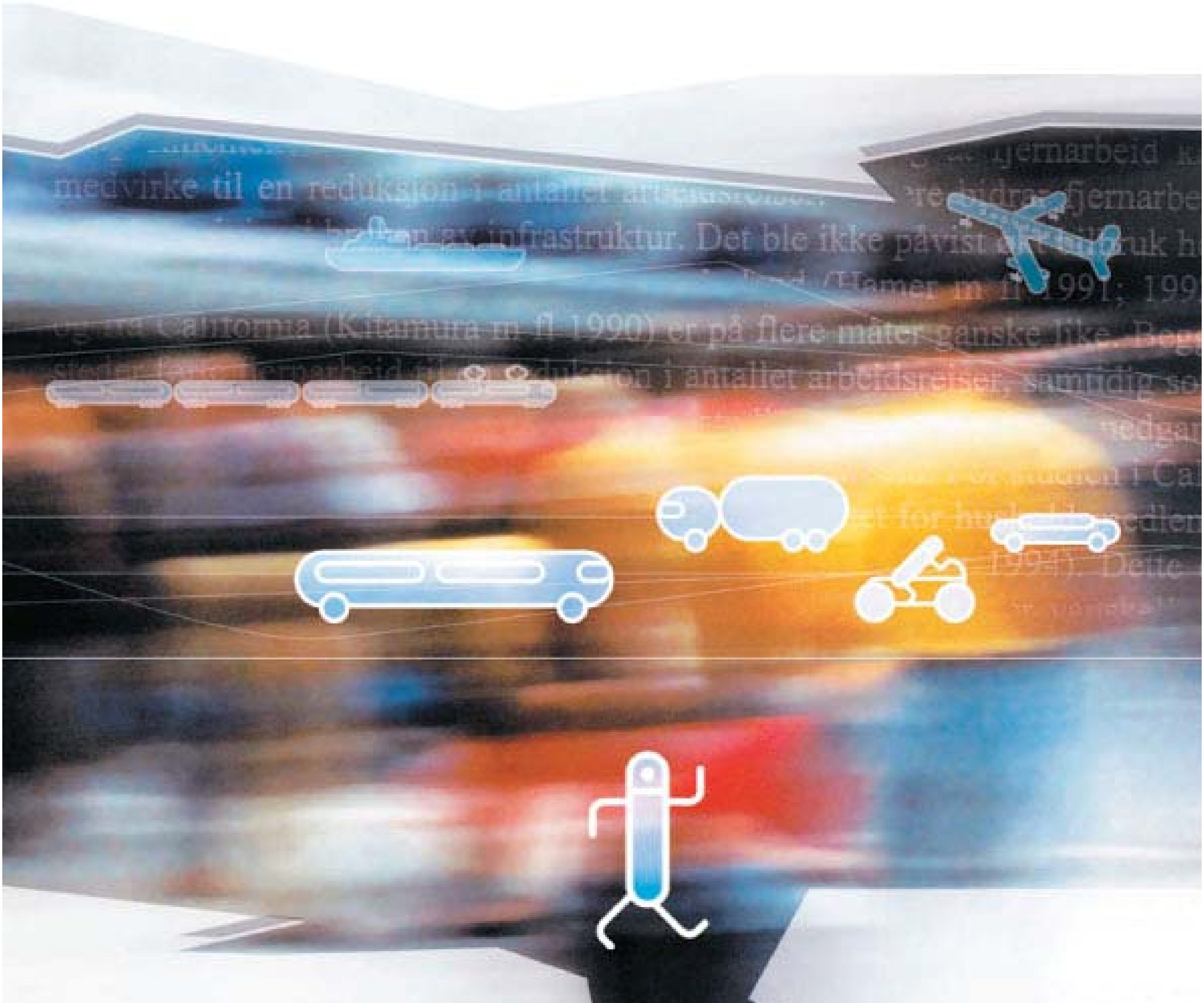
Institute of Transport Economics

Has progress in improving road safety come to a stop?

A discussion of some factors influencing long term trends in road safety



Rune Elvik

TØI report 792/2005

TØI report
792/2005

Has progress in improving road safety come to a stop?

A discussion of some factors influencing long term trends in road safety

Rune Elvik

ISSN 0808-1190
ISBN 82-480-0545-3 Paper version
ISBN 82-480-0546-1 Electronic version

Oslo, November 2005

Title: Has progress in improving road safety come to a stop?

Author(s): *Rune Elvik*

TØI report 792/2005
Oslo, 2005-11
37 pages
ISBN 82-480-0545-3 Paper version
ISBN 82-480-0546-1 Electronic version
ISSN 0808-1190

Financed by:
Ministry of Transport and Communications

Project: 3054 Long term trends in road safety

Project manager: Rune Elvik

Quality manager: Marika Kolbenstvedt

Key words:
Road safety; Long term trends; Poisson regression; Statistical analysis

Summary:
Analyses have been made in order to identify factors that influence the rate of change in the number of road accident fatalities and injured road users during the period 1979-2003. In particular, explanations were sought for the slowdown in the decline of fatalities after 1996. The analyses did not identify factors that successfully explain why the number of fatalities tends to drop markedly in some periods, but not in other period. The variations in the rate of change are to a large extent random. Simple trendlines fitted to the dat without making use of any explanatory variables describe long term trends almost as well as multivariate models.

Tittel: Er bedringen av trafikksikkerheten stoppet opp ?

Forfatter(e) *Rune Elvik*

TØI rapport 792/2005
Oslo: 2005-11
37 sider
ISBN 82-480-0545-3 Papirversjon
ISBN 82-480-0546-1 Elektronisk versjon
ISSN 0808-1190

Finansieringskilde:
Samferdselsdepartementet

Prosjekt: 3054 Langsiktige trender i trafikksikkerhetsutviklingen

Prosjektleder: Rune Elvik

Kvalitetsansvarlig: Marika Kolbenstvedt

Emneord:
Trafikksikkerhet; Langtidslinjer, Poisson regresjon; Statistisk analyse

Sammendrag:
Det er utført en analyse av utviklingen av antallet skadde eller drepte i trafikken i perioden 1979-2003, med sikte på å finne faktorer som kan forklare variasjoner i endringstakten, spesielt hvorfor nedgangen i antallet drepte i trafikken har stagnert etter 1996. Analysene kan i liten grad peke på bestemte faktorer som forklarer hvorfor antallet drepte i noen perioder synker drastisk, mens tallet i andre perioder ikke synker i det hele tatt. Variasjonene i endringstakt er stort sett tilfeldige. Enkle trendlinjer beskriver den langsiktige utviklingen nesten like godt som multivariate analyser.

Language of report: English

The report can be ordered from:
Institute of Transport Economics, the library
P O Box 6110 Etterstad N-0602 Oslo, Norway
Telephone +47 22 57 38 00 Telefax +47 22 57 02 90
Price € 25

Rapporten kan bestilles fra:
Transportøkonomisk institutt, biblioteket
Postboks 6110 Etterstad, 0602 Oslo
Telefon 22 57 38 00 - Telefaks 22 57 02 90
Pris kr 200

*

Preface

This report presents an analysis of a few factors that influence long term trends in road safety. Concern has been raised that the decline in traffic fatalities appears to have stopped. This seemed to be true during the period from 1996 to 2003, but the decline in fatalities has now resumed.

The project has been funded by the Ministry of Transport and Communications. Senior adviser Thomas Ruud Sollien has acted as project supervisor in the Ministry. Rune Elvik as been project manager at the Institute of Transport Economics. Peter Christensen performed the Poisson regression analyses presented in the report. Head of department Marika Kolbenstvedt has been responsible for internal peer review and quality checking of the report. Secretary Trude Rømming did the final editing of the manuscript and prepared it for printing.

Oslo, November 2005
Institute of Transport Economics

Lasse Fridstrøm
Managing director

Marika Kolbenstvedt
Head of department

Contents

Summary:

Has progress in improving road safety come to a stop?

The background for the study presented in this report is a concern that the trend towards fewer road accident fatalities appears to have slowed down in recent years. The highest number of road accident fatalities ever recorded in Norway was 560 in 1970. The lowest number recorded since then was 255 in 1996. A lower number has since not been observed, but it is likely that there will be fewer than 255 traffic fatalities in Norway in 2005. This report presents a study that tries to answer the following questions: What can explain the fact that the trend towards fewer traffic fatalities has slowed down in recent years (after about 1992)? Is it still possible to reduce the number of traffic fatalities, or have all effective road safety measures been exhausted?

Analysis of long term trends in fatalities, injuries and injury severity

In order to explain changes over time in the number of road accident fatalities, injured road users, and the proportion of all those injured who are killed or seriously injured, multivariate analyses have been performed. These analyses were restricted to the period from 1979 to 2003, as complete data for years before 1979 could not be obtained. Three dependent variables were used in the analyses:

1. The annual number of fatalities.
2. The annual number of injured road users (police reported).
3. The proportion of all killed or injured road users who were fatally or seriously injured.

The following explanatory variables were used:

1. The total volume of travel, stated in million person kilometres travelled, including travel on foot or by bicycle.
2. The number of kilometres driven by young drivers (aged 18-24 years).
3. The number of kilometres driven by heavy vehicles.
4. Kilometres travelled walking or cycling.
5. Sale of new cars (thousands per year).
6. Seat belt wearing among drivers (percentage wearing seat belts, stated as a weighted mean of urban and rural wearing rates).

The report can be ordered from:
Institute of Transport Economics, PO Box 6110 Etterstad, N-0602 Oslo, Norway
Telephone: +47 22 57 38 00   Telefax: +47 22 57 02 90

7. The number of fixed penalties (traffic tickets) issued per million vehicle kilometre of driving.
8. The number of vehicle kilometres driven on motorways.

The first four explanatory variables are intended to describe travel exposure and its composition with respect to groups that have different accident rates or a different potential for causing injury in accidents. The sale of new cars is an indicator of the business cycle. The wearing of seat belts greatly influences the probability of fatal or serious injury in the event of an accident. The number of fixed penalties issued per million vehicle kilometre of driving is intended as an indicator of the amount of police enforcement. Finally, the number of kilometres driven on motorways indicates the share of driving taking place on the safest roads.

The analyses of fatalities and injured road users were made by fitting Poisson regression models. A Poisson model was found to be adequate in both analyses, there being no statistically significant over-dispersion in the data. In the analysis of changes in the proportion of accident victims who are killed or seriously injured, a linear regression model was applied.

Good explanatory models are hard to find

With just 25 observations (data for 25 years) and 8 explanatory variables, it is difficult to develop good explanatory models for the trends observed and any irregularities in these trends. Emphasis was put on trying to explain the long term trend for fatalities. The analysis found that the somewhat slower decline in the number of fatalities observed in the period 1992-2003, compared to the period 1979-1991, may be related to a decline in police enforcement (from a peak in 1993), and a decline in the sake of new cars (from a peak in1986). The results are, however, highly uncertain and suggestive rather than conclusive.

In all analyses, it turned out that the dependent variable had a stronger statistical association with a trend term than with any of the explanatory variables. The trend term captures the effects of omitted variables that have, over time, systematically influenced the number of fatalities, the number of injured road users, or the severity of injuries in a certain direction. The trend term was negative for fatalities and the proportion of fatal or serious injuries. It was positive for the number of injured road users.

The explanatory power of the models fitted is only marginally better than that of simple trend lines fitted directly to the data without making use of any explanatory variables at all. This indicates that the omitted variables, which constitute the trend term, have a dominant influence on long term trends. These unknown variables include road safety measures that have been introduced during the period covered by the study.

The simplest questions are the most difficult to answer

One of the most frequently asked questions regarding road safety, is why the number of fatalities or injured road users has gone up, or down, from one year to the next. It is almost a paradox that this simple question is one of the most difficult to answer in road safety research. There are many reasons for that.

In the first place, random fluctuations can lead to fairly large changes from year to year in the number of killed or injured road users. This applies in particular to the number of traffic fatalities. In the second place, the number of factors that influence road safety is vast; reliable data are available on just a few of these factors. In the third place, changes in a given year may depart markedly from a long term trend.

During the period from 1979 to 2003 there was a reduction in the number of road accident fatalities in Norway. An increase was observed, however, in 11 out of 24 years. The change in the number of fatalities from one year to the next was statistically significant at the 5% level in only 5 years out of 24. The following lessons can be learnt from the study presented in this report:

1. Changes in the number of fatalities from one year to the next are in most cases well within the bounds of random variation only.
2. This fact is not inconsistent with the existence of a long term trend for numbers to go up or down. After 1970, the long term trend for traffic fatalities in Norway has been for the numbers to go down.
3. Departures from a long term trend in any year, or even a string of years, do not necessarily imply that the trend has come to a halt or turned. Periods of stagnation were observed in Norway between 1981 and 1990, and between 1996 and 2004.
4. The fact that quite long periods of stagnation may occur, suggests that at least 10 years of data are needed to reliably determine a long term trend with respect to traffic fatalities.
5. It is only to a small extent possible to identify factors explaining variation in the rate of decline of traffic fatalities in Norway after 1970. Simple trend lines, not incorporating the effects of any explanatory variables, fit the data almost as closely as a Poisson-model including eight explanatory variables plus a trend term.

Have all effective road safety measures been spent?

It is still possible to influence the number of road accidents and road accident victims by means of road safety measures. Estimates that have been developed as part of the preparation of the National transport plan for the 2010-2019 term shows that, in principle, the number of road accident fatalities in Norway can be reduced by 50% by 2020. The number of seriously injured road users can also be reduced substantially, but not by 50%. A smaller reduction of the number if slightly injured road users is also, in principle, attainable.

There is no evidence suggesting that all effective road safety measures have already been introduced to their full potential. New safety measures are being developed, in particular new vehicle safety features. A more effective use of traditional traffic engineering measures has still got a potential for improving road safety.

TØI-rapport 792/2005
Forfatter: Rune Elvik
Oslo 2005, 37 sider

Sammendrag:

Er bedringen av trafikksikkerheten stoppet opp?

Utgangspunktet for denne rapporten er at nedgangen i antallet drepte i trafikken i Norge har gått langsomt de siste årene. Det hittil laveste tallet på drepte i trafikken etter 1970 ble registrert i 1996 med 255 drepte. Siden den gang har tallet vært høyere, men i 2005 er det sannsynlig at det vil bli færre enn 255 drepte i trafikken. Hovedproblemstillingene i rapporten er: Hva kan forklare at nedgangen i antallet drepte i trafikken har vært svakere de siste årene enn i perioden fram til ca 1992? Hva kan gjøres for å oppnå en raskere nedgang i antallet drepte eller hardt skadde i trafikken?

Analyse av langtidsutviklingen av antall skadde eller drepte i trafikken

For å finne forklaringer på utviklingen over tid i antallet skadde eller drepte i trafikken, er det utført multivariate analyser. Disse analysene er begrenset til perioden 1979-2003, da komplette data for perioden før 1979 ikke lar seg fremskaffe. Tre avhengige variabler er benyttet i analysene:

1. Antall drepte (per år)
2. Antall skadde (per år)
3. Andelen av de skadde eller drepte som er drept eller hardt skadd. Hardt skadde omfatter gruppene meget alvorlig og alvorlig skadde

Følgende forklaringsvariabler inngikk i analysene:

1. Totalt reiseomfang i millioner personkilometer. Her er også reiser til fots og med sykkel inkludert.
2. Antall kilometer kjørt av unge bilførere (alder 18-24 år)
3. Antall kilometer kjørt av tunge kjøretøy
4. Gang- og sykkeltrafikk i millioner kilometer
5. Salg av nye biler (tusen biler per år)
6. Bilføreres bruk av bilbelter (prosent bruk, veid gjennomsnitt for tettbygd strøk og veger utenfor tettbygd strøk)
7. Antall ilagte forenklede forelegg for trafikkforseelser, regnet per million kjøretøykilometer
8. Antall kilometer kjørt på motorveg klasse A

Rapporten kan bestilles fra:
Transportøkonomisk institutt, Postboks 6110 Etterstad, 0602 Oslo
Telefon: 22 57 38 00   Telefax: 22 57 02 90

De fire førstnevnte av forklaringsvariablene beskriver eksponering for risiko i trafikken og endringer over tid i sammensetningen av eksponeringen mellom grupper som har ulik risiko for å bli innblandet i ulykker eller i ulik grad kan volde skader ved ulykker. Bilsalget er ment som en konjunkturindikator. Bruk av bilbelter er en viktig risikofaktor for skader ved ulykker. Antallet ilagte forelegg, regnet i forhold til trafikkarbeidet, er ment som en indikator på omfanget av politikontroll. Trafikkarbeidet på motorveger er ment som en indikator på andelen av trafikken som avvikles på de sikreste vegene.

Analysene der antall drepte eller antall skadde er avhengig variabel, er utført ved hjelp av Poisson-regresjon. Det viste seg at en modell med et Poissonfordelt restledd ga brukbar føyning til data i begge tilfeller. Analysen der andelen av alle skadde som er drept eller hardt skadd er avhengig variabel, er utført med lineær regresjon.

Gode forklaringsmodeller er vanskelige å finne

Med bare 25 observasjoner (data for 25 år) og 8 forklaringsvariabler er det vanskelig å finne særlig gode forklaringer på den langsiktige utviklingen i antallet skadde eller drepte. Det er lagt mest vekt på å analysere utviklingen i antallet drepte. Analysen tyder på den noe langsommere nedgangen i antallet drepte i perioden 1992-2003, sammenlignet med perioden 1979-1991, kan ha sammenheng med redusert politikontroll (færre forenklede forelegg per million kjøretøykilometer er ilagt etter toppåret 1993) og med et redusert salg av nye biler (høyeste antall, 210.000 nye biler, ble nådd i 1986). Resultatene er imidlertid usikre.

I samtlige analyser viser det seg at den avhengige variabelen har sterkest sammenheng med et trendledd, ikke med forklaringsvariablene. Trendleddet fanger opp virkninger av alle utelatte variabler som over tid systematisk har påvirket antallet skadde eller drepte i en bestemt retning. Trendleddet er negativt for antall drepte og for andelen drepte eller hardt skadde. Det er positivt for antall skadde.

De multivariate modellene gir kun marginalt bedre føyning til dataene enn enkle trendlinjer som føyes direkte til datapunktene uten å trekke inn noen forklaringsvariabler i det hele tatt. Dette viser at de utelatte variablene, som inngår i trendleddet, har en dominerende innflytelse på utviklingen av antallet skadde eller drepte. Blant slike variabler er trafikksikkerhetstiltak som er gjennomført i perioden.

De enkleste spørsmålene er vanskeligst å svare på

Ett av de spørsmål som oftest blir stilt er hvorfor antallet drepte eller skadde i trafikken har gått opp eller ned fra ett år til det neste. Dette enkle spørsmålet er, paradoksalt nok, blant de vanskeligste å svare på. Det har flere grunner.

For det første kan rent tilfeldige variasjoner medføre relativt store endringer fra år til år, spesielt for antallet drepte. For det andre er det svært mange forhold som påvirker trafikksikkerheten; kun et fåtall av disse har man pålitelige opplysninger om. For det tredje kan endringer fra år til år avvike betydelig fra den langsiktige trenden.

I perioden fra 1979 til 2003 gikk antallet drepte i trafikken ned, men i 11 av 24 år var det en økning fra året før. Kun i 5 av 24 år var endringen i antall drepte fra året før statistisk signifikant på 5% nivå. Følgende lærdom kan trekkes av den studien som er presentert i denne rapporten:

1. Endringer i antallet drepte i trafikken fra år til år er i de fleste tilfeller ikke større enn at rent tilfeldig variasjon kan forklare dem.
2. Dette faktum er ikke uforenlig med at det kan være en langsiktig trend i retning av flere eller færre skadde eller drepte. Etter 1970 har den langsiktige trenden vært i retning av færre drepte i trafikken i Norge.
3. Avvik fra en langsiktig trend kan forekomme ofte, og til dels i flere år på rad, uten at dette nødvendigvis betyr at trenden har snudd eller stoppet opp. I Norge stagnerte nedgangen i antallet drepte fra 1981 til 1990 og igjen fra 1996 til 2004.
4. Perioder med stagnasjon innebærer at man trenger data for minst 10 år for å kunne bestemme den langsiktige trenden for antallet drepte med god nok presisjon.
5. Det er i liten grad mulig å identifisere faktorer som kan forklare variasjon i takten i nedgangen i antallet drepte etter 1970. Enkle trendlinjer føyd direkte til datapunktene uten opplysninger om noen forklaringsvariabler, beskriver den langsiktige trenden nesten like godt som en Poisson-modell med åtte forklaringsvariabler pluss et trendledd.

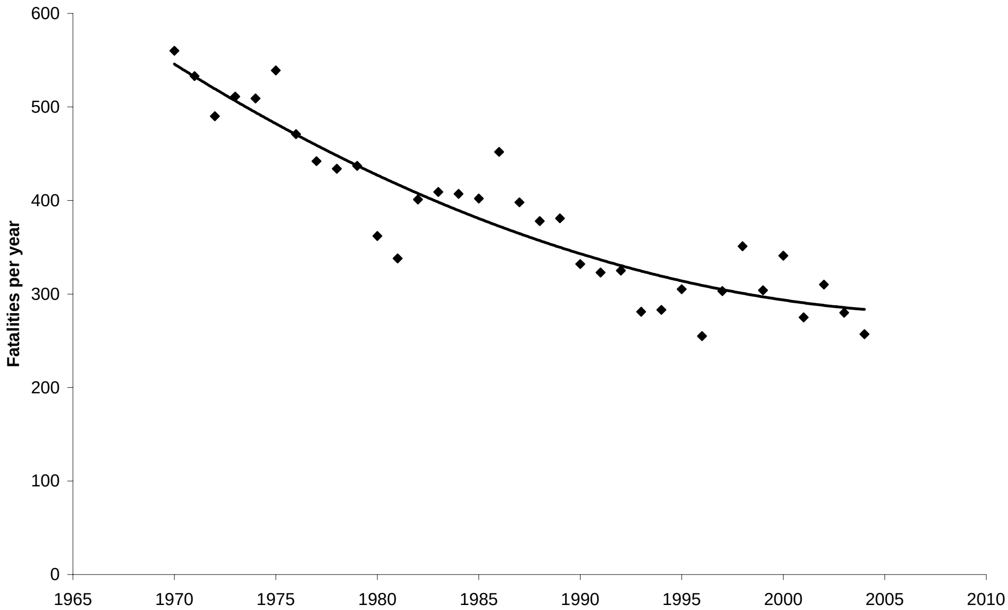
Er vi i ferd med å bruke opp trafikksikkerhetstiltakene?

Det er fremdeles mulig å påvirke den fremtidige utviklingen av antallet drepte eller skadde i trafikken ved hjelp av trafikksikkerhetstiltak. Beregninger som er gjort i forbindelse med arbeidet med Nasjonal transportplan for perioden 2010-2019 viser at det i prinsippet er mulig å halvere antallet drepte i trafikken fram til 2020. Det ser ikke ut til å være mulig å halvere antallet hardt skadde, mens antallet lettere skadde i enda mindre grad kan reduseres.

Det er imidlertid ikke noe som tyder på at mulighetene for å bedre trafikksikkerheten ved å iverksette effektive trafikksikkerhetstiltak er i ferd med å bli brukt opp. Nye tiltak utvikles stadig, særlig på det kjøretøytekniske området. Det er også mulig å effektivisere bruken av tradisjonelle veg- og trafikktekniske tiltak, og dermed oppnå en større virkning av disse.

1 Background and problem

The number of road accident fatalities has declined considerably in many highly motorised countries from a peak level that was reached around 1970. In Norway, the highest number of road accident fatalities ever recorded was 560 in 1970. By 1996, the number of road accident fatalities had declined to 255, the lowest number in more than 40 years. Since then, however, there has not been any further decline in road accident fatalities. Figure 1 shows the number of road accident fatalities in Norway from 1970 to 2004.



Source: TØI report 792/2005

Figure 1: Number of road accident fatalities in Norway 1970-2004. Source: Statistics Norway

A trend line has been fitted to the data. This line indicates a marked slow-down in the rate of decline towards the end of the period. In fact, if one fits a trend line to the years after 1990, it shows a mean annual decline of only 0.7 percent in the number of fatalities, as opposed to a mean annual decline of 2 percent for the whole period 1970-2004.

Preliminary figures so far in 2005 suggest that the decline in the number of road accident fatalities observed in 2003 and 2004 continues. There is nevertheless reason to ask why progress in reducing fatalities has been so much slower after 1990 than it was before. A similar period of stagnation occurred between 1980 and 1986. Why does the long-term trend towards fewer road accident fatalities sometimes slow down or even reverse? What can be done to sustain and reinforce the trend towards fewer road accident fatalities? These are the main problems discussed in this report.

2 A taxonomy of factors influencing road safety

Road safety is influenced by a very large number of factors. There are many ways of categorising these factors. An instructive taxonomy has been proposed by Fridstrøm (1999). He describes the taxonomy in the following terms (page 11):

“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, accidents 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."

Fridstrøm used this taxonomy as the basis for developing a large statistical model designed to explain variation in accident counts between counties in Norway, using monthly data for each county for the period 1973-1994. The present study does not aim to reproduce or update this extensive modelling effort, but will rely on a more limited analysis. An attempt will be made to identify selected factors influencing road safety in the following three categories:

1. Factors that are generally regarded as exogenous with respect to road safety policy, i.e. factors that are not directly influenced by means of commonly applied road safety measures.
2. Risk factors that influence road safety and that may in principle be influenced by means of road safety measures.
3. Road safety measures for which sufficient records have been kept to assess changes over time in their use.

The influence of a few selected factors in each of these main categories on the number of killed or injured road users in Norway will be evaluated. The objective of the analysis is to try to identify factors that are associated with variation in the rate of decline over time in the number of road accident victims, in particular fatally injured road users.

3 Analysis of long term trends in road safety

3.1 Factors included in study

The following factors have been selected for study. These factors were selected mainly on the basis of the size of their likely influence on road safety and the availability of easily accessible long time series of data:

1. Exogenous factors
    a. Changes in total travel exposure (person kilometres of travel, pedestrian and cyclist travel included)
    b. Changes in travel exposure for novice drivers (defined as car drivers aged 18-24)
    c. Changes in travel exposure for pedestrians and cyclists
    d. Changes in travel exposure for heavy vehicles
2. Risk factors
    a. Changes in the use of seat belts among car drivers
    b. Changes in the purchase of new cars
3. Road safety measures
    a. Changes in the number of fixed penalties for traffic violations, stated as a rate per million vehicle kilometres of driving
    b. Changes in the amount of traffic on motorways

The available data on each of these factors is briefly discussed below.

3.1.1 Changes in total travel exposure

Travel exposure is known to be one of the most important factors influencing the number of road accident victims (Elvik and Vaa 2004). A large number of studies have evaluated the relationship between travel exposure and the number of accidents, number of road accident fatalities and number of injured road users. In general, these studies find (Elvik 2004A) that the number of injury accidents and the number of injured road users, all else equal, increase in almost in proportion to travel exposure. The number of fatalities increases less than in proportion to travel exposure.

Most of the studies that have evaluated the relationship between travel exposure and road safety outcomes have relied on cross-sectional data. It is not obvious that the relationships found in cross-sectional studies also apply to time-series data. On the contrary, not even the sign of the effects may be the same. There has for a long time been a tendency for accident and injury rates per kilometre of travel to decline. Thus, in time-series data one may even find a negative effect of travel exposure on the number of accidents, fatalities or injured road users.

Exposure is surveyed periodically by means of travel behaviour surveys, but estimates are made annually (Rideng 2004). In this study, exposure to the risk of traffic injury is measured in terms of person kilometres of travel.

3.1.2 Changes in novice driver exposure

Novice drivers have a substantially higher accident rate than more experienced drivers. Hence, variations over time in the share of all travel performed by novice drivers can contribute to variations in the number of accidents and accident victims.

Unfortunately, annual data on travel exposure by age group are not available. The only data that are available refer to car drivers for the years 1979 (Vaaje 1982), 1985 (Bjørnskau 1988), 1992 (Bjørnskau 1993), 1998 (Bjørnskau 2000) and 2001 (Bjørnskau 2003). These data have been examined, in order to determine changes over time in the share of car driving performed by drivers of the ages 18-19 and 20-24, which are the two age groups that represent the highest risk of injury. The results are presented in Table 1.

Table 1: Percentage of driver exposure by age group. Car drivers. Based on travel behaviour surveys. Sources: See text.

	Percent distribution of kilometres of driving by age. Car drivers			
Year	18 to 19 years	20 to 24 years	25 years or above	Total
1979	2.9	10.8	86.3	100
1985	5.4	13.2	81.4	100
1992	2.7	13.2	84.1	100
1998	1.9	8.1	90.0	100
2001	2.5	6.4	91.1	100

Source: TØI report 792/2005

The share of exposure represented by young drivers increased until 1985, but has since declined substantially. Values for the intervening years have been interpolated, by applying data on the number of new driving licences issued each year as a scaling factor. Details of the estimation are given in the Appendix.

3.1.3 Changes in travel exposure for pedestrians and cyclists

Pedestrians and cyclists run a substantially higher risk of injury per kilometre of travel than other groups of road users (except moped and motorcycle riders). Thus, all else equal, a decline in pedestrian and cyclist travel may be associated with fewer traffic injuries.

Complete data on travel exposure for pedestrians and cyclists are not available. However, like the case for novice drivers, data are available for 1979 (Vaaje

1982), 1985 (Bjørnskau 1988), 1992 (Bjørnskau 1993), 1998 (Bjørnskau 2000) and 2001 (Bjørnskau 2003). These data are not complete. In particular, travel exposure for those below the age of 13 is missing for 1985, 1992, 1998 and 2001. Travel behaviour surveys in Sweden include all ages. Based on the results of Swedish travel behaviour surveys (Gustafsson and Thulin 2003), the results of the Norwegian travel behaviour surveys in 1985, 1992, 1998 and 2001 have been adjusted, so that all age groups are included.

The estimate of cyclist travel for the year 1979 (Vaaje 1982) is based on surveys of cycling in 1975 and 1980. As shown by Bjørnskau (1993), these surveys tend to overstate the amount of cycling on public roads. They include recreational cycling off road in addition to cycling in traffic. Moreover, the fact that the survey is presented as a cycling survey may tempt some respondents to overstate their cycling. Hence, the estimate for 1979 has been adjusted by dividing it by 1.99. Table 2 shows the original and adjusted estimates for the amount of walking and cycling in Norway.

Table 2: Estimates of the amount of walking and cycling in Norway Based on travel behaviour surveys. Sources: See text.

	Million person kilometres of travel done walking or cycling			
Year	Pedestrians original estimates	Pedestrians adjusted estimates	Cyclists original estimates	Cyclists adjusted estimates
1979	1200	1260	1350	678
1985	1467	1658	468	534
1992	1104	1248	662	755
1998	1212	1357	589	666
2001	1178	1319	524	592

Source: TØI report 792/2005

Based on the adjusted estimates given in Table 2, a complete series of exposure data for pedestrians and cyclists has been developed by estimating values for intervening years by means of linear interpolation. Exposure in 2002 and 2003 was assumed to be identical to 2001. The full data series and details of its estimation are given in the Appendix.

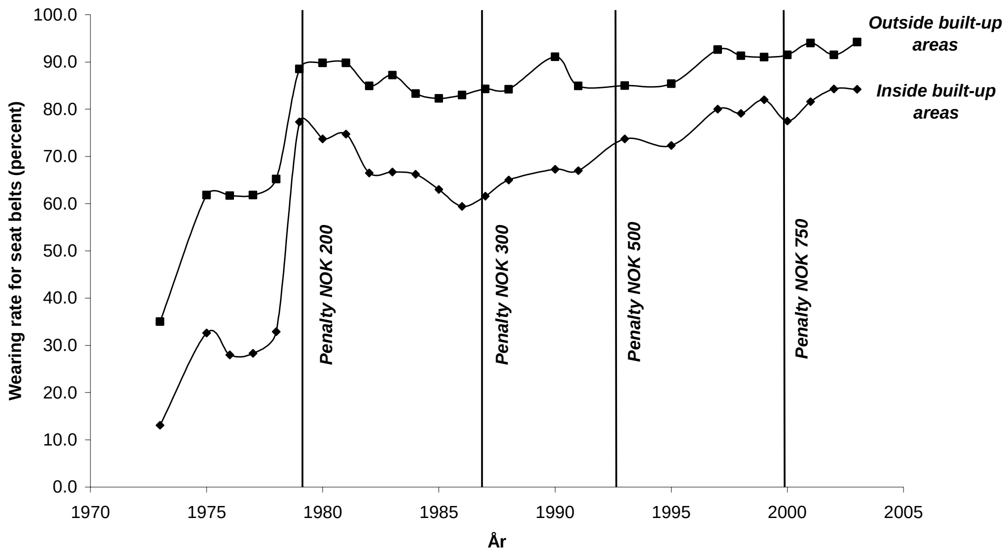
3.1.4 Changes in heavy vehicle exposure

For all police reported injury accidents, Elvik (2004B) reports that 2.7 percent of all victims involved were killed. The proportion of involved victims who are killed is often referred to as the case fatality rate. For accidents in which and single truck or a truck pulling a trailer were involved, case fatality rates were 5.8 percent and 10.5 percent, respectively. Involvement of a heavy vehicle in an accident greatly increases the probability that the accident may be fatal or lead to serious injury. Thus, the higher the proportion of heavy vehicles in traffic, the more likely one would expect an accident to be fatal or serious.

Rideng (2004) publishes annual data on vehicle kilometres of travel performed by heavy vehicles. These data were used in this study.

3.1.5 Changes in seat belt wearing

Seat belt wearing is one of the few types of road user behaviour that has been monitored regularly in Norway for a long time (Muskaug et al 2005). Initially, this monitoring included drivers only. From 1985, passengers have been included. However, since a complete time series exists only for drivers, it has been used in this study. Figure 2 shows seat belt wearing by car drivers in Norway from 1973 to 2003. Only data for the period from 1979 to 2003 have been used in this study.



Source: TØI report 792/2005

Figure 2: Seat belt wearing by car drivers in Norway 1973-2003

Values for the years 1989, 1992, 1994 and 1996, during which there was no monitoring of seat belt wearing, have been interpolated linearly. Also shown in Figure 2 is the fixed penalty for not wearing seat belts that was first introduced in 1979 and subsequently increased in 1987, 1993 and 2000. A previous study (Elvik and Christensen 2004) found that increasing the fixed penalty for not wearing seat belts was associated with an increased wearing rate.

3.1.6 Changes in the purchase of new cars

Previous studies (Wagenaar 1984, Partyka 1991) have found that road safety is related to economic activity. In particular, traffic volume increases more rapidly when personal income increases rapidly than in periods of stagnating personal income. The purchase of new cars is associated with changes in personal income and real interest rates. While new cars are often believed to be safer than older cars, research at the Institute of Transport Economics (Fosser and Christensen 1998) has found the opposite. New cars are driven longer annual distances than old cars. There has been a trend for engine size and acceleration performance in new cars to increase over time (Elvik and Vaa 2004). On the other hand, new cars that perform well in crash tests have been found to protect occupants better in real accidents than older cars or new cars that do not perform well in crash tests (Lie and Tingvall 2001).

3.1.7 Changes in the risk of apprehension for traffic violations

Previous studies (Elvik 1997, Elvik and Amundsen 2000) show that the number of road accident fatalities and injuries can be greatly reduced if all road users comply with important provisions of road traffic law, such as speed limits, blood alcohol limits, and mandatory seat belt wearing. Today, violations of these and other provisions of road traffic law are widespread. One would therefore expect the amount of enforcement, and changes in it over time, to influence the number of traffic violations and thus the number of road accident victims.

There are no data showing the actual amount of police enforcement in Norway year by year. As an indicator, the number of fixed penalties that have been issued has been used. The number of fixed penalties (traffic tickets) issued probably depends more directly on the amount and effectiveness of enforcement, than on the rate of violations. Hence, the risk of apprehension for traffic violations has been measured in terms of the number of fixed penalties issued per million vehicle kilometres of driving (motor vehicles only included).

3.1.8 Changes in the share of traffic on motorways

Motorways, i.e. roads that have at least four lanes, a median, full access control, and no pedestrians, cyclists or slow moving vehicles allowed, are the safest type of road (Elvik and Vaa 2004). Hence, all else equal, one would expect the overall accident rate (accidents per million vehicle kilometres driven) to decline if the share of traffic using motorways increases.

Estimates for the number of vehicle kilometres performed on motorways are available for the years 1977-1980 (Muskaug 1985), 1986-1989 (Elvik 1991), 1993-1996 (Ranes 1998), 1993-2000 (Ragnøy, Christensen and Elvik 2002) and 2004 (Elvik et al 2004). Based on these estimates, a full time series of data has been developed by using the length of motorways in kilometres, and growth in overall kilometres of travel as scaling factors. Details are given in the Appendix.

3.1.9 Other variables

There are of course very many other variables that influence road safety than the eight that have been discussed above. However, the analysis has been limited to the selected variables for the following reasons:

1. There are only 25 observations, i.e. each of the years from 1979 to 2003. In general, it is not possible to estimate the effects of explanatory variables when the number of such variables approaches the number of observations.
2. Limited data are available. Even for the eight variables that were included, it was necessary in some cases to interpolate values in order to get a complete time series of data. For a number of other potentially important

variables, like drink-driving, speeding, or the use of low-cost traffic engineering safety treatments, no meaningful data are available at all.

3. Things that change over time have a tendency to be highly correlated, even if the correlation may not always represent a causal relationship. This means that problems of multi-collinearity among explanatory variables arise easily in time-series data.

Problems that may be caused by omitted variables are discussed later in the report.

3.2 Period studied

The study covers the 25 year period from 1979 to 2003. This period was selected for two main reasons. In the first place, data going back to the years before 1979 are incomplete, in particular with respect to the traffic exposure of pedestrians ands cyclists. Data for the year 2004 are also not yet completely available; hence 2003 is the final year. In the second place, no major changes in the rules for reporting of injury accidents in Norway have taken place between 1979 and 2003. These rules were changed both in 1977 and 1978. The effects of these changes have been studied by Fridstrøm (1999), who describes their effects in the following terms (page 184):

"On January 1st, 1977, a *new and more complete set of road accident reporting forms and routines* were introduced. The dummy capturing this change suggests that the recorded number of injury accidents is thereby inflated by some 10 per cent."

"The only legislative variable with a clear effect on accidents was the dummy capturing the *new highway code and reporting routines* in effect from October 1st, 1978. From this date one, an estimated 10 per cent *decrease* in the accident count is effectuated. The greater part of this effect is most probably due to the change in reporting routines rather than to the (relatively minor) amendments to the highway code. According to the new routines, road accidents with only "insignificant" personal injury are no longer subject to mandatory police reporting."

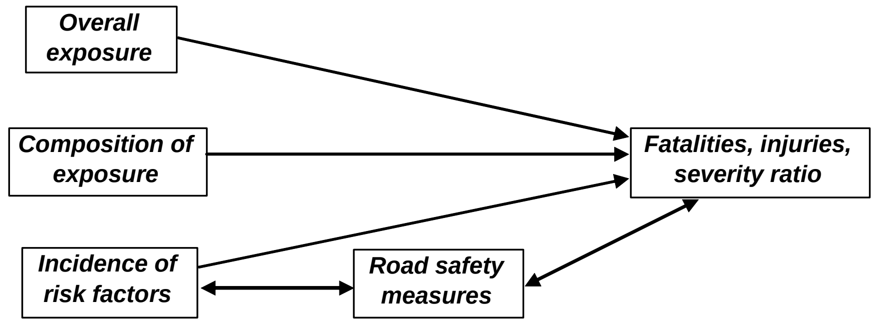
3.3 Approach to analysis and model structure

Three dependent variables were used in the analyses:

1. The annual number of road accident fatalities
2. The annual number of road users injured (including fatal injuries)
3. The ratio of the number of fatal and severe injuries to the total number of injuries (severity ratio)

The analyses have been performed by applying appropriate multivariate techniques. Poisson regression models were fitted in the analyses employing the count of fatalities and the count of injured road users as dependent variables. The potential presence of over-dispersion in the data, i.e. systematic variation not explained by the Poisson model, was assessed in terms of the over-dispersion parameter. If the over-dispersion parameter of the Poisson model was statistically significant, a negative binomial regression model was fitted. For the analysis of the severity ratio, an ordinary least squares linear regression model was fitted.

The relationship between the main variables included in the study can be described in terms of the causal model shown in Figure 3.



Source: TØI report 792/2005

Figure 3: Causal model of main variables included in the study

Both overall exposure and its composition according to groups of road users can probably be regarded as exogenous variables, that is as variables that are not (greatly) influenced by other variables included in the analysis. The same point of view applies to very many of the risk factors that influence accidents. In this study, one of risk factors included is seat belt use. This variable may, in principle, be endogenous, in particular if it is influenced by enforcement, which is one of the road safety measures included in the study. Thus, a double arrow has been drawn between the incidence of risk factors and road safety measures. If an endogenous variable is treated as exogenous, estimates of the effects of that variable could be misleading. It is therefore important to assess the possible presence of endogenous variables in the data.

Enforcement may influence seat belt wearing, and vice versa. Likewise, the level of enforcement may be influenced by recent accident history. If there has been an increase in the number of accidents or victims, enforcement may be increased in order to reverse the trend. A double arrow, indicating the possibility of causal influences in both directions, has therefore been drawn between road safety measures and fatalities, injuries and severity ratio.

This study does not permit any sophisticated econometric testing for endogeneity. A simple approach has been applied. It has been assumed that an endogenous causal influence is lagged, which means, for example, that a drop in seat belt wearing in year N may lead to increased enforcement in year N + 1. The correlation between percentage change in seat belt wearing in year N and percentage change in enforcement (fixed penalties per million vehicle kilometres) in year N + 1 was estimated. A correlation coefficient of – .201 was found. This coefficient indicates a negative relationship: increases in seat belt wearing one year are associated with reductions in enforcement the next year. This is as expected, but the correlation is fairly low and not statistically significant ($F_{1,22}$ = 0.924, p = 0.347). The simple (non-lagged) correlation between enforcement and seat belt wearing is .296. It is concluded that seat belt wearing can be treated as an exogenous variable in the analysis.

Similar tests have been made with respect to the relationship between enforcement and the three dependent variables used in the study. The percentage changes in the number of fatalities, injured road users and severity ratio in year N was correlated with changes in enforcement in year N + 1 to determine if changes in enforcement are endogenous. Positive correlations were found with respect to all dependent variables, showing that unfavourable changes in any of these variables in year N are correlated with increased enforcement in year N + 1. There is thus a tendency for enforcement activity to respond to recent changes in road safety. Enforcement is, accordingly, to some extent an endogenous variable. However, none of the correlations were statistically significant at the 5% level. Moreover, two of the three simple (not lagged) correlations between traffic enforcement and the three dependent variables were strongly negative (indicating that more enforcement is associated with improved safety) and statistically significant at the 5% level. It is therefore concluded that the element of endogeneity for police enforcement is smaller than the exogenous influence of this variable on road safety, and that it may therefore be treated as an exogenous variable in the analysis.

4 Results

4.1 Fatalities

Table 3 shows the coefficient estimates for the Poisson regression model fitted to explain the number of fatalities.

Table 3: Coefficients estimated for Poisson regression model to explain the number of road accident fatalities in Norway 1979-2003

Variable	Coefficient	Standard error	P-value
Constant term	11.710336	8.684501	0.1775
Log of total person kilometres of travel	-0.676924	0.794222	0.3940
Pedestrian and cyclist kilometres of travel	0.001206	0.000579	0.0373
Heavy vehicle kilometres of travel	0.000642	0.000161	0.0001
Novice drivers kilometres of travel	-0.000074	0.000085	0.3838
Number of new cars registered	-0.000513	0.000628	0.4132
Seat belt wearing rate by drivers	-0.019106	0.007024	0.0065
Fixed penalties per million vehicle kilometres	-0.055193	0.030056	0.0663
Kilometres driven on motorways	0.000539	0.000124	0.0000
Annual trend	-0.099047	0.017365	0.0000

Source: TØI report 792/2005

The mean value of the dependent variable was 345.36. The variance was 3013.32. This means that 88.5% of the variation in the number of fatalities is systematic, 11.5% is random. The Poisson model fitted the data very well. The over-dispersion parameter was estimated to 0.000589, with a standard error of 0.001865. The P-value for the over-dispersion parameter was 0.7524, which is very far from the level of conventional statistical significance (P-value of 0.05 or less). The Poisson regression model explained 97.4% of the systematic variation in the number of fatalities (according to the Elvik index measure of goodness-of-fit, see Fridstrøm et al 1995).

The coefficients have no simple interpretation. The influence of each variable on the number of fatalities can be estimated by inserting the coefficient estimate, and the value of observed each year for the variable into the following equation:

$$\text{Estimated number of fatalities} = e^{\sum_{i=1}^{n} \text{coefficients} \cdot \text{variables}}$$

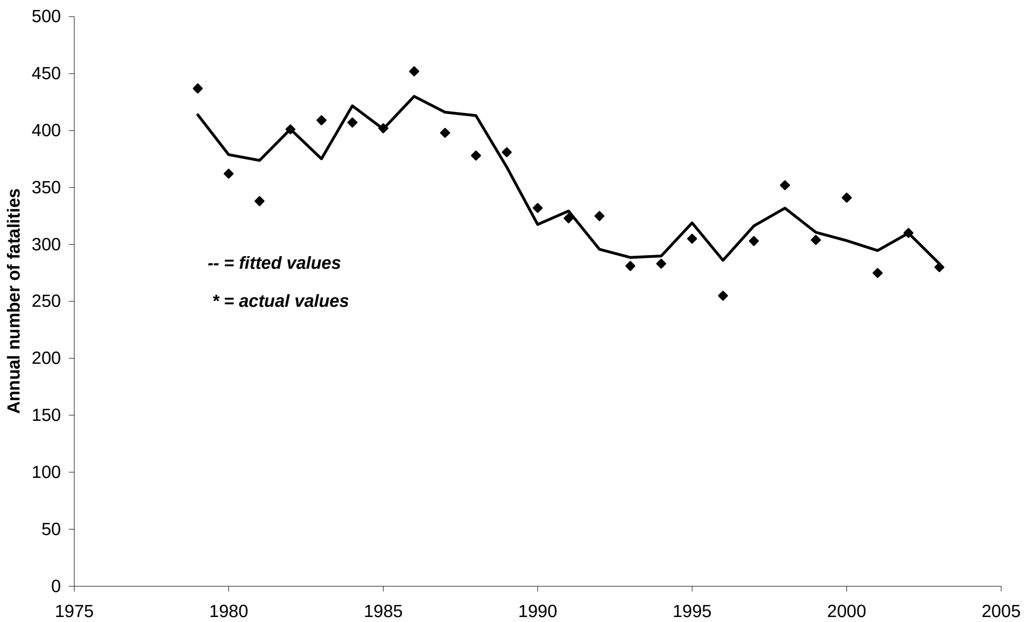
In this equation e denotes the exponential function. Total travel exposure is negatively associated with the number of fatalities, indicating that the number of fatalities per million kilometres of travel has declined. The association is not statistically significant at conventional levels.

Increases in pedestrian and cyclist exposure, and in heavy vehicle exposure, are both associated with an increasing the number of fatalities. These associations are statistically significant.

An increasing exposure of new drivers and of new cars are both associated with a reduction in the number of fatalities. However, none of these effects are statistically significant. The sign of the effect for novice drivers is surprising.

Increased seat belt wearing and an increase of traffic enforcement (penalties per million vehicle kilometres of driving) both appear to contribute to fewer fatalities. The number of kilometres driven on motorways is, somewhat surprisingly, positively related to the number of fatalities. This variable is, however, almost perfectly correlated with the number of kilometres driven by heavy vehicles. As expected, the annual trend is highly negative.

Figure 4 shows the fitted and actual values of fatalities from 1979 to 2003. The fitted values are shown by the line, the actual values are shown by the dots. The fitted numbers closely track year-to-year changes in the actual number of fatalities. The difference between the actual and the fitted number of fatalities exceeds two standard deviations in only one of 25 cases.



Source: TØI report 792/2005

Figure 4: Fitted (line) and actual (dots) values for traffic fatalities in Norway 1979-2003. Fitted values are based on a Poisson regression model

The model captures the slowdown in the rate of decline in the number of traffic fatalities after 1991. It would thus seem that the model has identified at least some of the factors that may explain why the decline in road accident fatalities until 1991 has not been sustained after 1991. Did any of the factors that are associated with a reduction in fatalities develop less favourably after 1991 than before, and did any of the factors that are associated with an increase in fatalities grow faster after 1991 than before 1991?

There has been a decline in pedestrian and cyclist travel exposure after 1991, but there was no decline before 1991. Changes in pedestrian and cyclist travel exposure cannot therefore explain the slowdown of the decline in fatalities after 1991. By the same token, changes in the rate of growth of heavy vehicle exposure can be ruled out as an explanation for the slower decline in fatalities after 1991 than before 1991. Changes in seat belt wearing were also, on the whole, more favourable after 1991 than before 1991. The effect of kilometres driven on motorways is counterintuitive and difficult to interpret due to the high correlation with kilometres driven by heavy vehicles.

The number of fixed penalties per million vehicle kilometres reached its highest value in 1993. If that value had been realised in all years from 1994 to 2003, the predicted number of fatalities for these years would have been 2933, compared to 3044 given the reduction in traffic enforcement that seems to have taken place in this period. Thus, the reduction in traffic enforcement after 1993 is one factor that may have contributed to a slower rate of decline in the number of fatalities.

The sales of new cars was also found to be associated with fewer fatalities, although the association was far from statistically significant. The all time high with respect to the sale of new cars was reached in 1986. If sales in all subsequent years had remained at that level, the number of fatalities predicted for the years from 1992 to 2003 becomes 3478, compared to 3628 given the actual number of new cars sold each year from 1992 to 2003.

Figure 5 summarises the combined effects of the reduction in the sales of new cars after 1986 and the reduction of traffic enforcement after 1993. In Figure 5, the solid line shows the predicted number of fatalities given the actual values for the sale of new cars and the number of fixed penalties per million vehicle kilometres. The dashed line shows the predicted number of fatalities if the sale of new cars had remained at the level observed in 1986 during all subsequent years, and if the number of fixed penalties had remained at the level observed in 1993 during all subsequent years. It is seen that the counterfactual data predict a lower number of fatalities than the actual data. The analyses therefore indicate that a reduction in the sale of new cars, and a reduction in traffic enforcement are two of the factors that may have contributed to a slowdown in the rate of decline in the number of road accident fatalities in Norway after about 1991.

This finding obviously does not rule out a host of other possible explanations. There may, for all we know, have been an increase in drink-driving after 1991, an increase in the mean speed of traffic, or numerous other changes in road user behaviour or the quality of roads and vehicles. Unfortunately, reliable data regarding these factors are not available; hence, their effects cannot be tested. There are, however, indications that speed may have increased over time and that speeding is becoming more widespread, despite the increasing use of speed cameras to enforce speed limits. Table 4 shows the percentage of motorists exceeding the speed limit based on data for four different periods in Norway (Elvik, Mysen and Vaa 1997, Elvik and Christensen 2004, Solheim 2005).

The rate of violations is seen to generally increase over time. The speed limit of 100 km/h did not exist before 2001. The average rate of speed limit violations is now close to 50 percent.

Source: TØI report 792/2005

Figure 5: Comparison of actual data and counterfactual data(high sales of new cars and high enforcement) used to predict traffic fatalities in Norway

Speeding appears to have increased more in recent years than earlier, thus possibly contributing to a slowdown in the decline of fatalities.

Table 4: Rate of violation of different speed limits in Norway during four periods. Sources: See text

	Percent of motorists exceeding the speed limit			
Speed limit	1971-1977	1980-1984	1995-2003	2004
50 km/h	35	44	55	54
60 km/h	20	35	45	61
70 km/h	20	30	59	62
80 km/h	15	42	43	46
90 km/h	20	55	--	45
100 km/h	--	--	--	55

Speed is one of the factors that has a very strong relationship with road safety, in particular the number of fatalities (Elvik, Christensen and Amundsen 2004).

4.2 Injured road users

Table 5 shows the coefficient estimates for the Poisson regression model fitted to explain the number of injured road users.

Table 5: Coefficients estimated for Poisson regression model to explain the number of injured road users in Norway 1979-2003

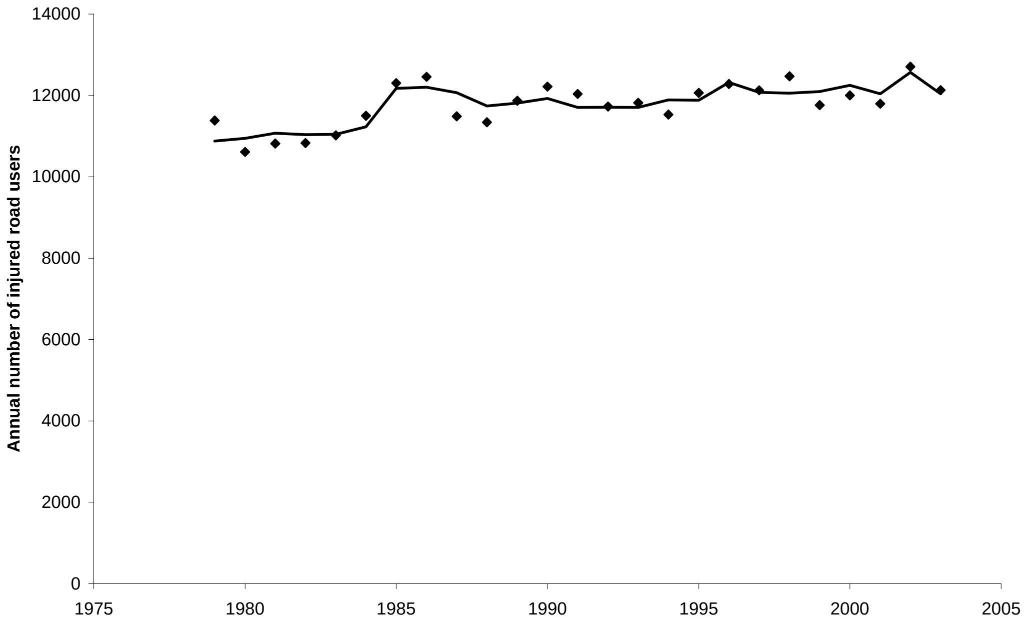
Variable	Coefficient	Standard error	P-value
Constant term	6.554801	1.492128	0.0000
Log of total person kilometres of travel	0.289966	0.137054	0.0344
Pedestrian and cyclist kilometres of travel	-0.000118	0.000099	0.2319
Heavy vehicle kilometres of travel	-0.000051	0.000028	0.0621
Novice drivers kilometres of travel	0.000013	0.000015	0.3598
Number of new cars registered	0.000429	0.000110	0.0001
Seat belt wearing rate by drivers	0.000683	0.001194	0.5674
Fixed penalties per million vehicle kilometres	-0.023032	0.004788	0.0000
Kilometres driven on motorways	-0.000078	0.000021	0.0002
Annual trend	0.009416	0.003023	0.0018

Source: TØI report 792/2005

The mean annual number of injured road users was 11,771.60 The variance was 304,641.33. Systematic variation thus made up 96.1% of the total variation. The over-dispersion parameter was not statistically significant (0.000483, P = 0.1223). The Poisson model is therefore regarded as adequate. The model explained 77.1% of the systematic variation in the number of injured road users.

The first thing to note about the results, is that several of the coefficients have the opposite sign in the model for injured road users compared to the model for fatalities. This applies to the coefficients for overall travel exposure, pedestrian and cyclist exposure, heavy vehicle exposure, novice driver exposure, sale of new cars, use of seat belts, kilometres driven on motorways and the trend term. Interestingly, the only coefficient that has the same sign is the coefficient for traffic enforcement, indicated by the number of fixed penalties issued per million vehicle kilometres of driving. The reason for the change in sign of most coefficients is probably that the long term trend for injuries is the opposite of that for fatalities. While fatalities have gone down, the number of injured road users has tended to increase slowly. The variability of the time series of injured road users is, however, much smaller than the variability of the fatality counts. The model fits the data less well than the model for fatalities. The residuals exceeded two standard deviations in 14 out of 25 cases.

Figure 6 shows the actual and fitted values for injured road users. In general, the fitted values track the actual number of injured road users fairly closely from year to year, despite the fact that many residual values are greater than two standard deviations. The explanations for the increasing trend in the number of injured road users are clearly not the same as the explanations for the decline in the number of fatalities. However, some of the same factors may explain both why the decline in fatalities has slowed down and why there has not been a decline in injured road users. In particular, the reduction of traffic enforcement would appear to such a factor, since the sign of its impact is the same for fatalities as for injured road users. A model was therefore fitted for injured road users, using the maximum level of enforcement, observed in 1993, to predict the number of injured road users in the years 1994 to 2003.



Source: TØI report 792/2005

Figure 6: Fitted (line) and actual (dots) values for injured road users in Norway 1979-2003. Fitted values are based on a Poisson regression model

According to the basic model, based on the actual values observed for traffic enforcement during the years 1994-2003, the total predicted number of injured road users for this period was 121,218. According to the model, based on the level of traffic enforcement observed in 1993, the total predicted number of injured road users for the period 1994-2003 was 119,320.

As the main focus in this report is on fatalities and serious injuries, a further analysis of factors influencing the number of injured road users has not been made.

4.3 The share of fatal or serious injuries

The proportion of all injured road users who are killed or sustain serious injuries has gone down substantially during the last 25 years. This proportion was 0.236 in 1979 and 0.105 in 2003. A linear regression model has been fitted in order to test explanations for this decline. Table 6 shows the coefficients estimated.

Most of the independent variables do not seem to be strongly associated with changes over time in the proportion of fatal or serious injuries. The annual trend is clearly the most significant predictor variable. The signs of the coefficients are as expected for most variables. The sale of new cars is an exception, but the coefficient is far from statistically significant at conventional levels.

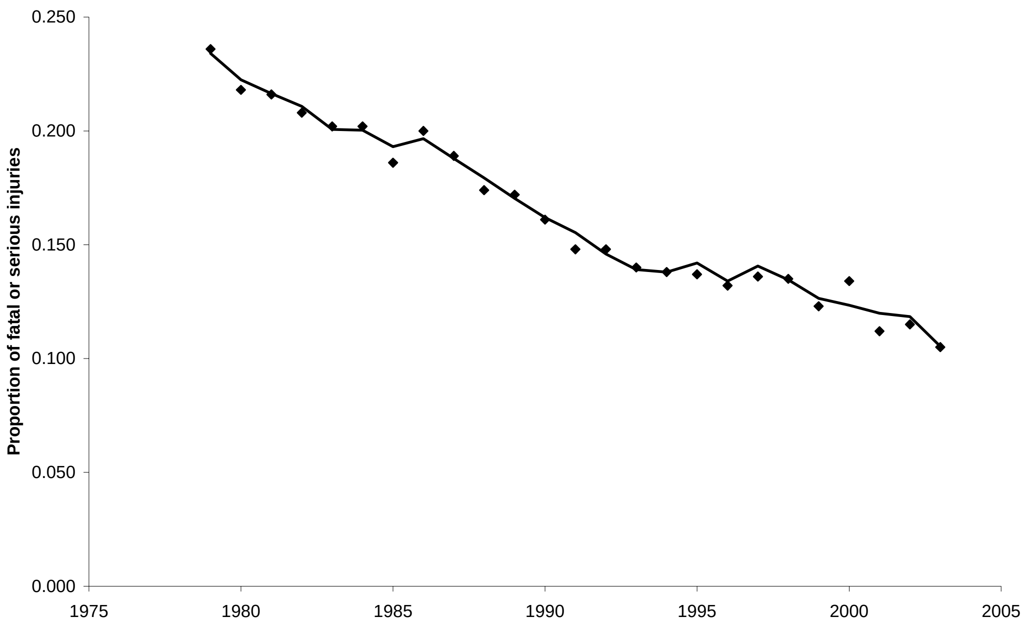
Despite the lack of statistical significance for the majority of independent variables, the model fits the data very well, with an adjusted multiple squared correlation coefficient of 0.9814.

Table 6: Coefficients estimated for linear regression model to explain the share of injured road users who were killed or seriously injured in Norway 1979-2003

Variable	Coefficient	Standard error	P-value
Constant term	0.269244	0.130186	0.0563
Total person kilometres of travel	-0.000002	0.000002	0.2572
Pedestrian and cyclist kilometres of travel	0.000003	0.000056	0.9616
Heavy vehicle kilometres of travel	0.000050	0.000016	0.0074
Novice drivers kilometres of travel	-0.000000	0.000008	0.9066
Number of new cars registered	0.000058	0.000061	0.3568
Seat belt wearing rate by drivers	-0.000378	0.000673	0.5824
Fixed penalties per million vehicle kilometres	-0.005793	0.002859	0.0608
Kilometres driven on motorways	0.000036	0.000012	0.0120
Annual trend	-0.011053	0.001706	0.0000

Source: TØI report 792/2005

Figure 7 shows the fitted and actual values for the proportion of fatal or serious injuries in road traffic accidents in Norway from 1979 to 2003. The actual values are shown by black dots, the fitted values by a solid line.



Source: TØI report 792/2005

Figure 7: Fitted (line) and actual (dots) values for the proportion of fatal and seriously injured road users in police reported injury accidents in Norway 1979-2003

The proportion of road users who are killed or seriously injured has declined by more than 50 percent from 1979 (about 23 percent) to 2003 (about 10 percent). The rate of decline does not seem to have slowed down in recent years.

5 Measures to improve road safety

5.1 Road safety measures implemented in Norway

The main problem addressed in this report is why the rate of decline in traffic fatalities has slowed down in recent years. Some factors that may have contributed to this were discussed in chapter 4. In addition to the factors discussed in chapter 4, a slowdown in the process of improving road safety may be the result of already having implemented the most effective road safety measures, leaving only less effective measures for current or future implementation.

In an international perspective, Norway has to a large extent implemented a number of road safety measures that are widely recognised as important, and that have been found to be effective in reducing traffic injury. These measures include (but are not limited to):

- Speed limits on all public roads. Norway has always had speed limits, and by international standards, the limits are fairly low. The criteria for setting speed limits have been revised several times, in order to make the limits as effective as possible in improving road safety.
- Speed cameras to enforce speed limits. Speed cameras were introduced in 1988 in Norway and the use of speed cameras has expanded greatly in recent years.
- A per se blood alcohol limit. Norway introduced such a limit in 1936 and lowered it from 0.05 to 0.02 percent in 2000.
- Mandatory use of crash helmets for moped and motorcycle riders was introduced in 1977.
- Mandatory use of seat belts for car drivers was introduced in 1979, for all car occupants in 1988.
- Mandatory use of daytime running lights for all motor vehicles was introduced in 1988.
- Conversion of junctions to roundabouts started around 1980 and more than 600 junctions on national roads have been converted.

The question therefore needs to be asked what the potential is for further improving road safety in Norway by continued use of known road safety measures or the introduction of new road safety measures. According to recent policy analyses (Elvik 2001, 2003, 2005), there is a huge potential for improving road safety in Norway. Which are the road safety measures representing this potential?

5.2 Potential for further improving road safety

Table 7 presents the main findings of a recent analysis of the potential for further improving road safety in Norway by means of cost-effective road safety measures (Elvik 2005). A cost-effective measure is one whose benefits are greater than its costs. The analysis concentrated on opportunities for improving road safety in the 2010-2019 planning term. Expected effects of measures during the period 2005-2009 have, however, also been included. Measures are listed by main category only.

Table 7: Potential for further improving road safety in Norway by means of cost-effective road safety measures 2005-2009 and 2010-2019. Source: Elvik 2005

	Road users killed		Road users seriously injured	
Main categories of road safety measures	Predicted number	Effects of measures	Predicted number	Effects of measures
Estimated effects during 2005-2009 planning term				
Expected 2009 without any road safety measures	288		1099	
- Road investments		-29		-107
- Vehicle inspection		-4		-9
- More speed cameras		-5		-14
- New vehicle technology		-24		-60
Expected 2009 with all road safety measures	226		909	
Estimated effects during 2010-2019 planning term				
Expected 2020 without any road safety measures	246		982	
- Road investments		-26		-94
- Vehicle inspection		-4		-9
- Lower speed limits		-16		-37
- New legislation		-7		-23
- Section control by camera		-5		-14
- More police enforcement		-30		-87
- New vehicle technology		-39		-113
Expected 2020 with all road safety measures	125		640	

Source: TØI report 792/2005

In principle, it is possible to greatly reduce the number of road accident fatalities and serious injuries during the next fifteen years. Expected innovations in vehicle technology that are already spreading fast will contribute substantially to this. These innovations include electronic stability control, seat belt reminders, improved neck injury protection in rear-end collisions, and increasing use of the EuroNCAP programme by both car manufacturers and consumers. Other potentially effective road safety measures are likely to be more controversial. Lowering speed limits from 90 to 80 kph, and from 80 to 70 kph remains cost-effective in Norway, but is likely to encounter resistance. A substantial increase of police enforcement is cost-effective, but is nevertheless not very likely to be implemented. Speed enforcement by means of so called section control may be introduced in Norway before 2020. This technology for speed enforcement relies on the use off two speed cameras: one camera takes pictures of all cars entering a road section, the next camera takes pictures only of those who violated the speed limit when passing the road section. This technology could make speed cameras effective for longer sections of road; today effects are only observed in the immediate vicinity of each speed camera.

Road investments can still contribute to improving road safety, but by 2020 it seems likely that the marginal returns from such investments in Norway will be rapidly declining, at least if the selection of locations to be treated is effective. An effective selection of locations for treatment by means of road investments goes for the worst sites first, leaving sites that have less serious road safety problems for future treatment. By 2020 all sites that have serious road safety problems which are amenable to treatment ought to have been treated.

6 Discussion and conclusions

6.1 Why the simplest questions are the most difficult to answer

One of the most frequently asked questions with respect to road safety is why the number of accidents, in particular the number of fatalities, has gone up, or down, from one year to the next. This simple question is actually one of the most difficult to answer as far as road safety is concerned. From 1970 until today, the annual number of road accident fatalities in Norway has been reduced by more than 50%. Yet, most of the changes from year to year in the number of fatalities during the period 1979-2003, which has been studied in this report, were not statistically significant at the 5% level. In fact, statistically significant changes were found only in 5 cases (out of 24) during this period. Two of the statistically significant changes were increases, despite the clear long-term trend towards a reduction of the number of fatalities.

In fact, the number of fatalities increased from the previous year in 11 out 24 cases during the period 1979-2003, thus contravening the general trend. There were never more than two consecutive years with an increasing number of fatalities. There has, however, been long periods during which the decline in the number of fatalities has come to a halt. The number of fatalities dropped to 338 in 1981. A lower number was not realised until 1990, when 332 fatalities were recorded. In 1996, there were 255 fatalities. A lower number has not since been observed, although it is very likely that the number of fatalities in 2005 will be less than 255, possibly around 205 (extrapolating preliminary figures for January through September to the whole year). What can we learn from these observations? These lessons are the most important:

1. Changes in the number of road accident fatalities from one year to the next are in most cases well within the bounds of random variation only.
2. The fact that most year-to-year changes are random does not necessarily mean that there is no long-term trend, but data for at least 10 years are needed to determine the presence of any clear long-term trend.
3. Even in the presence of a clear long-term trend, changes from year-to-year that go against this trend will occur quite often. An increase in the number of fatalities in any given year does not necessarily imply that a declining trend has turned.
4. Prolonged periods of stagnation – between 5 and 10 years – may occur in the presence of a long-term trend for the number of accidents or fatalities to go down. Again, such periods may not always signify a turn of the trend.

The analyses presented in this report are, at best, able to identify some of the factors that have shaped the long-term trend towards fewer fatalities and a lower proportion of fatal or serious injuries in the period 1979-2003. It should be recognised, however, that the annual fluctuations around the trend line fitted in Figure 1 (page 1 of the report), are almost entirely random.

It will be noted that for all dependent variables that have been studied, the explanatory variables account for only a minor portion of the trend; a parameter labelled “annual trend” is by far the most significant in all analyses. What goes into this term is a matter of guesswork. It is not unreasonable to believe that the trend term captures the effects of many road safety measures. At least with respect to infrastructure measures, these tend to be introduced in small and almost constant doses over a very long period. The year-to-year variations in the rate at which road-related safety measures are introduced are too small to be captured in the analyses. The renewal of the vehicle fleet also typically takes place at a slow and almost constant rate, although the sales of new cars may vary more from year to year than the use of highway and traffic engineering measures. Although it was not possible to estimate the effects of road safety measures, other than seat belt wearing and police enforcement, it is reasonable to believe that the introduction of many such measures account for a large part of the annual trend towards fewer fatalities and a smaller proportion of serious injuries.

6.2 Has the trend towards fewer fatalities speeded up again?

In the last few years, the number of road accident fatalities in Norway has once more gone down substantially, following the period of stagnation after 1996. The number of road accident fatalities was 310 in 2002, 280 in 2003, 257 in 2004 and is likely to be around 205 in 2005. This is an impressive reduction. It is, however, by no means unique.

In Sweden, the number of road accident fatalities (excluding those who were diagnosed as cases of illness) was 564 in 2000, 551 in 2001, 532 in 2002, 529 in 2003, 480 in 2004, and 447 so far in 2005 (last twelve months including August 2005).

In Denmark, the number of road accident fatalities was 498 in 2000, 431 in 2001, 463 in 2002, 432 in 2003, and 369 in 2004.

In Great Britain, the number of road accident fatalities declined from 3508 in 2003 to 3221 in 2004, the lowest number recorded since 1927, following a period of many years during which there was no decline in the number of road accident fatalities. In the Netherlands, a remarkable reduction from 1088 deaths in 2003 to 881 in 2004 was observed.

The fact that rather large reductions are found at the same time in several countries suggests that factors that are common to these countries are contributing to the reductions. One such factor is innovations in vehicle safety systems. A period of less than 10 years is definitely too short to reliably identify a long-term trend. However, the fact that rather large reductions in the number of road accident fatalities have been observed in several countries within a period of less than five years suggests that these changes are not merely chance fluctuations.

As far as Norway is concerned, a number of safety measures have been introduced in recent years that may have contributed to a reduction in the number of road accident fatalities. Some of these measures include:

- Speed limits were lowered on a number of very hazardous road sections in 2001. Lowering the speed limit from 80 to 70 kph lead to a large reduction in the number of fatal and serious injury accidents (Ragnøy 2005).
- Speed cameras have been installed at more locations.
- A demerit point system was introduced in 2004. An evaluation of its effects is still going on.
- The proportion of new cars sold that have 5 EuroNCAP stars increased from 2% in 2000 to 31% in 2004.
- There is a trend for seat belt wearing to increase.

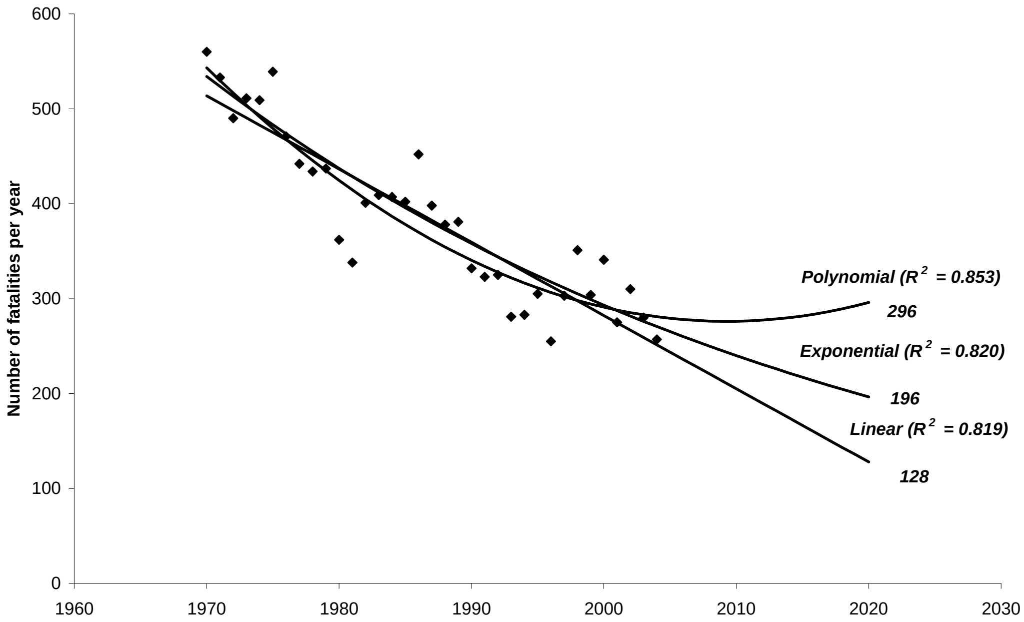
It is not possible to quantify the contributions of these factors to the overall reductions of the number of fatalities.

6.3 Does explaining past trends help in predicting future trends?

It is sometimes believed that the more successful we are in explaining past trends, the better will be the predictions we can make of future trends. This belief is unfounded. Predictions based on models that perfectly fit past data can be seriously wrong (see Partyka 1991 for an instructive example). Moreover, models that provide equally precise descriptions of past trends may give very different predictions of future trends.

The model fitted to explain fatality counts, explained 97.4% of the systematic variation, corresponding to 86.2% of the total variation of the time-series. This is only marginally better than simple curve fitting, not involving any explanatory variables at all.

Figure 8 shows three different trend lines that can be fitted to fatality counts for the years 1970-2004 (admittedly a longer period than the one used in the Poisson regression analysis). A second order polynomial best fits the data, with a squared correlation coefficient of 0.853. Extrapolating the polynomial gives a predicted number of fatalities of 296 for the year 2020. Also shown in Figure 8 are an exponential trend line, assuming a constant 2% reduction in the fatality count each year, and a linear trend line. These two trend lines fit the data almost as closely as the polynomial. The predictions obtained by extrapolating the exponential and linear trend lines are, however, very different. 196 fatalities in 2020 are predicted from the exponential trend line, 128 fatalities in 2020 are predicted from the linear trend line. Thus, extrapolation of simple trend lines, all of which closely fit past data, give predictions ranging from 128 to 296 fatalities in 2020.



Source: TØI report 792/2005

Figure 8: Extrapolation of trend lines fitted to fatality counts for the period 1970-2004. Predicted number of fatalities in 2020

For the purpose of prediction, the gain in explanatory power obtained by the multivariate analysis is very marginal, and comes at a price: To use the Poisson regression model for prediction, one would have to predict all the explanatory variables. The uncertainty involved in such a prediction is perhaps as large as the uncertainty given by the range of predictions shown in Figure 8.

6.4 Main findings and conclusions

The main findings of this study can be summarised as follows:

1. An analysis has been made of some factors that may influence the number of road accident fatalities, the number of injured road users, and the proportion of injuries that are fatal or serious. It was found that the stagnation in the decline of fatalities in recent years can, to some extent, be attributed to less police enforcement and a slowdown (after a peak in 1986) in the sales of new cars.
2. Increasing police enforcement is consistently found to be associated with fewer fatalities, fewer injured road users, and a smaller proportion of serious injuries.
3. Increased seat belt wearing is associated with fewer fatalities and a lower proportion of serious injuries.
4. The effects of the explanatory variables included in the study could not be determined with great precision, and the Poisson regression model fitted to the time series of fatality counts had only a marginally better explanatory power than simple trend lines fitted to these data.

5. Various trend lines can be fitted to fatality data for the period 1970-2004, all of them describing long-term trends quite well, yet giving widely divergent predictions for the number of road accident fatalities in 2020.
6. Analyses of road safety policy show that it is, in principle, possible to reduce the number of road accident fatalities by 50% by 2020. Recent evidence suggests that the trend towards fewer fatalities may have speeded up again.

7 References

Bjørnskau, T. Risiko i persontransport på veg 1984/85. Rapport 2. Oslo, Transportøkonomisk institutt, 1988.

Bjørnskau, T. Risiko i veitrafikken 1991/92. Rapport 216. Oslo, Transportøkonomisk institutt, 1993.

Bjørnskau, T. Risiko i veitrafikken 1997/98. Rapport 483. Oslo, Transportøkonomisk institutt, 2000.

Bjørnskau, T. Risiko i trafikken 2001-2002. Rapport 694. Oslo, Transportøkonomisk institutt, 2003.

Elvik, R. Ulykkesrisiko på riksveger 1986-89. Rapport 81. Oslo, Transportøkonomisk institutt, 1991.

Elvik, R. Vegtrafikklovgivning, kontroll og sanksjoner. Notat 1073. Oslo, Transportøkonomisk institutt, 1997.

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

Elvik, R. How would setting policy priorities according to cost-benefit analyses affect the provision of road safety? Accident Analysis and Prevention, 35, 557-570, 2003.

Elvik, R. Traffic safety. Chapter 16 in Kutz, M. (Ed): Handbook of Transportation Engineering. New York, NY, McGraw Hill, 2004A.

Elvik, R. Transportarbeid og risiko for ulike trafikantgrupper. Arbeidsdokument SM/1607/2004. Oslo, Transportøkonomisk institutt, 2004B.

Elvik, R. Tiltak for å halvere antall drepte eller hardt skadde i vegtrafikken innen 2020. Arbeidsdokument SM/1698/2005. Oslo, Transportøkonomisk institutt, 2005.

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

Elvik, R.; Christensen, P. Virkninger av økte satser for gebyr og forenklet forelegg på lovlydighet i trafikken. Rapport 725. Oslo, Transportøkonomisk institutt, 2004.

Elvik, R.; Christensen, P.; Amundsen, A. H. Speed and road accidents. An evaluation of the Power Model. Report 740. Oslo, Institute of Transport Economics, 2004.

Elvik, R.; Christensen, P.; Amundsen, A. H.; Vaa, T. Kapitler i Trafikksikkerhetshåndboken revidert i 2003 og 2004. Arbeidsdokument SM/1623/2004. Oslo, Transportøkonomisk institutt, 2004.

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

Elvik, R.; Vaa, T. The Handbook of Road Safety Measures. Oxford, Elsevier Science, 2004.

Fosser, S.; Christensen, P. Bilers alder og ulykkesrisiko. Rapport 386. Oslo, Transportøkonomisk institutt, 1998.

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

Fridstrøm, L. et al. Measuring the contribution of randomness, exposure, weather, and daylight to the variation in road accident counts. Accident Analysis and Prevention, 27, 1-20, 1995.

Gustafsson, S.; Thulin, H. Gående och cyklister – exponering och skaderisker i olika trafikmiljöer för olika åldersgrupper. VTI-meddelande 928. Linköping, Väg- och Transportforskningsinstitutet, 2003.

Lie, A.; Tingvall, C. How does Euro NCAP results correlate to real life injury risks – a paired comparison study of car-to-car crashes. Paper presented at 17th International Technical Conference on the Enhanced Safety of Vehicles, Amsterdam, June 4-7, 2001. Proceedings in Report DOT HS 809 220. Washington DC, National Highway Traffic Safety Administration, 2001.

Muskaug, R. Risiko på norske riksveger. En analyse av risikoen for trafikkulykker med personskade på riks- og europaveger utenfor Oslo, avhengig av vegbredde, fartsgrense, trafikkmengde og avkjørselstettet. TØI-rapport. Oslo, Transportøkonomisk institutt, 1985.

Muskaug, R.; Nygaard, L. M.; Hagerupsen, A., Redisch, W. Tilstandsundersøkelser 2004. Rapport 2/2005, Veg- og vegtrafikkavdelingen. Oslo, Statens vegvesen Vegdirektoratet, 2005.

Partyka, S. Simple models of fatality trends revisited seven years later. Accident Analysis and Prevention, 23, 423-430, 1991.

Ragnøy, A. Speed limit changes: effects on speed and accidents. Report 784. Oslo, Institute of Transport Economics, 2005.

Ragnøy, A.; Christensen, P.; Elvik R. Skadegradstetthet. Et nytt mål på hvor farlig en vegstrekning er. Rapport 618. Oslo, Transportøkonomisk institutt, 2002.

Ranes, G. Analyse av personskadeulykker på motorveg. Notat datert 22. april 1998. Oslo, Statens vegvesen Vegdirektoratet, 1998.

Rideng, A. Transportytelser i Norge 1946-2003. Rapport 721. Oslo, Transportøkonomisk institutt, 2004.

Solheim, T. Vi kjører for fort, men ikke mer enn før. Samferdsel, 5 (juni), 2005, 6. Oslo, Transportøkonomisk institutt, 2005.

Vaaje, T. Risiko i vegtrafikken. Temahefte 11 i temaserien Samferdsel. Oslo, Transportøkonomisk institutt, 1982.

Wagenaar, A. C. Effects of macroeconomic conditions on the incidence of motor vehicle accidents. Accident Analysis and Prevention, 16, 191-206, 1984.

Appendix: Data used in analyses

Dependent variables

Table A.1 shows the dependent variables used in the study.

Table A.1: Dependent variables

Year	Number of fatalities	Number of injured road users	Proportion of injured road users killed or seriously injured
1979	437	11384	0.236
1980	362	10610	0.218
1981	338	10818	0.216
1982	401	10831	0.208
1983	409	11017	0.202
1984	407	11501	0.202
1985	402	12304	0.186
1986	452	12458	0.200
1987	398	11488	0.189
1988	378	11340	0.174
1989	381	11871	0.172
1990	332	12218	0.161
1991	323	12035	0.148
1992	325	11729	0.148
1993	281	11817	0.140
1994	283	11530	0.138
1995	305	12061	0.137
1996	255	12280	0.132
1997	303	12126	0.136
1998	352	12472	0.135
1999	304	11764	0.123
2000	341	12003	0.134
2001	275	11797	0.112
2002	310	12705	0.115
2003	280	12131	0.105

Source: TØI report 792/2005

Total exposure

Total travel exposure is made up of:

1. Travel by car (including bus) in million person kilometres
2. Travel by moped or motorcycle in million person kilometres
3. Walking in million person kilometres
4. Cycling in million person kilometres

Data on the first two variables have been taken from Rideng (2004). Estimates of the amount of walking or cycling have been developed as explained in the main text. Table A.2 reproduces exposure data.

Table A.2: Exposure data

	Amount of travel in million person kilometres				
Year	Car	Motorcycle	Cycle	Walking	Total
1979	37838	552	678	1260	40328
1980	37221	501	654	1326	39702
1981	36863	518	630	1392	39403
1982	36929	550	606	1458	39543
1983	37459	572	582	1524	40137
1984	38516	592	558	1591	41257
1985	43847	629	534	1658	46667
1986	46977	698	565	1600	49840
1987	48850	716	597	1541	51704
1988	49913	691	628	1483	52715
1989	50520	704	660	1424	53308
1990	50615	705	691	1366	53377
1991	50260	701	723	1307	52991
1992	50515	704	755	1248	53221
1993	51352	708	740	1266	54066
1994	52096	709	715	1284	54804
1995	52277	724	700	1302	55003
1996	54406	768	686	1321	57181
1997	54998	840	670	1339	57847
1998	56255	924	666	1357	59202
1999	56707	1000	641	1344	59692
2000	57494	1068	616	1331	60509
2001	58635	1130	592	1319	61676
2002	59997	1192	590	1315	63094
2003	60687	1260	590	1315	63852

Source: TØI report 792/2005

Table A.3 shows the data on pedestrian and cyclist exposure that were available and the estimates that have been developed from available data.

Table A.3: Available and estimated data on pedestrian and cyclist exposure

	Estimated travel (mill km)		Available data on travel (mill km)	
Year	Cycling	Walking	Cycling	Walking
1979	678	1260	1350	1200
1980	654	1326		
1981	630	1392		
1982	606	1458		
1983	582	1524		
1984	558	1591		
1985	534	1658	468	1467
1986	565	1600		
1987	597	1541		
1988	628	1483		
1989	660	1424		
1990	691	1366		
1991	723	1307		
1992	755	1248	662	1104
1993	740	1266		
1994	715	1284		
1995	700	1302		
1996	686	1321		
1997	670	1339		
1998	666	1357	589	1212
1999	641	1344		
2000	616	1331		
2001	592	1319	524	1178
2002	590	1315		
2003	590	1315		

Source: TØI report 792/2005

The estimation involved the following operations:

1. Increasing travel volume in 1985, 1992, 1998 and 2001 by about 13% to include travel by individuals below the age of 13 years. This was based on Swedish travel behaviour surveys.
2. Reducing cycling volume in 1979 to half the reported value, based on evidence reviewed by Bjørnskau (1993) indicating that the surveys of cycling made in selected years overstate the amount of cycling. Moreover, the surveys of cycling have been discontinued after 1992, leaving the travel behaviour surveys as the only source of data.
3. Increasing walking volume in 1979 by 5% to include pedestrians below the age of 7 years.

4. Interpolating values for intervening years linearly.

Travel exposure by young drivers, heavy vehicles, and on motorways

Estimation of travel exposure for young drivers (aged 18-24 years) was based on the number of new licences issued, combined with data for the years 1979, 1985, 1992, 1998 and 2001. Table A.4 shows the estimation.

Table A.4: Available and estimated kilometres driven by novice drivers

Year	Available data (mill km)	Licences issued (1000)	Estimated data (mill km)
1979	2589	53	2589
1980			2759
1981		55	2961
1982			3280
1983		57	3581
1984			3887
1985	4317	58	4317
1986			4659
1987		54	4846
1988			4763
1989		51	4678
1990			4552
1991			4372
1992	4197		4197
1993			4038
1994			3855
1995			3671
1996			3480
1997			3301
1998	3172		3172
1999		50	3074
2000			2996
2001			2967
2002	3056		3056
2003		49	3111

Source: TØI report 792/2005

Estimation of travel on motorways is shown in table A.5. Exposure is stated in million vehicle kilometres.

Table A.5: Estimation of travel on motorways- million vehicle kilometres

Year	Available data (mill km)	Length of motorways (km)	Estimated data (mill km)
1979	314 (for 42 km)	56	395
1980		54	390
1981		68	570
1982		71	650
1983		74	725
1984		74	730
1985		74	735
1986		74	740
1987	726	74	745
1988		75	750
1989		75	765
1990		75	770
1991		79	790
1992		79	795
1993		85	865
1994	384 (for 45 km)	94	935
1995		107	1045
1996		103	1085
1997		109	1105
1998		128	1285
1999		135	1365
2000		143	1455
2001		173	1735
2002		178	1810
2003	2400	213	2400

Source: TØI report 792/2005

Data on traffic exposure for heavy vehicles has been taken from Rideng (2004). For completeness, these data, along with the total number of kilometres driven, are reproduced in Table A.6.

Table A.6: Million vehicle kilometres driven by heavy vehicles and by all vehicles

Year	Heavy vehicles (mill km)	All motor vehicles (mill km)
1979	1932	18895
1980	1903	18769
1981	1799	18863
1982	1838	19642
1983	1871	20230
1984	2042	21355
1985	2177	23210
1986	2652	25319
1987	2855	26629
1988	3058	27060
1989	3143	27515
1990	3228	27755
1991	3313	27673
1992	3398	27795
1993	3482	28240
1994	3607	28772
1995	3795	29133
1996	3860	30261
1997	4292	30847
1998	4291	31716
1999	4311	32024
2000	4403	32569
2001	4474	33335
2002	4480	34341
2003	4200	34957

Source: TØI report 792/2005

Seat belt wearing, sales of new cars, and traffic enforcement

Table A.7 shows seat belt wearing for car drivers from 1979 to 2003. Values were interpolated linearly for the years 1989, 1992, 1994 and 1996, during which seat belt wearing was not monitored.

Table A.7: seat belt wearing by car drivers. Percentage wearing seat belts

Year	Urban roads (%)	Rural roads (%)	All roads (%)
1979	77.3	88.5	86.7
1980	73.7	89.8	87.3
1981	74.7	89.8	87.4
1982	66.5	84.9	82.1
1983	66.7	87.2	84.1
1984	66.2	83.3	80.7
1985	63.0	82.3	79.4
1986	59.4	83.0	79.6
1987	61.6	84.3	81.1
1988	65.0	84.2	81.5
1989	***66.1***	***87.6***	***84.7***
1990	67.3	91.1	88.0
1991	67.0	84.9	82.6
1992	***70.3***	***85.0***	***83.2***
1993	73.7	85.0	83.7
1994	***73.0***	***85.2***	***83.8***
1995	72.3	85.4	84.0
1996	***76.1***	***89.0***	***87.6***
1997	80.0	92.6	91.3
1998	79.1	91.3	90.1
1999	82.0	91.0	90.1
2000	77.5	91.5	90.2
2001	81.6	94.0	92.8
2002	84.3	91.5	90.8
2003	84.2	94.2	93.3

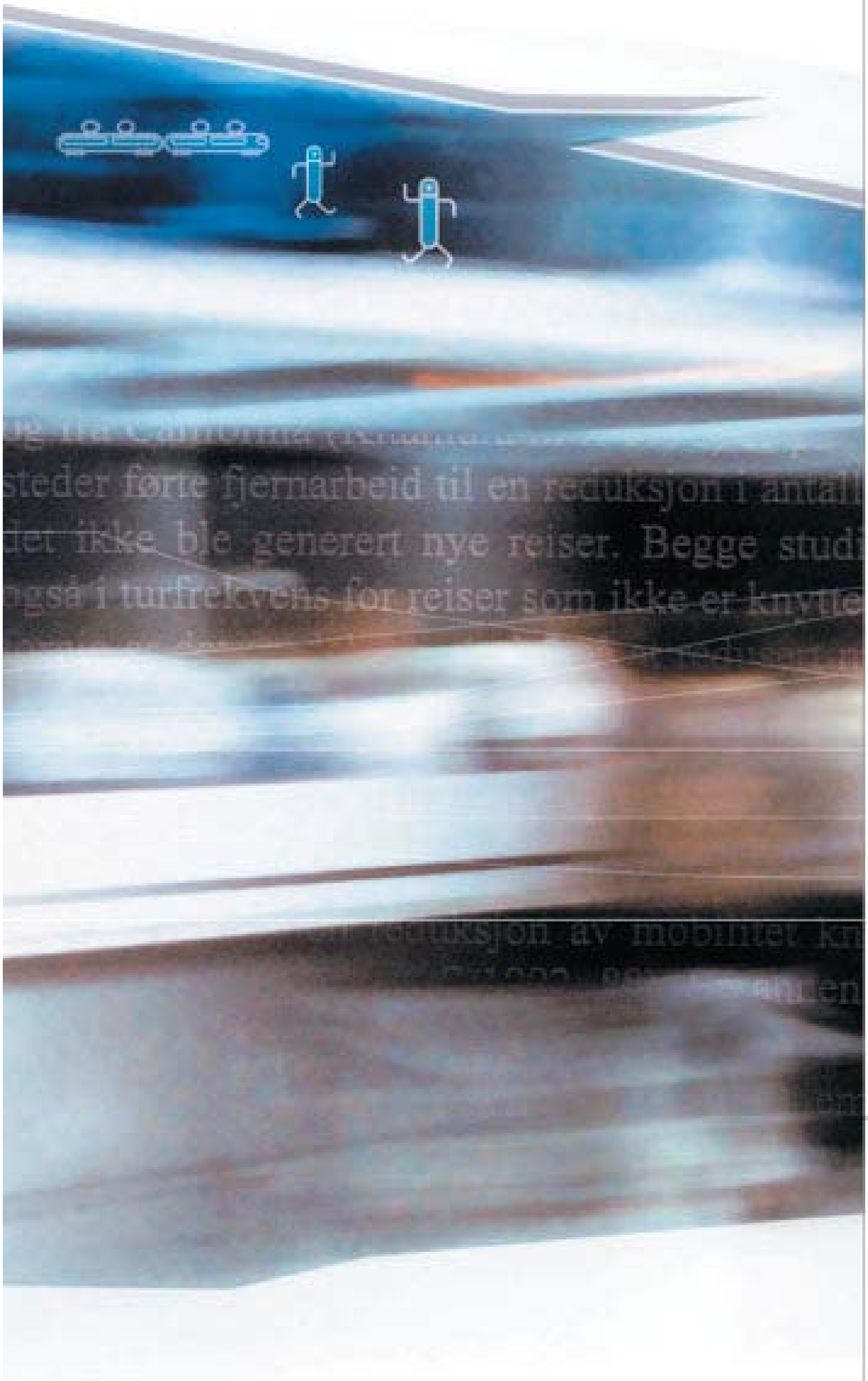
Source: TØI report 792/2005

Table A.8 shows the sales of new cars each year, the number of fixed penalties issued, and the number of fixed penalties per million vehicle kilometre.

Table A.8: Sales of new cars (thousands), fixed penalties, and fixed penalties per million vehicle kilometre

Year	Sale of new cars (1000)	Fixed penalties	Penalties/mill vehicle km
1979	105	102692	5.43
1980	111	102741	5.47
1981	124	95286	5.05
1982	138	105025	5.35
1983	135	112454	5.56
1984	135	107870	5.05
1985	202	102714	4.43
1986	210	126086	4.98
1987	147	132247	4.97
1988	90	145927	5.39
1989	72	145336	5.28
1990	85	152433	5.49
1991	71	164807	5.96
1992	80	178839	6.43
1993	85	187371	6.63
1994	115	187335	6.51
1995	128	183977	6.32
1996	162	180959	5.98
1997	165	197974	6.42
1998	154	197008	6.21
1999	134	192593	6.01
2000	133	184923	5.68
2001	129	204278	6.13
2002	117	154458	4.50
2003	121	200307	5.73

Source: TØI report 792/2005



Institute of Transport Economics

Norwegian Centre for Transport Research

- carries out research for the benefit of society and industry
- has a research staff of around 70 highly-qualified staff working in various areas of transport research
- co-operates with a number of organisations, research institutes and universities in Norway and in other countries
- carries out high-quality research and assessment projects within topics such as traffic safety, public transport, the environment, travel behaviour, tourism, planning, decision-making processes, transport economics and business transport
- publishes research findings in the Centre's own report series, the Internet, the periodical "Samferdsel" and other national and international journals and scientific publications

Institute of Transport Economics
Norwegian Centre for Transport Research
Box 6110 Etterstad
N-0602 Oslo

Tel.: +47 22 57 38 00
www.toi.no