problems should be updated regularly. New problems may emerge - talking on the mobile phone while driving, driving when fatigued - and some old problems may become less important - riding a motorcycle without a helmet, driving without daytime running lights.
REFERENCES


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