PERGAMON

Accident Analysis and Prevention 35 (2003) 557–570

ACCIDENT ANALYSIS & PREVENTION

www.elsevier.com/locate/aap

How would setting policy priorities according to cost–benefit analyses affect the provision of road safety?

Rune Elvik*

Institute of Transport Economics, P.O. Box 6110, Etterstad, N-0602 Oslo, Norway

Received 26 October 2001; received in revised form 27 December 2001; accepted 1 March 2002

Abstract

This paper analyses how setting priorities for road safety strictly according to cost–benefit analysis would affect the provision of road safety in Norway and Sweden. The paper is based on recent analyses of the efficiency of road safety policies in these two countries. The argument sometimes made by critics of cost–benefit analysis, that only a few road safety measures are cost-effective (have benefits greater than costs), is not supported. Cost-effective road safety policies could prevent between 50 and 60% of the current number of road accident fatalities in both Norway and Sweden, if pursued consistently during a period of 10 years (2002–2011). If current policies are continued, only about 10–15% of the current number of road accident fatalities are likely to be prevented during the next 10 years. A number of sources of inefficiency in road safety policy are identified. A source of inefficiency is anything that prevents policy priorities from being set according to cost–benefit analysis. These include: (a) lack of power, which means that national governments do not have the formal authority to introduce a certain road safety measure, in Europe, this applies to new vehicle safety standards, which are passed almost exclusively by the European Union; (b) the existence of social dilemmas, which means that measures that are cost-effective from a societal point of view are not so from the point of view of individual road users; (c) priority given to other policy objectives, in particular regional development. Scarcity of resources, which obtains when public budgets have to be increased to make room for all cost-effective measures, was not found to be a constraint. All cost-effective measures can be funded within current budgets, provided the use of inefficient measures ceases.

Keywords: Road safety; Policy; Efficiency; Cost–benefit analysis; Norway; Sweden

1. Introduction

Road safety has been greatly improved in many motorised countries since the number of road accident fatalities reached an all-time high around 1970. Nevertheless, there is still a large potential for further improving road safety, even in countries that have a comparatively good road safety record, like Norway and Sweden (Elvik, 2001a,b). Current road safety policies in these two countries are, however, rather ineffective in improving road safety. Recent analyses (Elvik, 1999a, 2001a; Elvik and Amundsen, 2000) indicate that current policy priorities are inefficient in both Norway and Sweden. These analyses conclude that road safety could be improved substantially if policy priorities were based on cost–benefit analyses to a greater extent than they are today.

The use of cost–benefit analysis to set priorities for road safety policy, is controversial. At least two arguments are often made against the use of cost–benefit analyses to set priorities for road safety:

1. Cost–benefit analysis is based on the assumption that road safety ought to be provided only to the extent that there is a demand for it (i.e. a willingness-to-pay for reduced risk). But, critics claim that one of the major problems of road safety policy, is that there is no demand for road safety. Hence, providing for road safety only to the extent that monetary benefits exceed costs will not result in a large improvement in safety. An OECD report (OECD Scientific Expert Group, 1993), for example, is based on the assumption that road safety needs to be "marketed" otherwise there will be an insufficient demand for it.
2. It is unethical to reject proposals for improving safety simply because monetary benefits are believed to be smaller than monetary costs.

Based on these arguments, this paper examines whether it is true that setting priorities for the provision of road safety according to cost–benefit analyses would in fact lead only to a small improvement in safety. The main question to be discussed is: does setting priority for road safety measures on the basis of cost–benefit analysis greatly restrict the scope for improving road safety? Next, the question is asked: what

* Tel.: +47-22-57-38-00; fax: +47-22-57-02-90.
E-mail address: re@toi.no (R. Elvik).

0001-4575/02/$ – see front matter © 2002 Elsevier Science Ltd. All rights reserved.
PII: S0001-4575(02)00034-9

prevents priorities from being based on cost–benefit analysis, given the fact that such policy priorities would improve road safety more than current policy priorities are doing? The objective of the paper is to try to identify and assess the contributions of various constraints to road safety policy making, in particular constraints that prevent priorities from being based on cost–benefit analysis. The ethical objections to using cost–benefit analysis will not be considered. A brief discussion is given in another paper (Elvik, 2001b).

2. Analyses of road safety policies in Norway and Sweden

2.1. Alternative strategies for road safety policy

Road safety policies in Norway and Sweden have recently been analysed (Elvik, 1999a, 2001a; Elvik and Amundsen, 2000). In these analyses, four main strategies for improving road safety were developed for both Norway and Sweden:

1. Continuing current road safety policy, the business-as-usual strategy.
2. Basing road safety policy strictly on cost–benefit analyses, the cost–benefit strategy.
3. Basing road safety policy on the principles of Vision Zero, the Vision Zero strategy.
4. Implementing all potentially effective road safety measures to the maximum conceivable extent, the maximum safety potentials strategy.

Each of these strategies was assumed to apply for 10 years: 2002–2011. Each strategy consisted of a number of road safety measures that were regarded as potentially effective. A measure was classified as potentially effective if:

1. evaluation studies have found that it reduces the number of accidents or the severity of injuries, or if;
2. the measure is known to favourably affect one or more risk factors that are known to contribute to accidents or injuries. As an example, all measures known to reduce driving speeds were regarded as potentially effective, because reduced speed is known to lead to fewer and less serious accidents (Elvik et al., 1997).

2.2. Screening of potentially effective road safety measures

In order to develop the strategies, a broad range of road safety measures was screened for the purpose of determining potential effectiveness. Of 132 road safety measures screened for Norway, 59 were regarded as potentially effective. Of 139 road safety measures screened for Sweden, 62 were regarded as potentially effective. Table 1 lists all measures that were considered.

Table 1 also presents the benefit–cost ratio in current use and optimal use (to be defined later) for all measures that were included in a formal assessment of costs and benefits. The term “inapplicable” in the column referring to optimal use indicates that it would be optimal not to use the measure at all.

Measures were excluded from a formal analysis of costs and benefits if one or more of the following five conditions obtained:

1. The effects of the measure on accidents or injuries were too badly known for meaningful quantification.
2. The measure was ineffective, which means that, according to available evaluation studies it did not reduce the number of accidents or the severity of injuries.
3. The measure has already been fully implemented. In Norway, for example, more than 99% of motorcyclists wear crash helmets.
4. The measure overlaps another measure or is dominated by it. As an example, general rehabilitation and reconstruction of existing roads was assumed to overlap both cross section improvements and changes in road alignment. To avoid double counting, just one of the measures was included.
5. The measure was analytically intractable, meaning that it was difficult to define its level of use in a way that permits costs and effects to be calculated. Land use planning is an example of a measure that was classified as analytically intractable.

For road safety measures that are currently being used, four alternatives were developed for use of the measure:

1. The measure is not used at all.
2. The measure is used to the same extent as today.
3. The measure is used to a somewhat higher extent than today.
4. The measure is used to the maximum conceivable extent.

For measures that are not currently used, or used only to a very minor extent, the alternatives for their use were:

1. The measure is not introduced at all.
2. The measure is introduced at the start of the last year of the period, 2011, and has an effect during 1 year (the final year of the planning period).
3. The measure is introduced at the start of the first year of the period, 2002, and has an effect during 10 years (all years of the planning period).
4. The measure is introduced retroactively at the start of the first year of the period, 2002, and is retrofitted on all older vehicles in the same year.

The four strategies that were developed can briefly be described as follows. The business-as-usual strategy consists of road safety measures that are used at present, and of new measures, which it has been decided to introduce. The cost–benefit strategy consists of all road safety measures whose marginal benefits are greater than or equal to the marginal costs. Marginal benefits were defined as total benefits for all transport policy objectives. Benefits were assessed in terms of current, official monetary valuations of

Table 1
List of road safety measures surveyed for a formal analysis of costs and benefits

Measure (short name)	Code	Included	Reason for exclusion	Benefit–cost ratio in current and optimal use			
				Norway		Sweden	
				Current use	Optimal use	Current use	Optimal use
Organisational measures	1	No	Effects unknown				
Information to policy makers	2	No	Effects unknown				
Targeted road safety programmes	3	No	Overlaps other measures				
Safe community programmes	4	No	Overlaps other measures				
Exposure control	5	No	Overlaps other measures				
Land use planning	6	No	Analytically intractable				
Road planning	7	No	Overlaps other measures				
Road safety audits	8	Yes		Not used	1.34	Not used	Inapplicable
Motor vehicle taxation	9	Yes		Not known	Inapplicable	Not known	Inapplicable
Road pricing	10	No	Effects unknown				
Changing the modal split of travel	11	No	Analytically intractable				
Road traffic legislation	12	No	Overlaps other measures				
Regulating commercial transport	13	No	Ineffective measure				
Automatic accident warning and location	14	Yes		Not used	Inapplicable	Not used	Inapplicable
Pedestrians bridges or underpasses	101	Yes		6.03	3.73	1.57	1.44
Motorways	102	Yes		0.80	Inapplicable	0.31	Inapplicable
Reconstructing two-lane roads to motorways	102	Yes		Not used	Not estimated	1.19	1.11
Bypass roads	103	Yes		0.88	Inapplicable	0.84	Inapplicable
New urban arterial roads	104	No	Ineffective measure				
Channelisation of junctions	105	No	Overlaps other measures				
Roundabouts	106	Yes		1.52	2.26	1.70	1.90
Geometric layout of junctions	107	No	Ineffective measure				
Staggered junctions	108	Yes		0.51	Inapplicable	0.28	Inapplicable
Interchanges	109	Yes		2.04	1.50	2.19	1.75
Black spot treatment	110	No	Overlaps other measures				
Cross section improvement	111	No	Overlaps other measures				
Roadside safety treatment	112	Yes		Not used	Inapplicable	1.28	1.28
Improving road alignment	113	No	Overlaps other measures				
General rehabilitation of roads	114	Yes		0.61	Inapplicable	0.55	Inapplicable
Guard rails on the roadside	115	Yes		1.18	1.18	0.69	Inapplicable
Median guard rails (not on motorways)	115	Yes		Not used	1.14	1.45	1.45
Preventing accidents involving animals	116	Yes		0.11	Inapplicable	1.83	1.11
Horizontal curve treatment	117	Yes		6.55	5.75	1.90	1.90
Road lighting	118	Yes		2.51	1.92	1.60	1.21
Upgrading substandard road lighting	118	Yes		4.32	2.62	Not known	Not estimated
Road tunnel safety measures	119	No	Overlaps other measures				
Rest areas	120	No	Effects unknown				
Resurfacing of roads	201	No	Ineffective measure				
Road surface roughness treatment	202	No	Ineffective measure				
Road surface friction treatment	203	No	Ineffective measure				
Brighter road surface	204	No	Ineffective measure				
Landslide protection	205	No	Effects unknown				
Winter maintenance of roads	206	Yes		Not known	3.17	Not known	2.67
Winter maintenance of walking areas	207	No	Ineffective measure				
Correcting erroneous highway signs	208	No	Overlaps other measures				
Highway work zone safety devices	209	No	Effects unknown				

Table 1 (*Continued*)

Measure (short name)	Code	Included	Reason for exclusion	Benefit–cost ratio in current and optimal use			
				Norway		Sweden	
				Current use	Optimal use	Current use	Optimal use
Area wide urban traffic calming	301	Yes		3.18	3.05	−0.50	Inapplicable
Environmentally adapted main roads	302	Yes		−0.67	Inapplicable	−0.30	Inapplicable
Pedestrian streets	303	No	Fully implemented				
Walking speed streets (7 km/h streets)	304	Yes		−2.61	Inapplicable	−0.76	Inapplicable
Access control on existing roads	305	No	Ineffective measure				
Priority roads	306	No	Ineffective measure				
Yield signs at junctions	307	No	Ineffective measure				
Stop signs at junctions (four-way stop)	308	Yes		Not used	Inapplicable	Not used	Inapplicable
Traffic signal control at junctions	309	Yes		3.38	3.38	3.96	3.96
Upgrading substandard traffic signals	309	Yes		1.66	1.51	Not known	Not estimated
Traffic signal control of pedestrian crossings	310	Yes		0.87	Inapplicable	0.66	Inapplicable
Adoption of optimal speed limits	311	Yes		Not used	4.47	Not used	1.00
Speed humps on residential roads	312	Yes		−8.75	Inapplicable		
Road markings	313	No	Fully implemented			−0.76	Inapplicable
Upgrading marked pedestrian crossings	314	Yes		2.07	1.75	1.46	1.14
Parking regulations	315	No	Overlaps other measures				
One way streets	316	No	Ineffective measure				
Reversible lanes	317	No	Ineffective measure				
Bus lanes (HOV-lanes)	318	No	Ineffective measure				
Dynamic route guidance	319	No	Effects unknown				
Variable message signs	320	Yes		1.45	1.33	Not used	1.13
Railroad-highway grade crossing	321	No	Fully implemented				
Tire tread depth	401	No	Fully implemented				
Use of studded tires/winter tires	402	No	Fully implemented				
ABS-braking systems	403	No	Ineffective measure				
High mounted stop lamps	404	Yes		3.89	3.92	9.07	7.89
Daytime running lights on cars	405	No	Fully implemented				
Daytime running lights on motorcycles	406	No	Fully implemented				
Self levelling headlamp requirement	407	Yes		Not used	2.19	Not used	1.39
Use of reflective devices by pedestrians	408	Yes		Not known	7.58	Not known	5.09
Use if reflective devices by cyclists	408	Yes		Not known	Inapplicable	Not known	Inapplicable
Steering, handling, stability of cars	409	No	Effects unknown				
Bicycle helmets, campaign and law	410	Yes		Not known	1.30	Not known	3.09
Helmets for motorcyclists	411	No	Fully implemented				
Seat belt reminder in passenger cars	412	Yes		Not used	Not estimated	11.85	11.34
Ignition interlock for seat belts	412	Yes		Not used	4.40	Not used	28.36
Child restraints	413	No	Fully implemented				
Air bags	414	Yes		0.66	Inapplicable	0.40	Inapplicable
Seat belts in heavy vehicles	415	No	Effects unknown				
Vehicle crashworthiness	416	No	Analytically intractable				
Modifying car instruments and controls	417	No	Effects unknown				
Intelligent cruise control	418	Yes		Not used	Inapplicable	Not used	Inapplicable
Regulating vehicle mass	419	No	Ineffective measure				
Intelligent speed adaptation devices	420	Yes		Not used	Inapplicable	Not used	1.37

Table 1 (*Continued*)

Measure (short name)	Code	Included	Reason for exclusion	Benefit–cost ratio in current and optimal use			
				Norway		Sweden	
				Current use	Optimal use	Current use	Optimal use
Motor power regulation of motorcycles	421	No	Ineffective measure				
Improving under run guard rails on trucks	422	Yes		Not known	1.18	Not known	Inapplicable
Front impact protection on trucks	423	Yes		Not used	Inapplicable	Not used	1.22
Safety equipment on motorcycles	424	No	Analytically intractable				
Safety equipment on bicycles	425	No	Overlaps other measures				
Safety equipment on trailers	426	No	Effects unknown				
Fire protection measures	427	No	Effects unknown				
Hazardous goods transport safety	428	No	Effects unknown				
Crash data recorder	429	Yes		Not used	1.11	Not used	1.50
New safety standards for front and bumper	430	Yes		Not used	4.66	Not used	6.80
Type approval of cars and spot checks	501	No	Overlaps other measures				
Periodic motor vehicle inspection	502	No	Ineffective measure				
Roadside inspections of trucks	503	Yes		10.13	9.50	Not known	1.24
Garage approval and inspection	504	No	Effects unknown				
Age limits for driver's license	601	No	Fully implemented				
Health regulations for drivers	602	No	Fully implemented				
Knowledge and skills requirements	603	No	Ineffective measure				
Reforming basic driver training	604	Yes		Not used	Inapplicable	Not used	1.43
Training of problem drivers (voluntary)	605	Yes		Not used	Inapplicable	Not used	Inapplicable
Driver's license examination	606	No	Fully implemented				
Training of motorcyclists	607	No	Ineffective measure				
Training of bus and truck drivers (voluntary)	608	Yes		Not known	2.16	Not known	Inapplicable
Graduated driver's license—curfews	609	No	Overlaps other measures				
Rewarding safe driving	610	No	Overlaps other measures				
Regulation of driving and rest hours	611	No	Fully implemented				
Safety regulation of emergency driving	612	No	Ineffective measure				
School bus transport for children	613	No	Fully implemented				
Training of pre-school children (age <6)	701	No	Ineffective measure				
Training of school children (age 6−)	702	Yes		Not known	Inapplicable	Not known	Inapplicable
Public information campaigns	703	No	Ineffective measure				
Extending "speak out!" safety campaign	703	Yes		16.80	7.01	Not used	Not estimated
Feedback signs and variable message signs	704	No	Overlaps measure 320				
Speed enforcement	801	Yes		Not known	3.62	Not known	2.89
Patrolling traffic (general enforcement)	802	No	Ineffective measure				
Regulation of drinking and driving	803	No	Fully implemented				
Random breath testing	804	Yes		Not known	1.51	Not known	1.50
Seat belt enforcement	805	Yes		Not known	3.85	Not known	2.67
Speed cameras	806	Yes		8.90	4.75	Not used	1.60
Red light cameras	807	Yes		Not known	Inapplicable	Not known	1.69
Simple traffic tickets	808	No	Ineffective measure				
Ordinary traffic tickets and imprisonment	809	No	Overlaps other measures				

Table 1 (*Continued*)

Measure (short name)	Code	Included	Reason for exclusion	Benefit–cost ratio in current and optimal use			
				Norway		Sweden	
				Current use	Optimal use	Current use	Optimal use
Demerit point systems	810	Yes		Not used	8.58	Not used	2.70
Motor vehicle insurance regulation	811	No	Effects unknown				
Alcohol ignition interlock for recidivists	812	Yes		Not used	4.19	Not used	3.01
Vehicle impoundment for unlicensed driving	813	Yes		Not used	8.23	Not used	2.86

First order benefit–cost ratio for measures that were included.

travel time, vehicle operating costs, road accidents, traffic noise, and air pollution in Norway and Sweden. Hence, the term "benefits" in the cost–benefit strategy refers to the total benefits with respect to all these impacts, not just impacts on road safety. Table 2 shows the impacts that were included in the cost–benefit analyses and the monetary valuation of these impacts.

The Vision Zero strategy was based on the main principles of Vision Zero for traffic accident fatalities. These principles are described in more detail in other papers (Elvik, 1999b, 2001a). As this strategy is not crucial to the analyses reported in this paper, it will not be considered further.

The maximum safety potentials strategy involves using all potentially effective road safety measures to the maximum conceivable extent. The concept of "maximum conceivable extent" is of course open to different interpretations. The following interpretations of this concept were chosen:

1. For measures related to road design, reconstructing all roads, or constructing new roads, according to current design standards, or the design standards implied by Vision Zero, was regarded as the maximum conceivable use of a measure. Many older roads have not been built according to current design standards, or Vision Zero standards;
2. For vehicle related measures, retrofitting new safety devices on the entire vehicle fleet was defined as the maximum conceivable use of a measure. A 95% compliance with such a requirement was regarded as maximum.
3. For police enforcement, 10 times the current level of enforcement was defined as the maximum conceivable use of the measure. This is close to the maximum level of enforcement for which effects on road safety have been evaluated.

For each level of use defined for each measure, effects on safety were estimated in terms of the prevented number of

Table 2
Monetary valuation of impacts included in cost–benefit analysis

Type of impact	Unit of valuation	Current monetary valuation per unit (national currencies; 1999 price level)			
		Norway (NOK; 1 NOK = 0.107 USD)		Sweden (SEK; 1 SEK = 0.092 USD)	
Travel time	1 vehicle hour for a car	82.4		120	
	1 vehicle hour for a truck	320.7		251	
	1 vehicle for a bus (including passengers)	837.7		770	
Vehicle operation	1 km of driving: car	0.92		1.00	
	1 km of driving: truck or bus	2.73		5.60	
Road safety	1 fatality	20.15 million		14.3 million	
	1 seriously injured person	5.75 million		6.2 million	
	1 slightly injured person	0.6 million		0.36 million	
Environmental impacts		Rural areas	Urban areas	Rural areas	Urban areas
	Traffic noise per car km of driving	0.00	0.14	0.008	0.067
	Traffic noise per bus or truck km of driving	0.00	1.14	0.040	0.617
	Emission of 1 kg of carbon dioxide (CO_2)	0.37	0.37	1.50	1.50
	Emission of 1 kg of nitrogen oxide (No_x)	33	66	60	72
	Emission of 1 kg of volatile organic compounds (VOC)	33	66	30	50
	Emission of 1 kg of sulphur dioxide (SO_2)	18	70	20	118
	Emission of 1 kg of particulate matter (PM10)	0	1700	0	3343

Norway and Sweden.

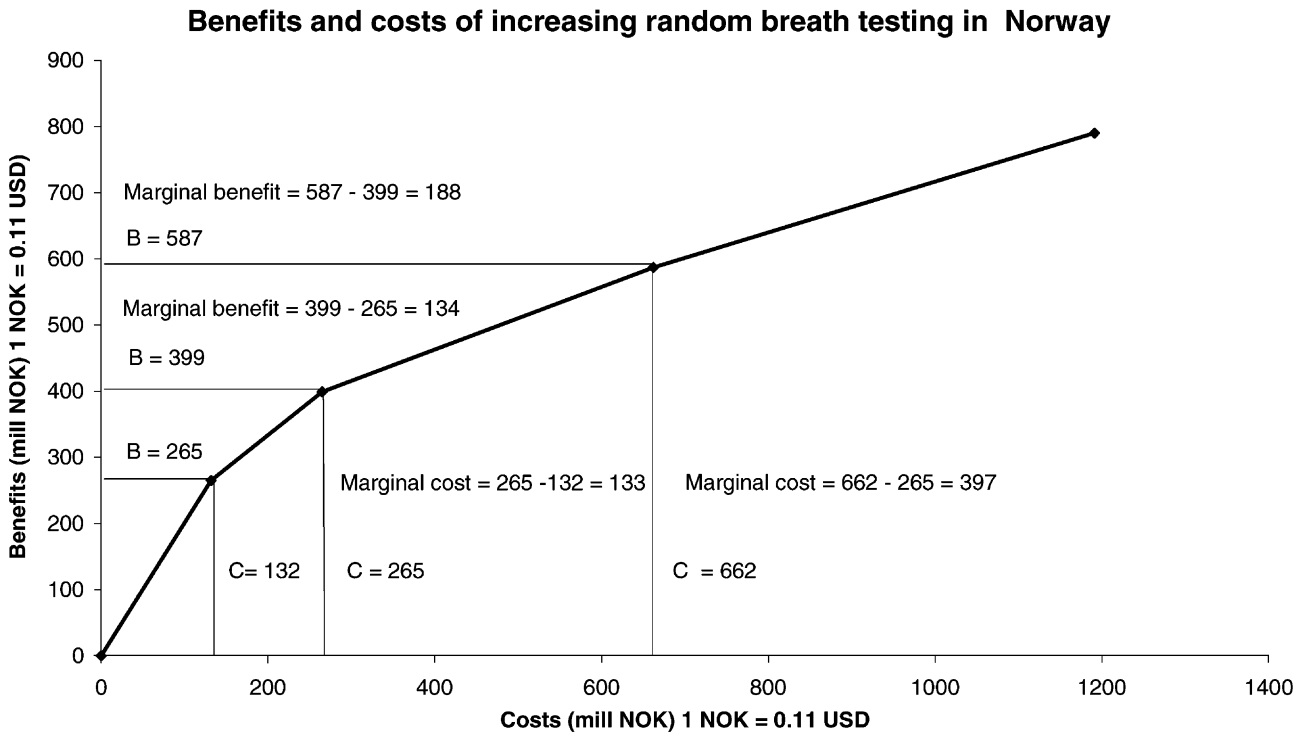

Fig. 1. Illustration of the concept of marginal costs and benefits.

people killed, seriously injured or slightly injured in road accidents. These effects will be referred to as first order effects. The first order effect of a measure is the effect it has on safety when applied alone, without regard to possible interactions with other measures.

A short explanation of the concept of marginal costs and benefits is given in Fig. 1. Marginal costs and benefits are defined in terms of the levels of use of each measure. Fig. 1 uses random breath testing in Norway as a case illustration. At the lowest level of use, benefits are estimated to 265 million NOK, costs to 132 million NOK. If random breath testing is stepped up, benefits at the next level of use are 399 million NOK, costs 265 million NOK. Marginal benefits of stepping up random breath testing are $399 - 265 = 134$ million NOK. Marginal costs are $265 - 132 = 133$ million NOK. Hence, at this level of use of the measure, marginal benefits are equal to marginal costs. This is the optimal use of the measure.

2.3. Combining measures into strategies

The combined effects of several measures affecting the same group of accidents or injuries were estimated as follows. Let E_i denote the first order effect of each measure in terms of the number of fatalities or injuries it prevents. Let R_i denote the "residual" of measure i, that is the number of fatalities or injuries it does not prevent. Both quantities are measured as proportions of the total number of fatalities or injuries affected by each measure. Suppose for example, a measure affects 300 injuries per year, and prevents 90 of these. For this measure, E_1 is:

$$\frac{90}{300} = 0.30,$$

and R_1 is:

$$\frac{300-90}{300} = \frac{210}{300} = 0.70.$$

Suppose another measure reduces the same category of injuries by 70 (i.e. $E_2 = 70/300 = 0.233$ and $R_2 = 230/300 = 0.767$). The combined effect of these two measures is then:

$$\text{combined effect of measures 1 and 2} = (1 - (0.700 \times 0.767)) = 0.463,$$

which corresponds to preventing $0.463 \times 300 = 139$ injuries. The combined effect is less than the sum of the first order effects, i.e. $90 + 70 = 160$ prevented injuries. The combined effect of all measures was estimated as:

$$\text{combined effect} = 1 - \prod_{i=1}^{n} R_i$$

This method is based on the assumption that the first order effect of each measure, stated in terms of the percentage reduction of the number of accidents or injuries, is independent of whatever other measures are introduced. It is not known how correct this assumption is. In some cases it is

Table 3
Estimated impacts on traffic fatalities of alternative strategies for road safety policy in Norway and Sweden 2002–2011 and policy constraints

Road safety strategies 2002–2011 and constraints	Norway		Sweden	
	Number of road accident fatalities	Contribution of policy constraint	Number of road accident fatalities	Contribution of policy constraint
Current number of road accident fatalities (mean 1990–99 for Norway; mean 1994–98 for Sweden) (1)	306 (100%)		554 (100%)	
Maximum number of fatalities that can be prevented by means of currently known measures (2)	248 (139–265) (81% (45–87%))		429 (276–534) (77% (50–96%))	
Contribution of constraints external to road safety policy: (1) − (2) = (3)		58 (41–167) (19% (13–55%))		125 (20–278) (23% (4–50%))
Number of fatalities that can be prevented by means of cost-effective measures (4)	183 (59–260) (60% (19–85%))		293 (146–391) (53% (26–71%))	
Constraint attributable to measures not passing the cost–benefit test: (2) − (4) = (5)		65 (5–80) (21% (2–26%))		136 (130–143) (25% (23–26%))
Number of fatalities expected to be prevented by continuing present policy 2002–2011 (6)	34 (−1 to 65) (11% (0–21%))		81 (26–133) (15% (5–24%))	
Constraint attributable to inefficiency of current road safety policy: (4) − (6) = (7)		149 (60–195) (49% (20–64%))		212 (120–258) (38% (22–47%))

Percentage of current number of road accident fatalities, 95% prediction interval in parentheses.

likely to be incorrect. One would, for example, expect reflective clothes or devices worn by pedestrians at night to be less effective on lit roads than on unlit roads. However, since the relative effectiveness of reflective devices with respect to road lighting has not been evaluated, the simplest credible assumption is to apply average effectiveness irrespective of whether or not roads are lit. The effects of all measures included in a certain road safety strategy were therefore estimated according to this model.

2.4. Estimated impacts of alternative road safety strategies

The estimated impacts on the number of road accident fatalities of the alternative strategies for road safety policy in Norway and Sweden are shown in Table 3. The current annual number of road accident fatalities is 306 in Norway and 554 in Sweden. In principle, a very large reduction in these numbers can be achieved by applying all road safety measures that are potentially effective to the maximum conceivable extent. The maximum safety potentials strategy can, in theory, prevent 81% of road accident fatalities in Norway and 77% of road accident fatalities in Sweden. A 95% prediction interval for the estimated effects has been inserted in parentheses in Table 3. Effects were also estimated for all injuries, but are not shown here, as discussions of road safety policy tend to focus on fatalities. Besides, other injuries are incompletely reported in official accident statistics.

The proportion of road accident fatalities which is not preventable, or which would not be prevented, by adopting a certain strategy for road safety policy can be interpreted as the effect of one more constraints on road safety policy. Based on the analyses of alternative strategies for road safety policy, a typology of constraints has been developed.

3. A typology of constraints for road safety policy

A constraint is anything that prevents you from doing what you want or ought to do. It limits the actions you can take. Policy constraints include everything that sets limits to policies. Some constraints are very basic, others are in principle possible to modify. Inspired by a taxonomy proposed by Fridstrøm (1999), the following constraints for road safety policy have been identified, tentatively listed from the most to the least basic:

(A) Constraints external to policy making
1. Pure random variation of the number of accidents or injuries (“randomness”).
2. Contributions of unknown risk factors to accidents or injuries (“ignorance”).
3. Contributions of risk factors that cannot be controlled by means of any known road safety measure (“lack of control”).

(B) Constraints internal to policy making
4. Institutional constraints, in particular lack of power or formal authority for national governments to implement road safety measures (“lack of power”).
5. Inadequate funding, which means that introducing measures whose benefits are greater than the costs would require additional expenditures (“scarcity”).
6. Too costly measures, which means that governments refrain from implementing measures because benefits are smaller than costs (“cost”).
7. Social dilemmas, which denotes a situation in which a road safety measure is cost-effective from a societal point of view, but not from the road users’ point of view (“social dilemmas”).
8. The existence of multiple and competing bases for setting policy priorities, meaning that policy makers face complex policy trade-offs in which they may give higher priority to other policy objectives than those that are addressed within the framework of current cost–benefit analyses (“conflicting objectives”).

A short name used to refer to each of these constraints has been inserted in parentheses. Constraints that are external to policy making are so basic that no road safety policy can ever remove or influence them. They represent, in a sense, what we cannot do anything about. Constraints that are internal to policy making are, however, in principle possible to modify. This paper will try to assess the relative importance of the constraints internal to road safety policy. The external constraints will not be considered. Below the nature of each of the constraints internal to policy making is described.

Lack of power: Formal authority to introduce road safety measures rests, broadly speaking, with three levels of government: International bodies, national governments, and local or regional governments. Lack of power denotes a situation in which the formal authority to introduce road safety measures rests with a higher level of government than the level at which a road safety programme is drafted. For example, national governments lack the power to introduce unilaterally road safety measures that are within the jurisdiction of international bodies, as is currently the case for vehicle safety standards in Europe.

Scarcity: If a road safety measure is cost-effective, which means that its benefits are greater than its costs, but introducing it would require additional expenditures on top of current expenditures, scarcity is said to obtain. It is important to note that scarcity in this sense exists only if a strictly optimal use of all road safety measures would require larger expenditures than the current use of road safety measures. If all cost-effective measures can be funded within current spending limits, there is no scarcity of resources. The rationale behind this definition of scarcity is that, by definition, society can afford what it currently spends on road safety. However, any additional expenditure would be at the expense of other public policy objectives.

Cost: Based on cost–benefit analysis, road safety measures can be categorised as cost-effective or inefficient. A cost-effective measure is one whose marginal benefits are greater than or equal to the marginal costs. An inefficient measure is one whose marginal benefits are smaller than the marginal costs. If one were to rely on cost–benefit analysis, inefficient measures would not be carried out, and would be considered as too costly. Cost, as a constraint on road safety policy, denotes a situation in which measures that could greatly improve road safety are too costly.

Social dilemmas: Cost–benefit analysis takes a societal perspective (Udvarhelyi et al., 1992). This means that it includes all impacts of measures that are economically relevant, irrespective of whether or not the impacts are subject to market transactions, and with no regard to how costs and benefits are distributed among various groups in society. A social dilemma occurs whenever a measure, which is cost-effective from a societal point of view, fails to be so from the point of view of a particular group, like road users. Lowering speed limits may be a case in point. Part of the benefits of lowering speed limits are external from the road user's point of view, that is they are not experienced as a personal gain by the road user as such. This includes part of the cost of road accidents, and perhaps all benefits in terms of less noise and pollution. In an assessment of the private costs and benefits to road users, which would not include the external benefits, the result could well be different from that of a cost–benefit analysis taking a societal perspective.

Conflicting objectives: One of the aims of cost–benefit analysis is, ideally speaking, to help make trade-offs between conflicting policy objectives in a systematic manner. Some policy objectives, notably distributional objectives, are of a nature that does not permit trade-offs to be made within the framework of cost–benefit analysis. If, for example, policy makers want to help regional development by investing in remote and sparsely populated areas, it will often be difficult to justify this priority by means of a cost–benefit analysis. This, of course, does not mean that such policy priorities are wrong, simply that they cannot be fully addressed within the framework of cost–benefit analysis.

4. Assessing the relative importance of constraints on road safety policy

4.1. Results for Norway

The logic of assessing the importance of the constraints internal to road safety policy making is best explained by means of a numerical example. The current expected, annual number of road accident fatalities in Norway is 306 (confer Table 3). By applying all potentially effective road safety measures to their maximum extent during a period of 10 years, it is theoretically possible (Elvik, 1999a) to prevent 248 (139; 265) of these fatalities. This is the estimated effect on fatalities of the maximum safety potentials strategy for Norway.

If the cost–benefit strategy is adopted, 183 (59; 260) road accident fatalities per year can be prevented in Norway (Elvik, 1999a). Hence, the cost constraint, which represents the proportion of road accident fatalities one would regard as too costly to prevent, amounts to:

$$248 - 183 = 65\,\text{fatalities}\,(5;\ 80),$$

or, about 21% (2; 26%) of the current number. Current road safety policy in Norway is, however, not guided by cost–benefit analysis exclusively, but incorporates a number of other considerations. According to an estimate made by the Institute of Transport Economics (Elvik, 1999a), continuing current road safety policy in the years 2002–2011 can prevent 34 fatalities per year. The difference in the number of fatalities prevented by a policy based on cost–benefit analysis and current policy represents the combined effects of the following policy constraints:

1. Lack Of Power;
2. Scarcity;
3. Social dilemmas;
4. Conflicting objectives.

The effects of these constraints represent $183 - 34 = 149$ fatalities per year according to the best estimate of the effects of the alternative road safety strategies made by the Institute of Transport Economics. Hence, the constraints that prevent policy priorities from being set strictly according to cost–benefit analysis contribute substantially more to limiting the effectiveness of road safety policy than the cost constraint.

Assessing the relative importance of each of the four constraints to basing policy on cost–benefit analysis is more difficult. The Ministry of Transport has developed a total of six strategies for transport policy 2002–2011 (Samferdselsdepartementet, 2000). One of these was labelled "the safety strategy". According to this strategy, 132 road accident fatalities could have been prevented. However, the Ministry did not recommend this strategy. The strategy recommended by the Ministry of Transport was estimated to prevent 79 fatalities. One way of indicating the importance of conflicting policy objectives is to take the difference between the road safety strategy and the recommended strategy in terms of the estimated number of road accident fatalities prevented by each strategy. This comes to $132 - 79 = 53$. Hence, by giving more weight to conflicting policy objectives, the Ministry of Transport abstains from preventing 53 road accident fatalities, or 17% of the current number.

It is reasonable to assume that the Ministry of Transport proposes only those road safety measures, which are within its power to implement. The potential for improving road safety by means of cost-effective measures that are outside the power of the Norwegian government, in particular new safety features on motor vehicles has been estimated at around 50 fatalities per year (Elvik, 1999a). Lack of power would then constrain the Norwegian government from preventing about 16% of the annual number of road accident fatalities.

Scarcity does not appear to constrain road safety policy. All the alternative policy strategies developed by the Ministry of Transport had the same budget limits. The analysis reported by the Institute of Transport Economics shows that all cost-effective road safety measures can be funded without having to increase current public expenditures (Elvik, 1999a, 2001a). In theory, one could implement the cost–benefit strategy simply by reallocating spending, without having to increase the total amount spent.

The importance of social dilemmas is difficult to assess. Once more, a rather simple indication is the closest one can get. Cost–benefit analyses show that lowering speed limits on rural highways in Norway is cost-effective from a societal point of view (Christensen, 1993, Statens vegvesen Vegdirektoratet, 1995, Elvik, 1999a). These changes are, however, not cost-effective from the road users' point of view, assuming that 40% of the savings in accident costs, and 100% of the environmental gains are external to the road users (Elvik, 1994; Eriksen et al., 1999). Moreover, public opinion polls (Fyhri, 2001) show that a clear majority of the population is opposed to lowering speed limits on rural highways. From the societal perspective, cost-effective reductions of the speed limits can prevent about 33 fatalities per year, or about 11% of the current annual number. This represents the constraint imposed by social dilemmas.

Fig. 2 summarises the estimated contributions of various constraints on road safety policy in Norway.

The numbers given should not be interpreted too literally; they are merely rough indications of the importance of the various constraints. It is, however, remarkable that scarcity does not appear to be a constraint.

4.2. Results for Sweden

A comprehensive analysis of Swedish road safety policy, has been reported by Elvik and Amundsen (2000). The following discussion is mainly based on this analysis. A government report, which has analysed alternative strategies for transport policy in Sweden, also exists (Samplan, 1999).

During the years 1994–1998, the mean annual number of road accident fatalities in Sweden was 554. It has been estimated, that by applying all known road safety measures to the fullest possible extent during the period 2002–2011, 429 (276; 534) fatalities can be prevented, corresponding to 77% (50; 96%) of the current number (Elvik and Amundsen, 2000). Cost-effective road safety measures can prevent 293 (146; 391) fatalities, or 53% (26; 71%) of the current number (Elvik and Amundsen, 2000). Hence, road safety measures that would be regarded as too costly according to cost–benefit analysis have a potential for preventing about 25% (23; 26%) of all road accident fatalities in Sweden.

If current road safety policy in Sweden is continued in the period 2002–2011, it will prevent only 81 (26; 133) road accident fatalities, or 15% (5; 24%) of the current number (Elvik and Amundsen, 2000). Thus, constraints that prevent policy priorities from being set strictly according to cost–benefit analysis contribute to around 38% (22; 47%) of the current number of road accident fatalities in Sweden. These constraints, as noted above, include lack of power, scarcity of resources, social dilemmas, and priority given to other policy objectives. It is difficult to estimate the precise contribution of each of these constraints.

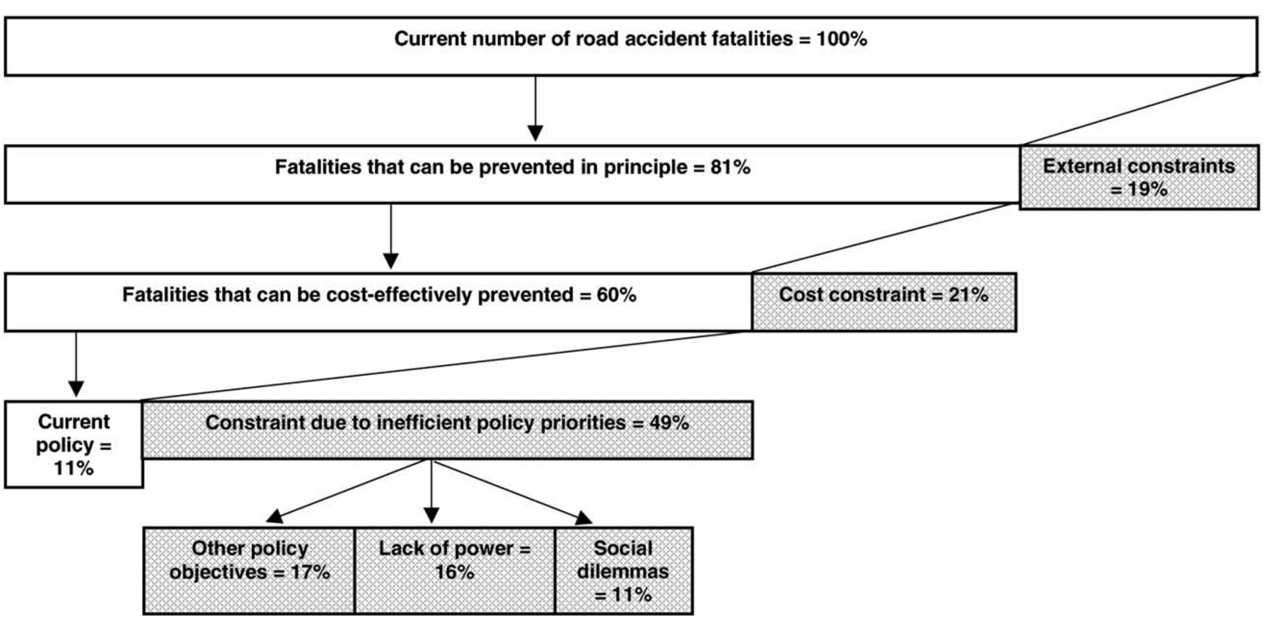

Fig. 2. Contributions of various constraints to road safety policy in Norway.

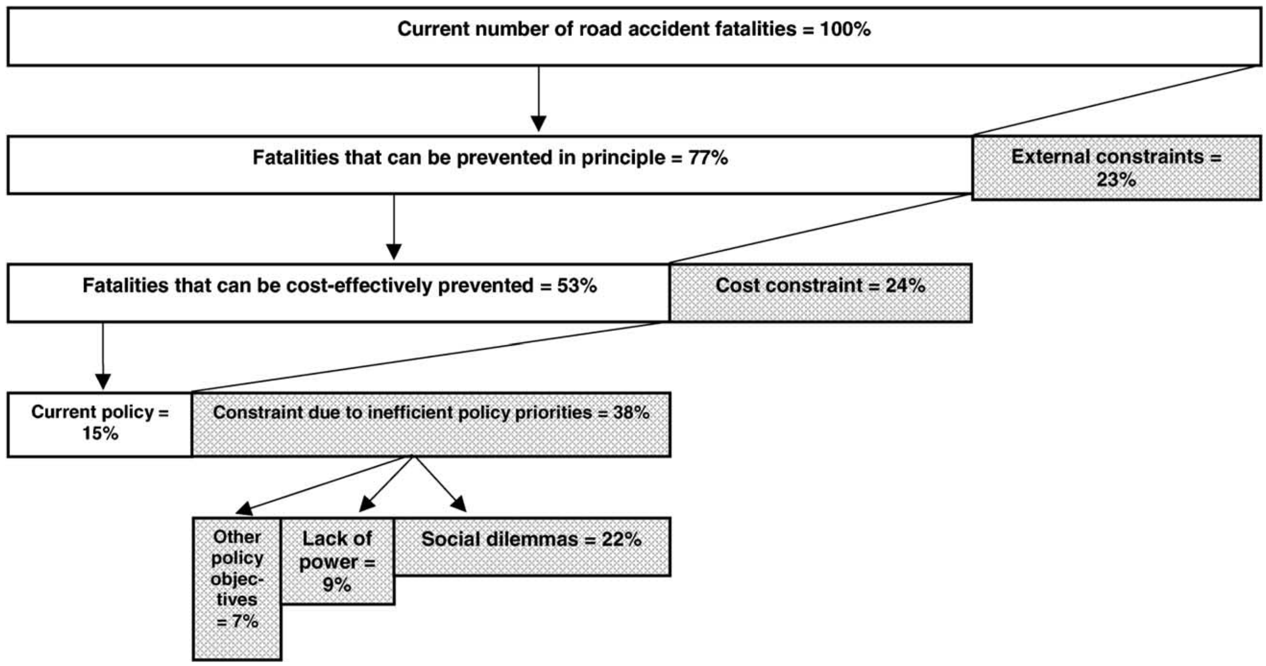

Fig. 3. Contribution of various constraints to road safety policy in Sweden.

According to the report by Elvik and Amundsen (2000), new cost-effective vehicle safety regulations that are outside the jurisdiction of the Swedish government could prevent about 50 fatalities per year. This can be taken to indicate the contribution of lack of power, amounting to 9% of the current number of road accident fatalities. Scarcity of resources does not appear to be a problem. Like in Norway, estimates (Elvik and Amundsen, 2000) show that all cost-effective road safety measures can be funded without having to increase the size of current public spending on road safety measures.

As for social dilemmas, an estimate of their potential contribution to preventing use of cost-effective road safety measures was derived by assuming that the benefits of reducing the net adverse external effects of traffic (Hansson, 1997) are not included in road user utility functions. The net external effects are those costs of accidents, noise, and air pollution that exceed public revenue from taxation on the use of motor vehicles. These net externalities make up about 5% of the costs of road accidents and about 20% of the costs of noise and air pollution. If cost–benefit analyses are redone, leaving out 5% of the benefits of savings in accidents, and 20% of the benefits of improving the environment, measures that could prevent 122 fatalities become inefficient (i.e. their private benefits are smaller than the costs). This amounts to 22% of the current number of road accident fatalities in Sweden.

The weight given to other policy objectives cannot be precisely known. By using all road safety measures that are cost-effective in Sweden, 293 fatalities per year could be prevented, as opposed to only 81 fatalities prevented per year by continuing current road safety policy. The difference is 212 (293 − 81) fatalities per year. According to the estimates above, the combined contributions of lack of power (50), scarcity (0), and social dilemmas (122) account for 172 of the fatalities that could, in principle be prevented by a cost-effective road safety policy. The residual, 40 fatalities, can be attributed to priority being given to other policy objectives. This is a conservative estimate. It is, however, consistent with the fact that, at present, measures whose benefits are smaller than the costs are being used in Sweden to a wide extent (Elvik and Amundsen, 2000). Fig. 3 summarises the estimated contributions of the policy constraints for Sweden.

5. Discussion

Norway and Sweden have long had some of the best safety records in the world among the highly motorised countries. In recent years, however, progress in reducing the number of road accident fatalities has slowed down in both countries. Policy analyses suggest that more successful results could be achieved if the use of road safety measures was based on cost–benefit analyses to a greater extent. Perhaps the most remarkable finding of the analyses that have been made is the fact that there still seems to be a great potential for improving road safety in both Norway and Sweden. The maximum potential is, of course, impossible to fully realise in practice. But cost-effective road safety measures can prevent more than 50% of road accident fatalities in both Norway and Sweden. What prevents this from happening?

No great reduction of the number of road accident fatalities is going to be achieved if current road safety policies are continued in Norway and Sweden. Current policies will only prevent about 10–15% of the current number of road accident fatalities during the next 10 years. If traffic continues to grow, there may not even be a net reduction of the number of road accident fatalities at all.

It is not correct that all cost-effective road safety measures have already been used, and that only expensive measures, that do not pass the cost–benefit test remain to be used. It is correct that according to cost–benefit analysis, some road safety measures will be too expensive—implying that society is willing to accept more than zero fatalities in road accidents. At present, however, a larger obstacle to reducing road accident fatalities appears to be the inefficiency of priorities. Many of the cost-effective measures are not carried out. A number of reasons may account for this; an attempt has been in this paper to indicate the importance of some of these factors.

By rejecting the use of cost–benefit analyses to set policy priorities, proponents of Vision Zero are in effect rejecting a road safety policy that would give far better results than current road safety policies are doing. Until critics of cost–benefit analysis can propose a better way of setting policy priorities, these critics are, at least by default, defending policies that deliver far smaller safety benefits than policies based on cost–benefit analyses would deliver.

There are many objections to this line of reasoning. Why, one might ask, should road safety policy be based on the "demand" for safety, as proponents of cost–benefit analysis call for? There is, of course, no compelling reason why it should. Cost–benefit analysis is based on a number of principles that are explicitly normative, and which are of course contestable. Normative principles do not have the same undisputable status as logical axioms. They can be questioned. The main point of this paper is not to defend the principles of cost–benefit analysis. It is simply to show that road safety policies based on such analyses would deliver far better results than current road safety policies, and indicate some reasons why inefficient policy priorities continue to be set.

The estimated demand for road safety, which is equivalent to the value of a statistical life used in cost–benefit analysis, is of course neither very precisely known, nor likely to remain constant over time. The monetary valuations of road safety used in current cost–benefit analyses of road safety measures in Norway and Sweden are based on evidence from the best available studies. At least in Sweden, a recent study (Persson et al., 2000) recommended a higher monetary valuation of road safety than the one currently approved by the Swedish government. The "true" demand for road safety may therefore be even greater than assumed in the analyses reported in this paper.

6. Conclusions

This paper has analysed the implications for road safety in Norway and Sweden of basing the provision of road safety strictly on cost–benefit analysis, which means using only those road safety measures whose benefits are greater than the costs. The main conclusions of the analysis can be summarised as follows:

1. Analyses have been made to determine the potential for improving road safety in Norway and Sweden, and to develop alternative strategies for road safety policy.
2. It was found that, by applying all road safety measures that are potentially effective to the maximum conceivable extent during a period of 10 years, it is in principle possible to prevent close to 80% of the current number of road accident fatalities in both Norway and Sweden.
3. If policy priorities are set strictly according to cost–benefit analysis, meaning that only those road safety measures whose benefits are greater than the costs (cost-effective measures) are used during a period of 10 years, about 50–60% of the current number of road accident fatalities can be prevented in both Norway and Sweden.
4. If current road safety policies are continued, only about 10–15% of the current number of road accident fatalities will be prevented during the next 10 years. Current road safety policies are inefficient. A number of sources of inefficiency, that is factors that prevent priorities from being set strictly according to cost–benefit analysis, were identified.
5. The main sources of inefficiency in current road safety policies in Norway and Sweden are: (a) lack of power to introduce new vehicle safety standards. This power now resides with the European Union; (b) the existence of social dilemmas, that is situations in which measures that are cost-effective from a societal point of view, are loss-making from the point of view of individual road users; (c) priority given to other policy objectives, which cannot be adequately assessed by means of cost–benefit analyses, primarily objectives related to regional development.
6. Scarcity of resources was not found to be a constraint for efficient road safety policy. The amounts that are currently being spent on road safety measures are large enough to cover the expenses of all cost-effective road safety measures, provided the use of inefficient measures ceases.

References

Christensen, P., 1993. Fartsgrense 80 km/t eller 70 km/t? En nytte-kostnadsanalyse. Rapport 185. Transportøkonomisk institutt, Oslo.

Elvik, R., 1994. The external costs of traffic injury: definition, estimation, and possibilities for internalisation. Accid. Anal. Prev. 26, 719–732.

Elvik, R., 1999a. Bedre trafikksikkerhet i Norge. Rapport 446. Transportøkonomisk institutt, Oslo.

Elvik, R., 1999b. Can injury prevention efforts go too far? Reflections on some possible implications of Vision Zero for road accident fatalities. Accid. Anal. Prev. 31, 265–286.

Elvik, R., 2001a. Improving road safety in Norway and Sweden: analysing the efficiency of policy priorities. Traffic Engineering and Control, January 9–16.

Elvik, R., 2001b. Ethics and human values: a discussion of some difficulties in developing ethical guidelines for injury prevention. In: Grivna, M., Svanström, L. (Eds.), Cost Calculation and Cost-effectiveness in Injury Prevention and Safety Promotion. Centrum epidemiologie a prevence detskych urazu, Praha, pp. 35–43.

Elvik, R., Amundsen, A.H., 2000. Improving road safety in Sweden. Main report. Report 490. Institute of Transport Economics, Oslo.

Elvik, R., Mysen, A.B., Vaa, T., 1997. Trafikksikkerhetshåndbok. Tredje utgave. Transportøkonomisk institutt, Oslo.

Eriksen, K.S., Markussen, T.E., Pütz, K., 1999. Marginale kostnader ved transportvirksomhet. Rapport 464. Transportøkonomisk institutt, Oslo.

Fridstrøm, L., 1999. Econometric models of road use, accidents, and road investment decisions, Vol. II. Report 457. Institute of Transport Economics, Oslo.

Fyhri, A., 2001. Trafikantenes kunnskaper om og holdninger til trafikksikkerhet. Arbeidsdokument SM/1263/01. Transportøkonomisk institutt, Oslo.

Hansson, L., 1997. Kostnadsansvaret för trafikens externa effekter. En jämförelse mellan vägtrafik och tågtrafik. Internationella institutet för industriell miljöekonomi, Lunds Universitet, Lund.

OECD Scientific Expert Group, 1993. Marketing of traffic safety. OECD, Paris.

Persson, U., Hjalte, K., Nilsson, K., Norinder, A., 2000. Värdet av att minska risken för trafikskador. Bulletin 183. Lunds Tekniska Högskola, Institutionen för teknikk och samhälle, Avdelning Trafikteknik, Lund.

Samferdselsdepartementet, 2000. Stortingsmelding 46, 1999–2000. Nasjonal transportplan 2002–2011. Samferdselsdepartementet, Oslo.

Samplan, 1999. Strategisk analys. Slutrapportering av regeringsuppdrag om inriktningen av infrastrukturplaneringen för perioden 2002–2011. Samplan rapport 1999, Vol. 2. Statens Institut för Kommunikationsanalys, Stockholm.

Statens vegvesen Vegdirektoratet, 1995. Utredning om fartsgrenser utenfor tettbygd strøk. Rapport Pan 7015 1995. Vegdirektoratet, Oslo.

Udvarhelyi, I.S., Graham, A.C., Rai, A., Epstein, A.M., 1992. Cost-effectiveness and cost–benefit analyses in the medical literature. Are the methods being used correctly? Ann. Int. Med. 116, 238–244.