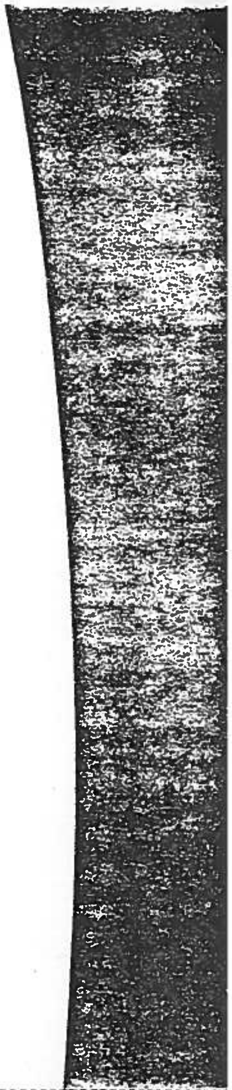
Ministerie van Verkeer en Waterstaat
Directoraat-Generaal Rijkswaterstaat

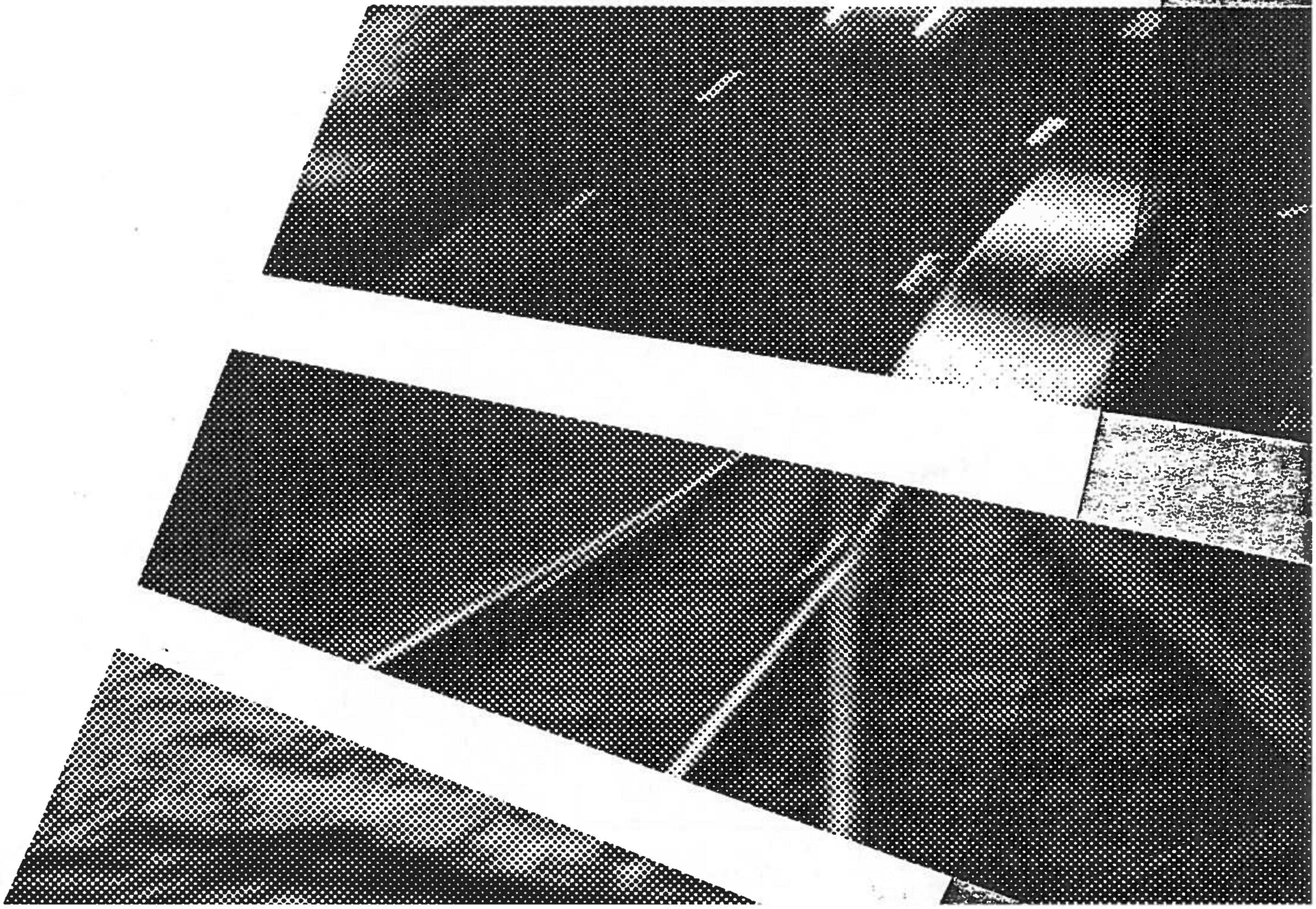
Adviesdienst Verkeer en Vervoer



Proceedings

Workshop TRC - VOLPE
19 - 21 april 1999
Rotterdam

Joop H. Kraay



WORKSHOP TRC- VOLPE

Rotterdam
The Netherlands
19 - 21 April 1999

The cooperation between TRC and Volpe is based on a governmental Memorandum of Understanding MOU between The Netherlands and the USA. A special agreement is layed down in a Letter of Intent between TRC and Volpe. This Letter of Intent desires to establish a mutually advantageous relationship in transportation research. This workshop is part of those joint activities.

Meetings were held on 19, 20 and 21 April at the TRC building in Rotterdam. The parties involved were besides TRC and Volpe, the SWOV Institute for Road Safety Research, Center for Environmental and traffic Psychology COV University of Groningen, Traffic Test and the Directorate-General for Passenger Transport of the Ministry of Transport. Each party gave at least one presentation of current or recent research.

On the basis of three days presentations and discussions the following suggestions were made. Within the framework of the US crash avoidance scenario and the accompanied human factors approach, subjects of mutual interest and possibilities for joint projects are proposed in the following fields.

* Exposure and Risk
    availability of exposure data by surveys of traffic and travellers; induced exposure
    combination of methods
    exposure dissaggregations
    exposure to risk (passenger km or encounters, etc.)
    own and others risk (risks to third parties)
    availability of data in EU and in USA
    comparability between countries, e.g. The Netherlands and USA
    corridor risk assessment
* Geographic Information Systems GIS
* Data-mining
* Intelligent Cruise Control ICC.

In order to be able to start next year joint activities on the fields mentioned, the following time schedule has been appointed.

* Volpe formulates questions on the before mentioned subjects before 1 June.
* TRC, together with its Dutch partners, prepares first proposals for joint projects before 1 July.
* Reaction to the proposed projects from Volpe by 1 August.
* Finalizing the project-proposals in a meeting in Boston at Volpe Center on 13 and 14 September.

Joop H Kraay
TRC-Ministry of Transport

POTENTIAL AREAS OF COOPERATION WITH THE MINISTRY OF TRANSPORT

The Volpe Center and the Ministry of Transport of The Netherlands share many common goals and research interests, and the potential for collaborative efforts can enhance both research programs. Collaborative research provides us with a 'national' peer group to share and review scholarly research. It also provides us with fertile databases for cross comparisons and opportunities for innovative research and data collection designs.

In our recent workshop on exposure and risk, several potential topics and methodologies for collaborative effort were identified. This brief document describes the general topic areas, some potential data and or methodological approaches that may be employed by our staff and some of the likely products or applications of the research.

Each of these topics will require an internal DOT sponsor as well as a sponsor in the Ministry of Transport, and should be thought of as a project that may be single or multi-year in length.

The general topic areas discussed in Rottedam were:

* Automobile / Road Safety
  Trend Analyses
  Driver Behavior
  Technological innovations and impacts on safety
  Crash Avoidance Research and Exposure Assessment
  Alternative methods of Data collection and interpretation
    Data collection through ITS
    Data mining
  Comparative risk analysis among modes and implications for individual choice models
* Model Development Using GIS
  Rail Applications
  Possible Development of a Roadway accident exposure model
  Congestion modeling employing a GIS platform

Within the area of Automobile / Road Safety a number of topics arose that could have significant potential for joint research programs. The value of collaboration exists in that the Dutch had significantly advanced methods of data collection (such as in-road traffic counters) or techniques (such as exposure modeling comparing many modes of transport).
The paper presented by Dr. Matthijs Koornstra comparing risk across all modes is one that should be duplicated for the U.S. as early as possible. This was an enlightening treatment of the perspective of the risk decision-maker and addresses the issue of risk transferrence admirably. Access to data and methodologies like these enhances both our knowledge and our imaginations. Employment of the available data allows US researchers to compare subsets of the U.S. (such as small study areas in a particular city) with the broader experience of The Netherlands.

Both the U.S. and The Netherlands have invested a significant amount of energy into the reduction of the fatality rate in automobiles. However, both groups acknowledge that fatality trends seem to be in a steady (but not "influenceable") decline. In some cases, there are upward fluctuations in the fatality trends, and the questions of whether these trends are consistent with the general downward trend, or special events due to exogenous factors is always of interest to policy makers. Exploratory research in this area is warranted and valuable to researchers as well as to policy makers. Moreover, comparative research allows us to establish whether there are societal, economic, or even "vehicle" specific trends that have affected this rate.

Some possible projects are suggested:
a) A comparative Analysis of Long Term fatality Trends in the US and in The Netherlands by interrupted time series modeling to identify the major contributors to trend deviations.

b) Driver Risk Taking Behavior and Attitudes as predictors of variations in accident rates - based upon work presented by the Dutch researcher Dr. Peter Lourens. He provided us a briefing on his research into risk taking behavior based upon surveys and the actual accident and violation experience of drivers. His research identified aspects of age cohorts that seemed to be homogeneous with respect to risk-taking behavior. This would allow researchers to identify specific age cohorts and analyze their behavior in the U.S. for comparative statistical analysis (with or without survey research).

Opportunities for designing and implementing traffic flow monitors by employing ITS technology (as a substitute for in-road counters) is one clear opportunity presented by this program for comparative research. Another is the development of congestion models based upon traffic counts, already developed and implemented in The Netherlands. The technology could be adapted and made available for certain locations in the U.S. providing a great planning tool for roadway planners as well as a service to the general public.

A third area of direct technology transference was in the area of Rail Safety Analysis. Ministry representatives indicated that the Dutch are now interested in upgrading their railroad control system technology, and were particularly interested in applying the corridor risk assessment model developed here at the Volpe Center. Since this model and its specifications are based upon nearly "universally" available data, it would be relatively simple to transfer the techniques and analysis methods to The Netherlands for their use. The project would simply consist of assessing the Dutch in development of the GIS base and the data necessary to build the model. One important improvement this can provide to the U.S. effort in this area is that the Dutch system has been under train control for many years. While the FRA must "estimate" the value of train control by hypothetically identifying accidents that may be prevented if this system is implemented, the Dutch have a wealth of data on the actual performance of the system. This data can be of enormous value to the FRA.

Several experiments in the area of Intelligent Cruise Control have been fielded in the US and in The Netherlands. These large scale demonstration programs provide the first opportunity to evaluate the implementation of these sophisticated early warning systems and to use the data to inform the design process. Dutch researchers discussed two large scale demonstration programs and descriptions current developments in the U.S. were provided by Volpe. Further data exchange, observation, and discussions of the results could be encouraged under an "ICC Research Umbrella" project.

Each or any of these topics might provide a method for fruitful collaboration between the two research departments. Our objective at this point is to define some specific topics and plan the undertaking in the coming year.

The Volpe Center has committed to develop one or more research proposals in these topic areas and secure funding to develop at least the concept papers and research methodology in the first quarter of FY 2000.

In the coming months meetings will be conducted with the Ministry of Transport during a visit to the Volpe Center to finalize these research topics. The Volpe Center hopes to identify research support from the FHWA and NHTSA, as well as FRA to sponsor this research.

Sherry S. Borener
Volpe National Transportation Systems Center

REVIEW OF DISCUSSIONS

Monday 19 April
Subject: Geographic Information Systems GIS
Participants: Sherry Borener (Volpe), Els Reinierse (TRC), Sten Bexelius (TRC) and Joop Kraay (TRC).

Tuesday 20 April
Subject: Exposure and Risk
Participants: Sherry Borener (Volpe), Judy Donk (DGP-VV), Aad Hage (DGP-VV), Matthijs Koornstra (SWOV), Ipe Veling (Traffic Test), Peter Lourens (COV University of Groningen), Ab van Poortvliet (TRC), Sten Bexelius (TRC) and Joop Kraay (TRC).

Wednesday 21 April
Subject: Geographic Information Systems GIS
Participants: Sherry Borener (Volpe), Angelique van den Broek (TRC), Sten Bexelius (TRC) and Joop Kraay (TRC).

Subject: Data-mining
Participants: Sherry Borener (Volpe) and Sten Bexelius (TRC).

Subject: Intelligent Speed Adaptation ISA Tilburg and Intelligent Cruise Control ICC
Participants: Sherry Borener (Volpe) and Angelien van Boxtel (TRC).

Ministry of Transport, Public Works and Water Management

Directorate-General for Public Works and Water Management

Transport Research Centre (AVV)

U.S. Department of Transportation

Research and Special Programs Administration

John A. Volpe
National Transportation
Systems Center

Kendall Square
Cambridge, Massachusetts 02142

January 16, 1998

Letter of Intent

The Dutch Ministry of Transport, Public Works and Water Management (the ministry)/ Transport Research Center (TRC) and the U.S. Department of Transportation (the department), Research and Special Programs Administration, Volpe National Transportation Systems Center (Volpe), desire to establish a mutually advantageous relationship in transportation research. TRC and Volpe will be referred to in this letter as "agencies."

TRC and Volpe hereby state their mutual intention to exchange information and experience in the areas of interest set out in the annex to this letter. These cooperative efforts are based on the memorandum of understanding, entitled "Cooperation in Transportation," between the ministry and the department, which envisaged "a program to achieve mutually advantageous cooperation in transportation research and development." The aim of the program is "to promote cooperation between the transportation specialists of the parties in finding solutions to problems of mutual concern, and to improve transportation systems and techniques without the costly and wasteful duplication of parallel national efforts."

The costs for each agency's labor, travel, and other costs in support of information-sharing as agreed upon in the annex will be born by the respective agency. Funding for future projects that may arise out of this agreement will be accomplished by separate funding agreement(s) to be negotiated between the agencies.

Personnel performing services agreed upon in the annex shall retain their status as employees of their respective governments. The supervision and administration of the personnel shall be in accordance with the policies and procedures of the agencies by which they are employed.

In principle information shared will be public information. To the extent permitted by law, the ministry and the department each agrees to honor disclosure restrictions as requested by the other.

The point of contact for TRC will be Max Klok (Ministry of Transport, Public Works and Water Management, Transport Research Center, P.O. Box 1031, Boompjes 200, 3000 BA Rotterdam 31102825756 telephone and 31102825642 fax), and for Volpe Center, William Lyons (U.S. Department of Transportation, Volpe Center, DTS-49, Kendall Square, Cambridge, MA 02142 (617) 494-2579 telephone and 494-3260 fax).

This letter of intent shall continue in effect for a period of two years and may be extended by letter signed by representatives of both agencies.

Houko Luikens
Director
Ministry of Transport,
Public Works and Water Management
Research Center

Systems Center

Date 16-01-1998

Richard R John

Richard R. John
Director
U.S. Department of Transportation,
Research and Special Programs Transport
Administration,
Volpe National Transportation

Date 1/16/98

Enclosure: Annex A

Annex A

Summary of Areas for Cooperation Between the Transport Research Centre and Volpe Center

The following areas for cooperation were identified by TRC and the Volpe Center during meetings at the Volpe Center, April 15-16, 1997, and expanded on in later communications.

1. Exchange information on inland transportation – routine (major trends and problems) and specific (identified topics). TRC will provide "eyes and ears" regarding research results in the Netherlands and Europe for Volpe, and Volpe in the U.S. for TRC. Project staff with shared interests will develop formal and informal contacts, and exchange documents and other information.

   1.1 Project: Sustainability. TRC will prepare a white paper to scan current thinking in Europe on sustainability, including use of national performance measures, social equity, and approaches to global warming. Volpe will invite TRC to participate in a workshop of experts on sustainability.

   Actions: Volpe will specify what is needed, and work with TRC on an action plan. Volpe may provide funding for labor or travel.

   Project Leaders: TRC – Paul Polak; Volpe – Kevin Green and William Lyons.

2. Technical support to specific ongoing projects

   2.1 Project: Performance measures for the Dutch National Transport Structure Plan. Continue work underway by Volpe for TRC, including insights from U.S. experience with the Intermodal Surface Transportation Efficiency Act (ISTEA) and Clean Air Act Amendments.

   Actions: TRC will provide specifics after reviewing the Volpe summary report.

   Project Leaders: TRC – Jan van der Waard; Volpe – William Lyons.

   2.2 Project: Innovative methods of policy analysis. Volpe is interested in TRC's research and applications of balanced economic, environmental, and safety measures to evaluate transportation strategies. Volpe has work underway in developing new approaches to project evaluation and funding decisions that link performance measures to cost-effectiveness analysis.

   Actions: TRC has provided Volpe with the study it completed on freight with RAND and will send related future reports as they are completed. TRC will discuss with Volpe how similar methods might be applied to other transportation problems, for example, traffic management.

Project Leaders: TRC -- Paul van der Gaag, Max Klok; Volpe -- Michael Wolfe and John O'Donnell.

2.3 Project: Human centered transportation systems and safety. Volpe is working to develop a national research program, including assessments of operator and vehicle interaction and fleet management, and the effects of information technology.

Actions: TRC will review Volpe materials to identify shared interests. In the future, TRC and Volpe might organize a workshop.

Project Leaders: TRC -- ~~Herman Moning~~ and Joop Kraaij; Volpe -- Donald Sussman and Mary Stearns.

2.4 Project: Ports and advanced logistics systems. Volpe and TRC share an interest in institutional, economic, and policy strategies to improve the performance of ports and logistics processes. The essence is a balanced approach that incorporates institutional factors as well as new technology and hardware.

Actions: TRC will provide the results of a study on ports and intermodal transport systems when it is completed. The agencies will exchange ideas and experiences, identify mutual interests and possible joint new projects, and possibly organize a joint workshop.

Project Leaders: TRC -- Gido van der Linde; Volpe -- Michael Wolfe and Bahar Barami.

2.5 Monitoring collective passenger transport. For policy development and evaluation of collective passenger transport, it is necessary to measure and understand current and future mobility. A project has been formulated in the Netherlands to inventory information requirements; identify information gaps; and design a monitoring system for policy support.

Actions: TRC and Volpe will exchange information on related efforts and potential areas for collaboration.

Project Leaders: TRC -- Francis Cheung; Volpe -- William Lyons.

2.6 Project: Advise on organization and finance. Both TRC and Volpe are interested in ideas on how to organize and finance their functions, and in an exchange of experiences with different approaches.

Actions: Exchange insights whenever possible, including during visits. Richard John, the Volpe Center Director, will discuss experiences with organizational structure and direct project financing with the TRC management team.

Project Leaders: TRC -- Houko Luikens and ~~Jaap Verkade~~; Volpe -- Richard John.

3. New initiatives and joint ventures. Cooperation will begin with areas 1 and 2. In the future, TRC and Volpe may identify new initiatives, possibly beginning with items 2.3 or 2.4, or other projects.

4. Administrative. Max Klok of TRC and William Lyons of the Volpe Center will serve as coordinators for developing and implementing this agreement. A steering group of representatives from TRC and Volpe will meet annually to discuss progress of mutual projects and define new areas of interest.

CONCEPT
16-02-'99

AGREEMENT BETWEEN VOLPE AND TRC
WORKING PROGRAM 1999

A less more than one year ago, January 16 1998, the Dutch Ministry of Transport, Public Works and Water Management/Transport Research Center (TRC) and the U.S Department of Transportation research and Special Programs Administration, Volpe National Transportation Systems Center (Volpe) signed a letter of intent to exchange information and experience in some areas of interest. In an annex this areas are expanded in six projects. Besides the projects the agreement makes it possible to identify new initiatives.

Evaluating what information and experience has been shared in 1998 and inventorying new initiatives new priorities can be set.

Evaluation of the project named in the annex of the letter of intend.

Project: Sustainability.
Project leaders
TRC: Paul Polak; Volpe: Kevin Green and William Lyons

Besides of initial e-mails there has been no action in 1998.
For the year 1999 the initiative to form a TRB task force/subcommittee can be an incentive for exchange of information and experience.

Project: Performance measures for the Dutch National Transport Structure Plan.
Project leaders
TRC: Jan van der Waard; Volpe: William Lyons
1998 Volpe finished a paper that TRC has used in the work for the NVVP/SVV3-process.
The TEA-21 process and the NVVP/SVV3-process are similar ones. In both processes studies and research has to be done to give an answer to questions that are raised during the implementation of strategic and operational ideas. This questions can be the core for the activities of the agreement in 1999.

Project: Innovative methods of policy analysis.
Project leaders
TRC: Paul van der Gaag and Max klok; Volpe: Michael Wolfe and John O'Donnell
!998 there have been no activities. As Paul van der Gaag is not working with AVV anymore this project will not have high priority in 1999 as far as it concerns TRC.

Project: Human centered transportation systems and safety.
Project leaders
TRC: Joop Kraaij; Volpe: Donald Sussman and Mary Stearns
This project has been the most substantial of the tasks on the agreement so far. Lies Duynstee of TRC stayed even some time at the Volpe Institute in Boston.
In 1999 this project will go on with a highlight in the week of April 18 to 22. In that week TRC-Volpe workshops on exposure and risk, on training techniques and on youngsters will be held in Rotterdam.

Project: Ports and advanced logistic systems.
Project leaders
TRC: Gido van der Linde; Volpe: Michael Wolfe and Bahar Barami
1998 the study 'Harbournetworks in the U.S.' has been finished with a report in the Dutch language.
There were no further actions.
For the year 1999 this project has no high priority.

From: J. Donk Mast. Mathematics
Date: 15 March, 1999
Subject: Summary Workshop Exposure & Risk

Risk policy traffic safety

To improve the safety of all kinds of risks a general safety report is written in which a global frame is described to compare all kinds of risks in transport, but also to compare risks of flood.
For traffic safety on roads two kinds of risks can be described:

- Small chance and large consequences : like a bus accident, or accidents in tunnels with fire with large numbers of people killed at once.
- Large-chance and small consequences: frequent traffic accidents with one or two people killed or wounded

For the first kind of risk a separate policy will be described, more in terms what is socially accepted. For the second kind of risk we use a goal formulation in absolute numbers as is also the national policy of traffic safety.

So to improve the traffic safety (the second kind of risk) we monitor the accident numbers of fatally injured and seriously injured persons. The purpose is to reduce the number of killed and wounded people with 50% respectively 40% in 2010 compared with 1986. This goal formulation still is a good approach, but will not be enough to reach these goals. Till recently it worked well, because in 1970 there where about 3000 fatalities a year in the Netherlands. Several measures were taken like: obligation to use safety belts, speed limits, priority round about etc. This set of measures lead to a reduction of the number of deaths to an average of 1200 a year, but the number of wounded did not reduce as was expected.

It's getting more and more difficult to find the cause of the accidents, because of the "thinning effect". This year the accident occurs at place A and the next year at place B. Besides that the national goal gives not enough direction for the road owners, like Provincial (Netherlands is divided into 12 parts with historical roots: the provincies), municipal and Regional authorities. They formulate their own goals in terms of reachable and payable. With the current goal it is difficult to taken into account regional differences or mobility developments.
It is also difficult to predict where, who and which measures should be taken with lowest costs as possible. The purpose of the risk policy is to give an answer to the described problems and to give a new impulse on the traffic safety policy.

At this moment we are thinking of the next way to fill in the risk policy:

- decentralized goals
- risk standard per road type (or per road owner)
- risk standard per group of people

The starting-point is the national goal for traffic safety.

A decentral goal per Province must be determined with an optimal use of means and money. The risk standard per road type gives for road owner an extra test instrument to determine if their road is safe enough or not. The last concept gives the Dutch government an instrument to decide whether or not a certain group of people needs more or less protection.

To work this out all kinds of basic numbers, calculating instrument, risk parameters and standards and weighting, instruments are necessary.

The groups of people who need these instruments, risk standards etc. are the road owners. To implement this at least a period of 5 years will be needed. This policy intention is needed to give a new impulse and guarantee the traffic safety for the future.

Risk Policy Traffic Safety

Exposure & Risk, 20 April 1999
Judi Donk, Mast. Math.
Ministry of Transport, Public Works and Watermanagement
Directorate-General for Passenger Transport
Traffic Safety and Vehicle Directorate

Content

1. Introduction

- History of Risk policy in the Netherlands/Ministry
- A general risk approach for: *road, rail, undergrounds,* waterways, flood, airtraffic

1. Introduction

Why thinking of new impulses for traffic safety
☐ National Traffic and Transport Plan (NVVP)
  - 4 corner stones
☐ Goal 2000
☐ Realisation Sustainable Safety
☐ Framework report Vehicle policy
☐ Framework report Railsafety

2. Safety policy

Goals

- Road traffic safety: 50% and 40 % less deaths and wounded in 2010 compared with 1986.
- Rail traffic safety: different safety levels for railtravellers, railworkers in risk terms

3. Risk policy

Problems with current safety policy

- more difficult to find cause (thinning effect)
- regional differences/ mobility developments
- prediction of "where, who, which" measures
- direction problem for road/rail/underground owners
- internal safety/external safety

3. Risk policy

Road safety

- central goal
- decentralized goals per region
- risk standards per road type
- risk standards per group of people (for example children)

4. Risk model

- Calculate risks for people, environment and nature and materials and compare them with standards
- Define risk reducing measures
- Define cost and effects of measures
- Evaluate the measures on a cost-benefit analysis- use the 1 milion ECU test

5 Final remarks

- Development of risk policy interactive way. Discussion with all the different road owners, safety groups
- Long period of time (5 years) needed to implement
- Discussion strongly related to financing

THE QUANTIFYING OF ROAD SAFETY DEVELOPMENTS

Matthijs J. Koornstra
SWOV Institute for Road Safety Research
P.O. Box 170, 2260 AD Leidschendam, The Netherlands

Abstract. The evaluation of the effectiveness of road safety policies and measures must be based on quantitative information on road safety developments and the relevant variables that influence that development. However, the quantifying of road safety is quite troublesome. Firstly, the concept of road safety itself is quantitatively not well defined. It concerns a multitude of related observable variables. Therefore, it is necessary that the relations between primary safety variables themselves, such as fatalities, serious and slight injuries and damage-only accidents, as well as their relation to exposure related variables (relevant for risk measurements), such as kilometrage, number of motor vehicles or optimally the frequency of encounters or conflict possibilities, are investigated in order to clarify the concept and its quantification. Secondly, road safety related variables are intrinsically unreliable due to random errors which may hide the true developments. The seldom used possibilities for error minimization in the quantification of road safety are discussed as part of the quantified concept. Thirdly, the relevant variables are incompletely recorded due to selective and varying underreporting which distorts and underestimates the real developments. Lastly the implications of these matters for a targeted road safety policy, its monitoring and evaluation are highlighted.

1. The concepts: 'road safety', 'risk' and 'exposure'

Lack of safety is an adverse aspect of our road traffic system. Because of the negative utility of accidents which sometimes are accompanied with losses of life, individuals and national policies try to avoid or reduce the adverse outcomes of traffic movements. In democracies the collective authorities with safety related responsibilities have to develop policies for the enhancement of road safety and have to implement measures for the prevention of road accidents. The prevention and cost effectiveness of the foreseen or implemented measures ask for a reliable measurement of the road safety developments, knowledge of measures with quantified effect predictions and evaluative studies with a statistical treatment of quantitative measurements of changed levels of road safety.

Frequencies of annual numbers of damage-only, injury and fatal accidents are relevant quantifications and relatively easy to define and to measure, but differences in definitions and incomplete reporting of somehow defined accidents are problems for a valid measurement of road safety. Moreover, even without definition and reporting problems, the quantification of the general road safety level that underlies the occurrences of accidents is not quite so simple. First of all, accidents as relatively rare adverse-outcomes of events in traffic and, therefore, accident frequencies are influenced by the partially random processes in traffic. Secondly the concept of road safety and the development of road safety generally is conceived to represent all different accident frequencies jointly and to describe their developments as a common development, but the relations between the different countable outcomes of conflicting events in traffic and the nature of their common content is not clear, while the basic research for its clarification seems lacking. Thirdly, as adverse outcomes of traffic events the level of the accident frequencies also certainly depends on the volume of the relevant traffic events that can produce the adverse outcomes or depends on what generally is called the level of exposure or exposure to risk. However, also the meanings of exposure and risk are not always unambiguous. The concepts of safety, risk and exposure can be independently defined, but often some tautological or circular reasoning is involved. Their quantifications generally are dependent on each other, as for example in: fatality risk = number of death/kilometrage and level of safety=fatality risk x kilometrage.

Following Hauer (1982) one may define

SAFETY = RISK X EXPOSURE

in such a way that the reasoning is not totally circular. The lucid description of Hauer, who in turn cites Hacking (1965), reads as:

> "The terms risk and exposure can be interpreted in close correspondence to concepts used in the philosophy of chance. Chance (probability) is considered (by one school of thought) to be a real property of some specific system. Thus, "the frequency in the long run of heads from a coin tossing device seems to be a property of the coin and device; the frequency in the long run of accidents on a stretch of highway seems to be the property of, in part, the road and those who drive on it" (Hacking, 1965). The name chosen for the 'system' the 'chance property' of which is examined, is a "chance set-up'. "A chance set-up is a device or part of the world on which might be conducted one or more trials, experiments or observations; each trial must have a unique result..."(Hacking, 1965).
> In the light of this terminology, the following correspondence suggest itself:
> A **unit of exposure** corresponds to a **trial**. The **result** of such a trial is the occurrence or non-occurrence of **an accident** (by type, severity, etc.). The **chance set-up** is the **transportation system** (physical facilities, users, and environment) which is being examined, and **risk** is the **probability** (chance) of accident occurrences in a trial, which thus describes the **safety property** of the transportation system examined"-

In this analysis the risks are defined as probability measures. Such a definition of risk in traffic seems now to be common in road safety research. It is, however, different from the definition of risk in utility theory, where the product of expectancy (probability) and the values (amount of loss) of accidents is taken into account. In order to avoid additional complication, reluctantly for the moment the risk definition as a probability is adhered, but in the explanation of risk behaviour of individual road users one has to introduce elements of utility theory for the understanding of individual risk acceptance as a somehow specified combination of expected probabilities and values for several accident outcomes.

Given the occurrence of a relevant traffic events (as 'trials') in a particular traffic condition, there is a probability for a particular category of adverse outcomes that partially occur and partially not. The probability definition depends on the set of 'trials' as the reference events independent of the defined outcome. There are several severity categories of adverse outcomes to distinguish, whereby the context of the concept of road safety becomes multidimensional. The frequencies of the severity categories determine for a given common set of reference events a distribution of probabilities for the different severity outcomes. One may order the categories of the possible adverse outcomes according to the severity of the outcome. In order to have some comparable risk (as a probability measure) for the ordered severity categories one needs to define the risk with respect to a single common set of reference events, where the volume of this set then is the union of all relevant events in traffic (as frequency of 'trials' in the traffic system as 'chance set up'). Otherwise the risks are conditional probabilities with respect to the chosen sets of reference events. It seems logically sound to define ordered conditional risks in such a way that products of these conditional risks correspond to the risks with respect to the union of the sets of relevant traffic events. This is illustrated by the next tabulation of conditional probabilities.

P1 | c2 = conditional fatality risk	**= fatal accid./(fat. + severe injury accid.)**
P2 | c3 = cond. fat. + sev. inj. risk	**= (fat. + sev. inj. accid.)/(fat.+ inj. accid.)**
P3 | c4 = cond. fat. + injury risk	**= (fat.+ inj. accid.)/accidents**
P4 | c5 = conditional accident risk	**= accidents/conflicts**
P5 | c6 = conditional conflict risk	**= conflicts/encounters**
P6 = encounter prob.	**= encounters/kilometres**

Table 1. Consecutive conditional risk probabilities.

Here the definition of the reference set of events ('trials') is such that each next set includes ~~to~~ the preceding set and, therefore, the products of these consecutive conditional risks are risks over the last larger set of reference events. One could take the volume of the events with injuries as a measure of exposure for fatal outcomes or the volume of the set of all accidents as the exposure measure for injury and fatal accident outcomes. However, one rather defines an exposure measure that on its own is not characterized as a set of adverse outcomes of traffic events. The volume of the set of all reference events that are relevant for safety related risks then would define the exposure measure, but it is still not a precisely defined set that can be measured. An estimate of the frequencies of encounters in traffic could serve that purpose. Conflicts as a somehow defined "near misses" then also can become a class of adverse outcomes with a certain probability. It seems appropriate not to define exposure by a set that is smaller than the set of encounters, since the occurrences of conflicts as 'near misses' also contributes to what one means by the concept of road safety. The set of encounters as the safety relevant "chance set up" of the traffic system seems also more appropriate then the larger set of all traffic movements, measured by kilometrage, since only the fraction of the traffic movements that are not seperated in time and place are events that can have any adverse outcome. The frequency of encounters is partially dependent on the physical facilities of the road system. For example the same amount of vehicle kilometres driven on a motorfreeway or driven on a rural road with level crossings and on-coming traffic will specify a different amount of possible encounters. Changes in the infrastructure may change the exposure as well as the risk, and sometimes in opposite ways. Great care in safety research must be taken to measure both indices of risk and exposure in order to evaluate safety measures.

It is not necessary to have an observable measure of encounters, because some other observable measure that has a fixed proportional relation to encounters, only changes P6 (see table 1 above) and a change to such a measure as well as changing the proportion serve equivalent purposes. For example, if traffic movements are independent and occur in a constant infrastructure the number of encounters between motorvehicles will be a fixed fraction of the squared kilometres driven in a defined area and time period. In case things change over time it is argued in the models for analysis of long term risk development (Oppe & Koornstra, 1990; Koornstra, 1992) that the growth of exposure is proportional to a reducing power transformation of the squared annual vehicle kilometres. One argument is based on the fact that changes in infrastructure are called for by a growing traffic volume and generally are of an encounter reducing nature too. An other argument is that growth of traffic generally increases the dependence of movements in traffic, which in turn reduces the frequency of encounters (as encounters between multiples of road users, instead of multiple encounters for pairs of the road users). A function of annual kilometres that approximates a proportional measure of the actual encounters, therefore, has to increase less than the squared annual kilometres. A suitable function is a power transformation with a power less than two. Moreover, exposure to single accidents will vary as a fraction of the untransformed kilometres. Also the majority of road accidents that involve pedestrians or cyclists are due to conflicting encounters with motorized traffic and thus their exposure mainly also varies as a function of the untransformed kilomatrage of motorvehicles. In several studies of the TRL the number of relevant encounters on crossings approximated a fixed proportion of the product of the square roots of traffic volumes on the crossing roads, which defines the crossing encounters also to be approximated by a fixed proportion of the kilometres in the area. A fraction of the kilometrage, therefore, might very well serve as a measure of exposure, instead of the unknown frequency of encounters. It implies that a constant fraction of annual kilometrage is a measure of the annually changing frequency of all pairs of traffic movements that are not separated in time and place, which defines the frequency of encounters between road users, as well as a measure of the frequency of encounters between road users and objects.

Although encounter frequencies or kilometrage as such are not indicators for what generally is understood by the concept of road safety, ~~it~~ they are not irrelevant factors for the level of safety. For example, if the most dominant aspect of road safety is the occurrence of injuries and fatalities then, with reference to table 1,

$$\text{Fatal + Injury Accidents} = P_3|_{c4} \;.\; P_4|_{c5} \;.\; P_5|_{c6} \;.\; P_6 \;.\; \text{Kilometrage}$$

the reduction of P_6 = encounter probability, even relative to a growing kilometrage, can contribute much to the enhancement of road safety. In fact the enlargement of the network of motorfreeways is one of the means to reduce encounters (no on-coming and crossing encounters as on the rural roads used partially before the enlargement) and has enabled traffic growth and more road safety in the past as well as recently, for example in Spain.

To define safety as a concept with different meanings for each outcome category, such as lack of safety for fatal accidents, lack of safety for injuries etc..is not what is understood by the concept of road safety. Although it makes sense to distinguish between objective or statistical recorded and subjective safety as a collective social awareness of the lack of road safety, generally road safety is thought to be a common characteristic that underlies the different frequency categories of adverse traffic outcomes in a particular area and certain period. Since a fixed proportion of the kilometrage in a defined period and area tends to correspond to the encounter frequency, one could define a quantitative concept of road safety as an underlying characteristic by the multiplication of kilometrage and a combination of the risks for the adverse outcome categories as:

$$SAFETY = F\{R_1, R_2, \ldots, R_5\}.kilometres$$

where function F has still to be defined and where the risks R_i are defined as below.

$R_1 = P_1 | c_2.P_2 | c_3.P_3 | c_4.P_4 | c_5.P_5 | c_6.P_6 =$ fatal accid./kilometres
$R_2 = P_2 | c_3.P_3 | c_4.P_4 | c_5.P_5 | c_6.P_6 - R_1 =$ sev. inj. accid./kilometres
$R_3 = P_3 | c_4.P_4 | c_5.P_5 | c_6.P_6 - R_2 - R_1 =$ slight injury accid./kilometres
$P_4 = P_4 | c_5.P_5 | c_6.P_6 - R_3 - R_2 - R_1 =$ damage-only accidents/kilometres
$R_5 = P_5 | c_6.P_6 - R_4 - R_3 - R_2 - R_1 =$ conflicts/kilometres

---

Table 2. Independent risks probabilities.

Here, in contrast to table 1 the risks are defined in such a way that the cumulative classes become exclusive and independent, in order to avoid dependent error variations for the terms of function F. One way to define function F can be based on the utility risk definition or expected losses, where each risk probability then is multiplied by a mean economic loss value per outcome for the severity categories and summed up to the mean expected economic loss. It defines the road safety costs, but it is not a quantification of the road safety concept itself. Following the original line of reasoning for risks as probabilities, one has to define safety by a function F as some combination of the separate risks for an overall risk that corresponds to safety as the underlying characteristic of the traffic system in a defined period and area. The way to combine risks can be based on the predictability of risks by each other, which is determined the correlations between the frequencies of the independently measured categories. In the sequel this will be further investigated after models for structural relations between the relevant variables (the frequencies for the different severity categories and exposure measures as well as kilometrage) are discussed.

If one distinguishes between objective collective risks, as probabilities of recorded accidents with different severity outcomes, and subjective collective risk as the socially experienced dangers of traffic, one could define **subjective collective risk and safety** as identical to $P_5 | c_6.P_6$, as subjective collective risk, or $P_5 | c_6.P_6$.kilometres, as the frequency of somehow defined conflicts that may, but most times do not, evolve into accidents or injuries or even more seldom into fatalities. If we define conflicts as conflicting encounters that without further actions would lead within a certain short time interval to a collision, the majority (R_5 x kilometres) are the threatening near misses as dangers not accounted for in the road statistics, as it is assumed to be for a concept of subjective collective risk. Despite the existing controversial opinions on objective and subjective safety, threatening non-accident conflicts or near misses as well as damage-only accidents, slight injuries and surely foremost severe injuries and fatalities are all adverse outcomes that all are somehow related to what one would mean by the concept of road safety.

2. The quantification of the concept 'road safety'

Up to now we have not considered the difference between observed frequencies as well as the correspondingly calculated observed risks, which are effected by randomness of the outcomes of the traffic system, and the underlying 'true expected frequencies' as well as the 'true expected risks' as the 'real chance properties' which constitute the underlying safety characteristic of the traffic system. Safety of the traffic system is not defined by the error contaminated observable variables, but by the 'true' expected values for several safety related outcomes of traffic events. A certain well defined combination of such expected values constitute the desired characteristic property that defines the safety of the traffic system. This characteristic property still must be estimated from observed outcome variables, but ought to minimize the random error fluctuations in the observed variables with an underlying structure of error and reliable parts, which latter parts are called variates or latent true components. These variates are to be distinguished from the countable observed event frequencies and risks. Appropriate examples of variates are the expected frequencies in the categories for the different severity of outcomes, such as expected fatalities or injury accidents per year in an area. The actual observed numbers are treated as realizations of the 'true' expected values. Observed outcome frequencies are observed variables which generally differ from the expected or 'true' frequencies, just as limited results from some dice differ from its expected outcome frequencies. Random error in observed variables, due to stochastic properties of the system, may hide real variate changes. The estimation of 'true' safety level or underlying safety as a latent variate from observed variables is crucial for a valid quantifying of the safety concept.

The given, still not fully specified, definition of underlying safety is a multidimensional based definition as the product of kilometrage and function F for multidimensional risks. In order to specify a rationally defined function over the different risks of the severity categories, one needs to know what the intrinsic relations between the different severity categories or risks are. Up to now only a few studies and hardly any basic research has been directed to the interrelations between the relevant variables and variates or its risks. Generally, observed fatal accidents or road fatalities are taken as representive for the safety level. The debilitating problem, however, is that fatal accidents occur relatively rare and are most irregularly spaced events in time and place. Therefore, frequencies of fatal accidents as an observed outcome category of the events of the traffic 'chance set up' are highly unreliable. The frequencies of the fatal outcomes relatively to other adverse outcomes will have the largest fluctuations around the expected 'true' values. In order to overcome this difficulty one has to enlarge the area or the observation period under equal conditions, which is seldom possible and often not acceptable for the evaluation of the effect of safety measures. Whether the other variables, like frequencies of severe or slight casualties, frequencies of accidents or even observed near misses or conflicts rather than accidents, are taken as proportional to the fatal frequencies or just as variables with their own meaning have been a topic of debate (Biecheler et al. 1985 p. 316-404). Seldom explicit considerations are stated in research reports and if stated explicitly they do contradict between researchers; for example conflicts as proportional to accidents (Glauz & Bauer, 1985) and conflicts as different from accidents and exposure (Hauer, 1982). An explicit formulation of the underlying structure of latent variate and error components for the relevant variables may clarify the matters of the debate.

Three different models for road safety with intrinsic different relations between the safety related variables as realizations of one or more common latent or generic underlying factors are proposed by Koornstra (1991). All three models define the variance of observed variables to consist of a 'true' part, related to the variances of common latent variates, and parts related to variable-specific or error variances. It defines the 'true' structure of road safety and exposure as well as a non safety related part of random error variance. Specific variates are defined as reliable parts of variables, which are mutually uncorrelated. Errors in observed frequencies are also assumed to be uncorrelated, unless they are not independently measured. For instance accident frequency includes the frequency of injury accidents, whereby the errors in each frequency then must be correlated, but damage-only and injury accidents have uncorrelated error terms. On statistical grounds, frequencies (with a meaning full zero scale point, instead of interval scales with arbitrary zero scale points) are assumed to have error distributions that are proportional to its expected frequencies (Poisson or (negative) exponential distributions).

The first model assumes that all observed frequency variables for different severity classes, are imperfect realizations of a single underlying common variate for road safety and a variable-specific and error component. This **single common factor model** for road safety resembles the common factor of intellectual ability of Spearman (Harman, 1970). In this factor model error and specific variance are confounded. This model is geometrically pictured in Figure 1 for three variables as vectors, where the confounded specific and error variances correspond to length of the (improperly correlated) vector projections on the base-plane. The lengths of the vertical projections correspond to the common factor variance in the variables.

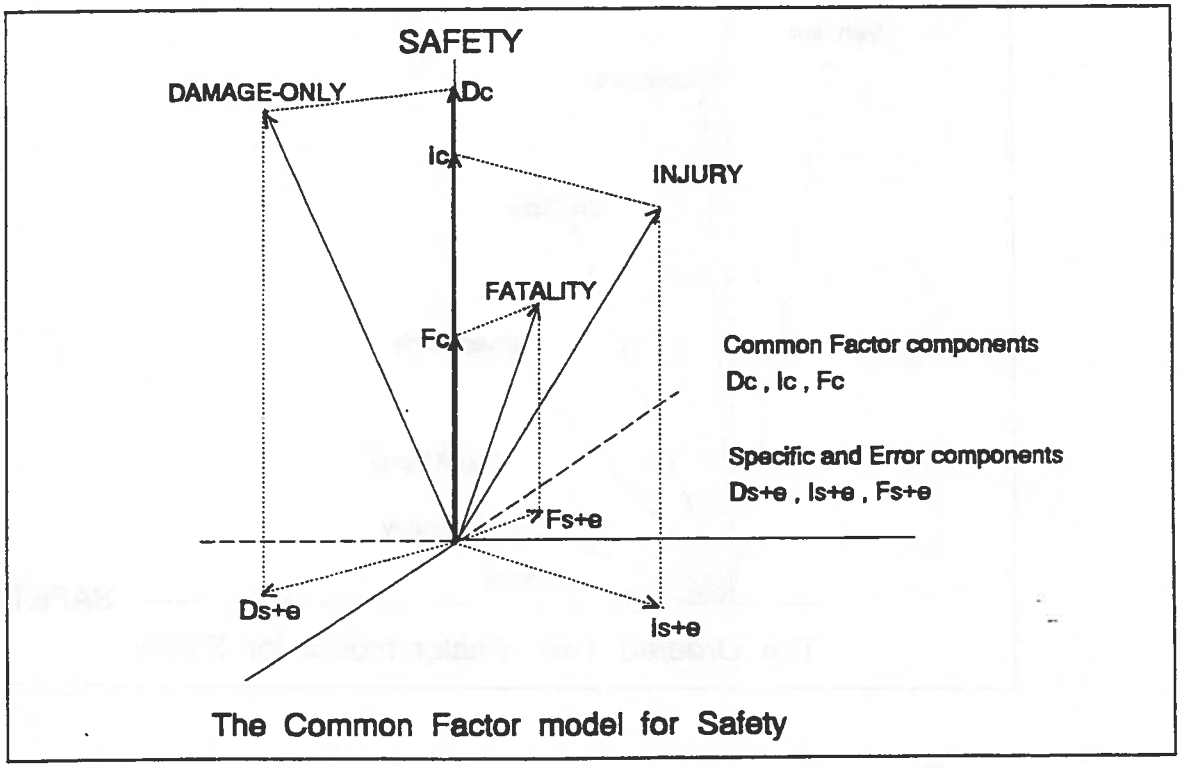


Figure 1. The single common factor model of road safety

In the single common factor model the severity rankorder of variables is not taken into account, while possible specific variable terms are confounded with the error terms in a non-repeated measurement design of variables. However, from the assumed rankorder of error variance proportions and the empirical rankorder of vector projections on the common factor the rankorder of specific variances may be deduced. The *expected values of all observed severity classes are thought to be proportional realizations of one common safety variate* as 'true' expected safety values for the observed variables.

Multiple factor models arise if it is hypothesized that adjacent variables in the severity rankorder of variables have more 'true' common variance than remote variables in that rankorder. This can be conceived in two different ways. In the second proposed model this is the result of an ordered mixture of two latent or underlying generic factors, which apart from random errors determine the observed variables as realizations without variable specific components. The generic factors are most closely related to the variables at each extremes of the ordering. One factor closely relates to the expected fatal accident frequencies and determines the outcome frequencies for so far as caused by the destructive energy that is absorbed in conflicting events in the traffic system. Going from fatal accidents to the other extreme of the severity ordering, kilometres or encounter frequency are most closely related to the second generic factor representing the outcome frequencies for so far as caused by the intended energy use for the purpose of transportation. The severity rankorder of the variables determines the rankorder of angles of variables with the generic safety factor. This **ordered two-factor model** for safety is shown in figure 2.

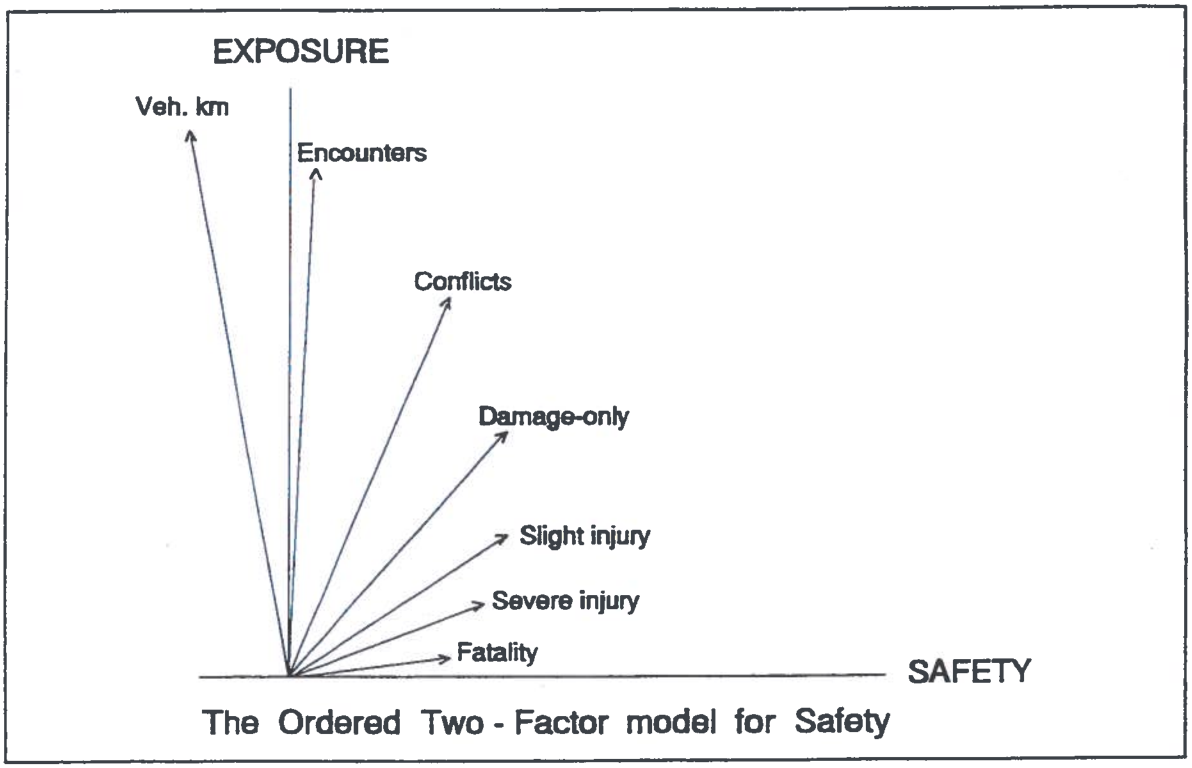


Figure 2. The ordered two-factor model of road safety and transport

The lengths of vector projections on two positive orthant dimensions correspond to the 'true' variance proportions that the variables share with the underlying factors. The error parts are not shown in figure 2, but are vector projections perpendicular to the plane of the generic factors which for clarity of presentation are not fully rotated to its positive orthant. In this model no additional specific and reliable variance proportions of the variables are assumed to exist. Although such can also be hypothesized to a lesser extent their non-existence, in contrast to the first model, becomes verified if the reversed rankorder of the added projections on the generic factors corresponds with the assumed rankorder of error variances for variables with lower frequencies. Apart from random error, every variable in the safety domain is a weighted combination of these two generic factors: frequency of transport events and frequency of destructive events, where the latter interpretation follows from the reasoning that the unintended kinetic energy absorption is less for resolved conflicts then for damage accidents and increases with increasing severity of accidents. *Each variable, in principle, is a realization of both underlying factors, but the proportion of variance shared with the safety variate increases with the severity rankorder of the variables on the one hand, while the variance proportion shared with the transport variate increases in the reversed rankorder.*

The third proposed model formulates the hypothesis of larger shares of common variances between adjacent variables in the severity rankorder in a different way. This third model assumes that the relevant variables can be ordered along a hierarchy of multiple latent variates, which correspond to several causal factors in the accident process. For example an injury accident between cars presupposes the causation of vehicle damage that has causal factors in common with the causation of injuries such as high speed and skidding, but also additional causes for injuries due to lack of protection devices such as wearing belts, airbags or constructive intrusion protection. In turn the occurrence of damage presupposes the causation of a traffic conflict by behavioural and infrastructural factors, which causal factors only partly are common in the causation of the material damage.

In the context of social and mental processes, Guttman (1954) analyzed these kinds of structural relations and named them an additive simplex, circumplex and radex. These metric structures have by definition as many factors as the number of independent generative factors in the process. Without knowledge of the generative process, no constraints on the structure and dimensionality are at forehand clear. Guttman (1966), however, also showed that, by multidimensional order analysis of correlation matrices for such structures, a compression into two-dimensional circumplex configurations is possible for a metric more dimensional radex structure and that a uni-dimensional order representation is possible for the additive simplex. If the frequencies of severity categories are the variables, then each consecutive variable in the ordering is assumed to share the generative factors of the prevailing variables and may add a possible new generative factor. This would yield the so-called additive simplex structure in a metric analysis. This third model as such a metric analysis model will be referred as the **additive multi-factor model** of road safety. Again no specific parts are present, since a specific part is a generic factor itself and the independently measured variables are assumed to have uncorrelated errors with error-variance proportions of magnitudes, which have an order of magnitude reversed to the magnitude of their frequency measurements. In this model the error variance components and the generic factors partially are confounded. Figure 3 gives a geometric picture of the additive multi-factor model for three safety variables only.

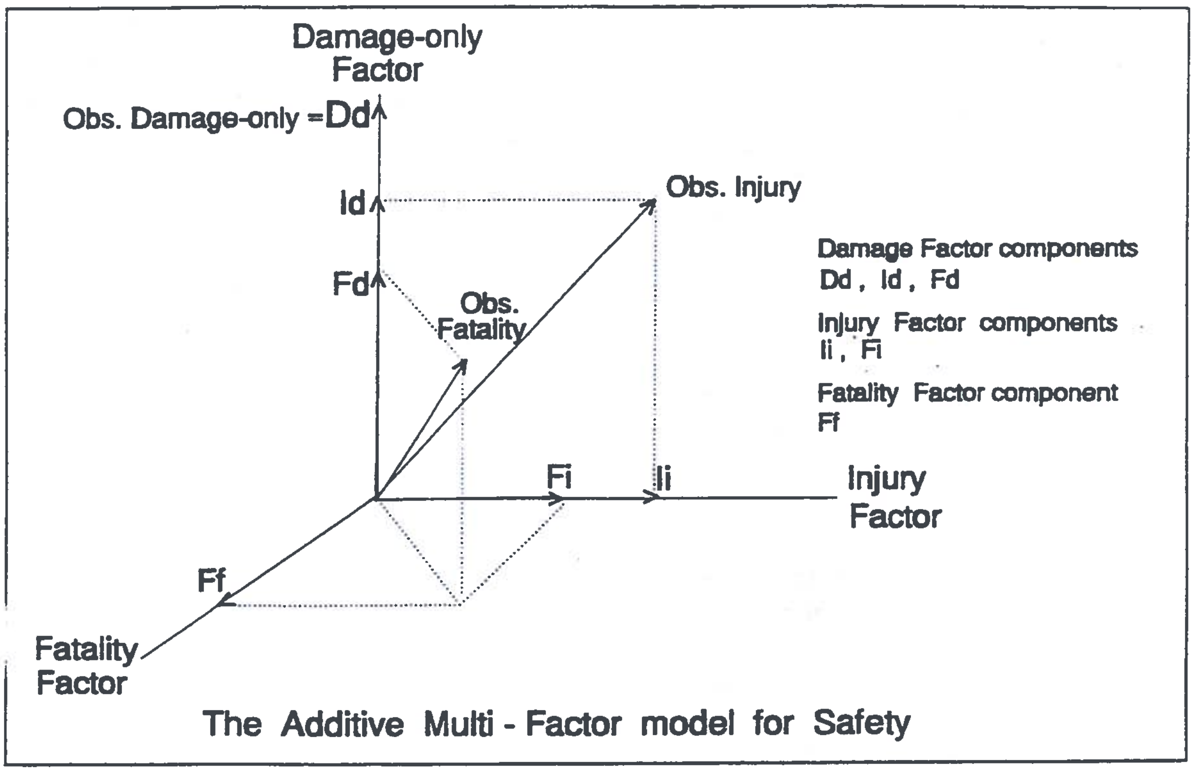


Figure 3. The additive multi-factor model for road safety

In the additive multi-factor model *each variable for a more severe outcome category is a realization of the underlying factors for the less severe outcome variables plus an additional factor, but the proportion of variance shared with the factors related to the less severe outcome variables decreases with the severity rankorder of the variables due to the increasing error variance proportion for the lower frequencies of more severe outcome variables* There is no single safety variate, but a cumulative stratification of safety related variates, which constitute a multi-facet concept of road safety. The additive multi-factor model has the problem that more parameters must be estimated the more unreliable the variable is and that the parameters are solved from a non-overdetermined set of equations.

The three models for the structure of the multivariate concept of system safety are summarized in Table 3 by an indicative presentation of the hypothesized loadings (contributions of factors to variables) as usual in factoranalytic studies.

	SINGLE COMMON FACTOR MODEL		ORDERED TWO-FACTOR MODEL			ADDITIVE MULTI-FACTOR MODEL					
ORDER VAR.	Fac-tor	Spec. +err.	Tran-sport	Sa-fety	Er-ror	Expo-sure	Con-flict	Mat. dam.	In-jury	Fa-tal	Er-ror
fatality	mid	mid	low	high	high	x	x	x	x	x	high
│	│	│	│	│	│	x	x	x	x	0	│
│	high	low	│	│	│	x	x	x	0	0	│
│	│	│	│	│	│	x	x	0	0	0	│
exposure	low	high	high	low	low	x	0	0	0	0	low

Table 3. Three models for the structure of road safety

A general overview of the mathematical modelling for the three factor models and some other factor analytic models has been given by Solomon (1960). The mathematical analyses for the first two models are described in textbooks on factor-analysis (Harman, 1970) or multivariate data-analysis textbooks (Van de Geer, 1971; 1986; Krzanowski, 1988). Their advanced statistical treatment by maximum likelihood methods can be found in Lawley and Maxwell (1971). The mathematical analysis of the additive multi-factor model as a special case of the radex is described by Guttman (1954) and can also be found in the multivariate statistical textbook of Morrison (1976). The usual correlation formulation of the three models can be modified by the analysis of covariance or raw cross-product matrices because of the meaningful frequency scales, but correlation matrix analysis will yield factor weights which are comparable as proportional contributions and as such can be related to risks as probabilities. A maximized generalizibility of the factor structure asks for a so-called image-analysis or alpha-factor analysis (Kaiser & Caffrey, 1965) that describes the structure of the variates and variables for so far as the variables are predictable by each other. It optimizes the validity for the use of the results in different traffic environments. Factor analyses of power transformed variables as described by Mc Donald (1962) may be an appropriate modification of the models. More generally the metric monotonic Box-Cox transformations (Box and Cox, 1964) of the multivariate analyses models developed by Gaudry (1984), may be in place if monotonic optimized fit of the models is asked for. For example speed and reaction-time reducing measures may have different power transformation effects on damage-only accidents and fatalities, while exposure may be optimally measured by some fitted power-transformation of vehicle kilometres. On the basis of an assumed Poisson error distribution of the observed frequency variables, one also ought to modify these analyses by solution procedures which also standardize error variances. Here the exposition of these relevant modifications is not pursued more deeply, nor are possible other structural representations for the concept of road safety, since even the simple models presented here are hardly investigated by empirical research.

In the single common factor model and the ordered two-factor model a change in factor value has effects on all variables, apart form a possible almost zero factor loading of a variable (for the variables at each extreme of the severity ordering in the ordered two-factor model). In the additive multi-factor model it only effects those variables with non-zero weights. Since independent measures for the severity ordered variables will not influence the preceding variables, but only the successive variables, the additive multi-factor model seems to have more theoretical justification, if measures are thought to originate from changes in causal accident factors. In the theory of adaptive evolution of traffic and safety (Oppe & Koornstra, 1990; Koornstra, 1992) the validity of the ordered common two-factor model is implicitly acknowledged by the analysis of time-series data. There the long term macroscopic development of traffic risks for several countries is analyzed by a negative exponential function of time. Denoting t as years, F_t as annual fatalities, I_t as annual injured persons and V_t as annual motorized kilometres that time dependent model defines

$$F_t/V_t = R_t = \exp(\alpha.t + \beta) \quad \text{and} \quad I_t/V_t = a.\exp(\alpha.t + \beta) + b = a.R_t + b$$

whereby it follows that also: $I_t = a.F_t + b.V_t$

It indeed is demonstrated (Koornstra, 1992) that a weighted sum of time-series of vehicle kilometres and fatalities gives a fairly good estimate of the time-series for injuries. Since the ordered two-factor model assumes that expected variables are linear combinations of each other, this finding contradicts the single common factor model and yields some evidence for the ordered two-factor model. Therefore, the single common factor model seems to have less empirical validity. Moreover, the dynamic system approach to road safety (Asmussen, 1982; Sanders-Kranenburg, 1986) describes a phase model of the accident process that is compatible with the additive multi-factor as well as the ordered two-factor model, which for the latter is shown by figure 4.

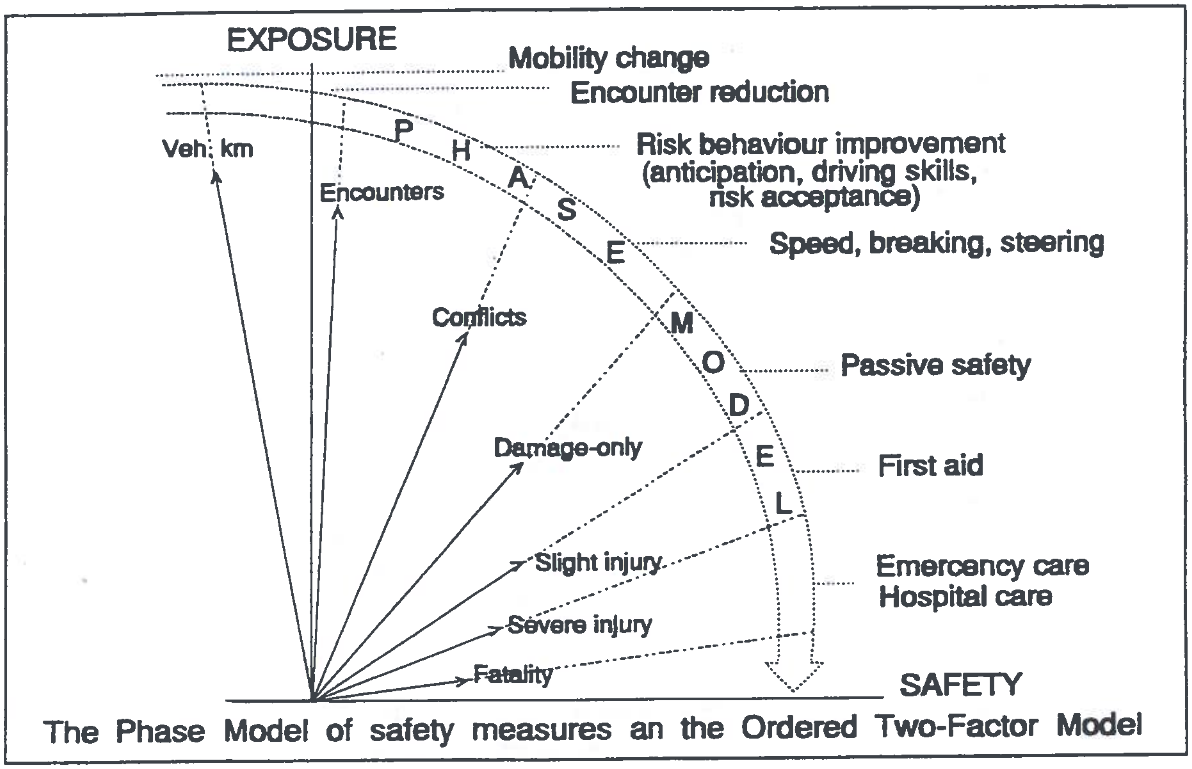


Figure 4. The phase-model and the ordered two-factor model.

The variables in the ordered two factor model consist of outcomes for the phases in the model and the ordering of the variables corresponds to the time-order of these phases. The traffic safety measures can be ordered along the same ordering, since their effects are aimed to enhance the control of the critical coincidence of circumstances in the transition to a particular consecutive phase. Thereby the probability of the occurrence of failures for a subsequent phase is reduced. Different emphasis of measures in different phases can change the factor structure, but generally the more priority there is for road safety or the more safe a country is, the more measures are taken in each of the phases. If so the angles between the vectors do not change very much, but the mean frequencies and the level of the variances and covariances will decrease. This joint influence of simultaneous measures for different phases in the accident process will lead to an overall effect on the variables, that does not change the structure of the ordered two-factor model. Nonetheless, if effects of safety measures for particular phases are different it must alter the factor loadings of its variables in the ordered two-factor model without changes for preceding variables. In that case the changes in the variables can only be described as generated from the original factors in the additive multi-factor model and not in the two-factor model. However, the structure from the additive multi-factor model becomes compressed to a two-dimensional factor structure of a partial circumplex or simplex, without loss of essential variances, by monotonic transformations of the variables.

Based on this preliminary overview of the three models it is concluded that the multi-factor model is the least parsimonious model that hardly can be falsified due to its non-overdetermined solution which does not yield a single quantification of the road safety concept. The common factor model is the moats parsimonious model, but it at least contradicts some empirical evidence and gives by its lower loadings for more severe outcome variables not a quantification of road safety that is in accordance with the general meaning of road safety as an underlying characteristic of the frequencies for the different severity categories. The two-factor model is a relative parsimonious model that most likely can describe the underlying generic structures as well as the multi-factor model and still can be empirically valid, since it at least is in accordance with some empirical evidence. Moreover, it yields a quantification of road safety which is in accordance with an underlying characteristic that is the more related to expected variables, the higher the severity for the variables is.

Returning now to the function that combines the multidimensional risks for a quantified safety measure, one has for the common and the ordered two factor model a weighted combination function of observed variables for the quantifying of the underlying road safety concept by the weights for the so-called component scores (Kaiser, 1962) of the safety factor. Only in the ordered two-factor model the weights will be higher the more reliable and the more severity related the variables are. Since this is generally what one expects for a meaningful and optimal reliable quantified safety concept, it is this weighted combination that ought to be used. Since in this model the weights for the scores of the other orthogonal component define the measurement of the exposure, which is assumed to coincide with the measurement of the kilometrage, the weights for the safety component also apply to the combination of risks as probabilities. Formally it is written with reference to table 2 as

$$\text{SAFETY} = \Sigma\{w_1.R_1 + \ldots + w_i.R_i + \ldots w_m.R_m\}.\text{kilometres}$$

where the weights w_i are solved by the weights for the component scores of the safety component from the two-factor model analysis of the m available frequency variables.

It minimizes error in the quantification of road safety, not by enlarging the number of 'trials' in the traffic 'chance set up' (longer periods and larger areas), but by combining the imperfectly and independently measured different relevant outcome variables for the underlying safety factor. As referred before the analysis of long term risks developments have shown that the two-factor model may yield an empirically valid function for the combinations of risks for the quantifying of the concept of road safety.

This can not be said for the single common factor model. It also would minimize in the same way the error in the risk estimation and also relates the quantified concept to a single underlying safety factor. However, the weights for the most severe outcome categories will be lower than the weight for the less severe outcome categories in this case and that must be regarded as a controversial quantification of the road safety concept. Moreover, the assumption of a proportional realization of the same underlying safety factor for all relevant frequency variables seems not to hold, since the long term risk developments of fatal, injury and damage-only accident risk are shown not to be identical.

It will be clear that for the additive factor model there is no single concept for underlying road safety, but a structured multi-facetted concept. Nonetheless the respective weights of the observed variables for the score estimation of its respective variates can be weights that can be applied in corresponding functions for sets of risks relevant for the accident phase under consideration in order to maximize the reliability of the estimation of the different safety facets.

3. National accident data and real safety developments

In the above explorations for the quantifying of road safety, it is assumed that the observed frequencies are representive for the actual occurrences of the adverse outcomes from events in road traffic. However, it has become rather clear that in no country the officially reported and in national databases recorded accidents are representive for the actual occurrences of accidents (IRTAD, 1994; ETSC, 1994). The accidents reported to or by the police generally are selective with respect to the severity of the accident outcome, the type of vehicle or road users involved and the type of accident. The percentages of underreporting differ also between nations. For national analyses it may not be a problem for particular questions, but probably there are also regional differences in underreporting as well as differences with respect to different road types. Moreover, there are indications that the underreporting percentages of the official statistics increase with the progression of the years. Therefore, at least the national statistics do not reflect the real occurrences of the adverse outcome frequencies of the traffic events and also probably do not reflect the 'true' developments of the frequencies, due to changing selectivity over time.

To summarize the main findings:

a) The less the severity of the accident outcome is, the less the coverage in the officially recorded accident data is:
- Virtually all fatal accidents are reported, although research has shown that fluctuations up to 5% less than the actual death in traffic may occur for death within 30 days after the accident.
- Serious injury accidents are underreported by percentages that range between 15% to 50% less, depending on the country and the type of accident.
- Slight injury accidents are underreported by percentages of 30% to 75% less, also depending of the country and type of accident.
- At least about 75% non-reported damage-only accidents are to be observed in some Nordic and North-West European countries.

b) Accidents involving only motorvehicles are more often reported, than accidents which involve non-motorized road users:
- Accidents between four-wheeled motor vehicles are underreported by 5% to 20%, where accidents between motorcyclists and four-wheeled motor vehicles

are underreported by 15% to 30% less.

- Accidents of non-motorized road users in conflict with motor vehicles are underreported by 30% to 60% less.
- Accidents that only involve non-motorized road users may even become underreported by 55% to 90% less.

c) Single accidents with casualties are less reported than multiple accidents with casualties:

- Single accidents of motor vehicles are underreported by 15% to 55% less for four-wheeled motor vehicles, for motorcycles by 50% to 85%, for mopeds 75% to 90% and for cyclists 85% to 95% less.

d) In some countries the coverage of the reported serious injured persons are reducing by about 10% less of the level before in every 10 to 15 years.

Given a particular area and period for the types of accidents considered, one should establish the relevant stratification of the underreporting if the real development of road safety is the topic of analysis. Due to possible changing percentages of the underreporting these percentages also ought to be followed over the years if one wants to keep track of the real safety developments. Especially the larger underreporting percentages of accident outcomes which involve pedestrians and cyclists may distort the needed priority setting for the road safety of vulnerable road users. It will be clear that safety developments must be corrected according to the different underreporting factors for subsets of accident outcomes. If one is able to establish such correction factors fi for the severity classes, than the real safety level and its developments should be described by

$$\text{SAFETY} = \Sigma\{f_1.w_1.R_1 + .. + f_i.w_i.R_i + .. + f_i.w_m.R_m\}.km$$

where at least for Nordic and North-West European countries the typical values of the correction factors vary as shown in table 4.

correction factor	maximum	minimum	median
fatal accidents	**1.05**	**1.01**	**1.03**
severe injury accid.	**2.00**	**1.18**	**1.60**
slight injury accid.	**3.33**	**1.33**	**2.33**
damage-only accid.	**-**	**-**	**4.00**

Table 4. Typical underreporting correction factors.

The same correction factors are needed if the weights are the respective mean economic loss per outcome in each category for a determination of the real economic loss due to lack of road safety. Such is done in the report of the ETSC on the transport safety costs for the European Union (ETSC, forthcoming). Based on the willingness to pay method it is estimated that the total socio-economic costs of road safety in the European Union for 1995 is just over 160 billion ECU.

4. Implications for targeted road safety policies

The setting of quantitative targets for road safety focus attention on the problem and motivates those who can contribute to their achievement. It is sometimes argued that the setting of a target creates a "no-win' situation politically, because if the target is achieved it must have been too easy, and if it is not achieved, embarrassment and political failure results. This argument could be discounted because any failure to achieve one target should be a spur to greater effort for the achievement of the next target, and in neither Sweden or Great Britain has it caused difficulties when a target for the reduction of fatalities has been achieved ahead of time: it just has been an encouragement to set a stiffer target for the future.

Nevertheless the quantitative setting of seif targets on the one hand must be realistic enough to be achievable in the period set for the targets and on the other hand must be challenging enough to stimulate the efforts for their achievements. Such a quantitative goal-setting and its evaluation both require reliable quantitative information about road safety. Generally the goal-setting is based on the development of road fatalities, although for instance in the Netherlands separate targets for fatalities and injured persons are set (50% reduction of fatalities and 40% less injured persons between 1986 and 2010). On the grounds explained in the sections above the observed past developments of the separate annual frequencies are influenced by random fluctuations and its extrapolations for some setting of realistic, but seif targets can be troublesome. Moreover, the overall macroscopic development trends of the relevant observed frequencies in the motorized countries have not been monotonic in the past, but more or less single peaked or even multiple peaked like in Japan. Therefore, any reliable and valid extrapolations of trends in observed frequencies is hardly possible.

However, the macroscopic trends in annual kilometrage and in the risks for the relevant annual frequency categories of accidents generally are rather monotonic. The traffic volumes tend to grow in a more or less S-shaped way, while the risks tend reduce in a exponential (for fatalities) or reversed S-shaped (for injuries) way. Medium term extrapolations of these monotonic trends, therefore, are a more sound basis for a realistic and challenging target setting. Moreover, the above quantifying of the road safety concept also yields, by its error minimization procedure, an optimally reliable procedure for the target setting based on the extrapolations of the S-shaped development of annual kilometrage and the negative exponential extrapolation of the development of the annual risk that corresponds to the underlying road safety quantification. By the inverse relation between the separate expected frequency categories and the variates for kilometrage and safety a more reliable and valid extrapolation for the different frequency predictions of fatal, serious injury, slight injury and damage only accidents for the target setting in each category can be obtained.

What one needs is an analysis of annual data for kilometrage and the different frequency variables for an as long as possible period of past years by the two-factor model. From this analysis the risk corresponding to the safety variate is calculated for the years in the past and that risk development is then fitted by a negative exponential function of time. It is to be expected that this exponential function fits better than any function for the observed risks of the different categories of accidents. If it has an excellent fit it also a valid function for its extrapolation. Given a national official estimates for the kilometrage in the future or extrapolated annual kilometres from a fitted S-shaped growth of kilomatrage the optimally reliable and valid predictions of the annual quantitative level of road safety in some not to far future can be obtained. From the relations of the expected frequencies of the different accident frequencies with the safety and kilomatrage variate the respective future developments of the different expected accident frequencies follows by a different weighted combination of both variate for each category. Consequently the predicted developments of the separate risk in the future are obtained by dividing the predicted frequencies by the predicted kilomatrage values. Clearly these predictions implicitly are based on the assumption that the effectiveness of the road safety policies in the future will be the same as in the past. For a somewhat more challenging target setting the targets may be taken to be a fraction lower than the predicted levels.

In this perspective a target setting can be a quit tricky affair. For instance the tentative target setting of 30.000 fatalities for the EU in 2010 by the rapporteur of the ETSC symposium "Strategies for Road Safety" in march 1966 (ETSC, 1966) must be qualified as a much to easy achievable target. As the figure 5 below shows traffic growth from 1980 to 1995 is not very different from linear in the EU. Although it must be assumed that traffic growth actually is S-shaped, the level of traffic growth in the EU still will be in the more or less linear middle part of some S-shaped curve. Therefore, a linear or probably somewhat less than linear extrapolation is an acceptable prediction. Moreover, the implied growth to 2010 amounts to about the growth level used for 2010 in official documents of DG VII.

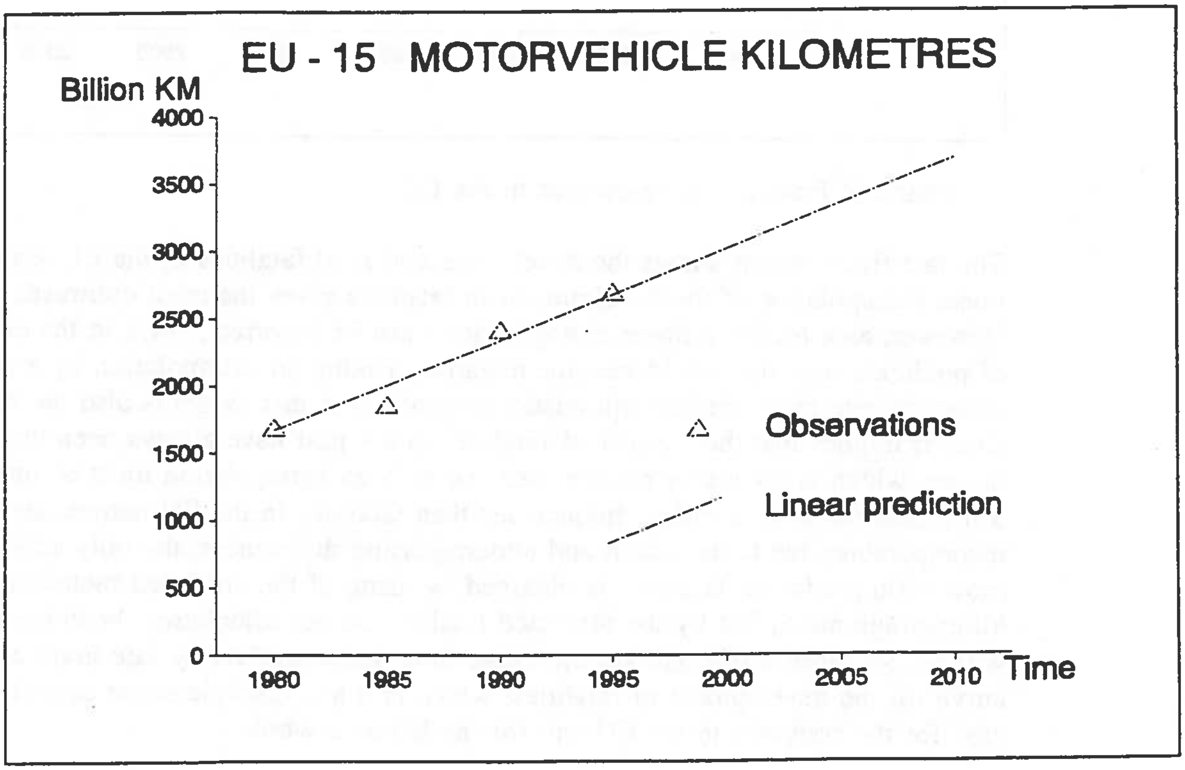


Figure 5. Growth of kilometrage in the EU

In the next figure it is shown that an exponential reduction of the fatality risk for the EU gives a quite good description of the risk development from 1980 to 1995. Its prediction by extrapolation of an exponential decrease seems, in view of the generally observed exponential reduction of fatality risk in the European countries, a best possible prediction. As remarked before it would imply an equal effectiveness of road safety policies in the EU-nations in the next 15 years as in the last 15 years.

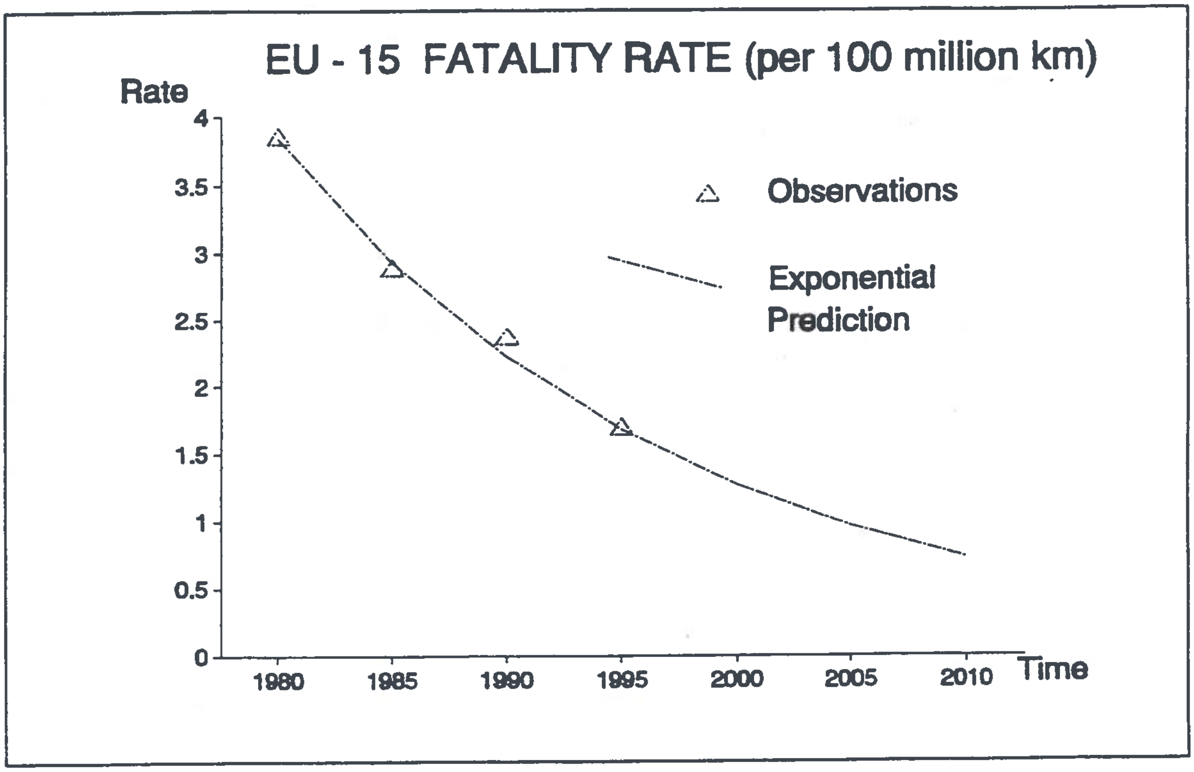


Figure 6. Fatal risk development in the EU

The last figure below shows the development of road fatalities in the EU since 1980. The linear extrapolation of the development in fatalities gives the most optimistic prognosis. However, as a model, a linear extrapolation must be incorrect, since in the end the number of predicted fatalities would become negative. Taking an extrapolation by a constant reduction rate gives the less optimistic prognosis, but this model is also not acceptable since it implies that the number of fatalities in the past have always been increasingly higher, which is obviously not the case. So such an extrapolation must be questioned also. Since data for other accident frequencies than fatalities in the EU-nations are incomparable, due to definition and underreporting differences, the only acceptable and most valid model for fatalities is obtained by using of the predicted motorvehicle kilometrage multiplied by the predicted fatality rate per kilometres. With linear as well as with an S-shaped traffic growth the exponential reducing fatality rate gives a single peaked curve for the development of fatalities, which in a macroscopic sense actually has been the case for the countries in the EU and for the EU as a whole.

In view of these findings and the fact that in the last 15 years the number of fatalities in the EU actually is reduced by 19,000 fatalities a target setting of a reduction by 15,000 in the next 15 years is not a real challenging target, as it is shown by the plotted predictions based on exponential risk and linear traffic growth in figure 7.

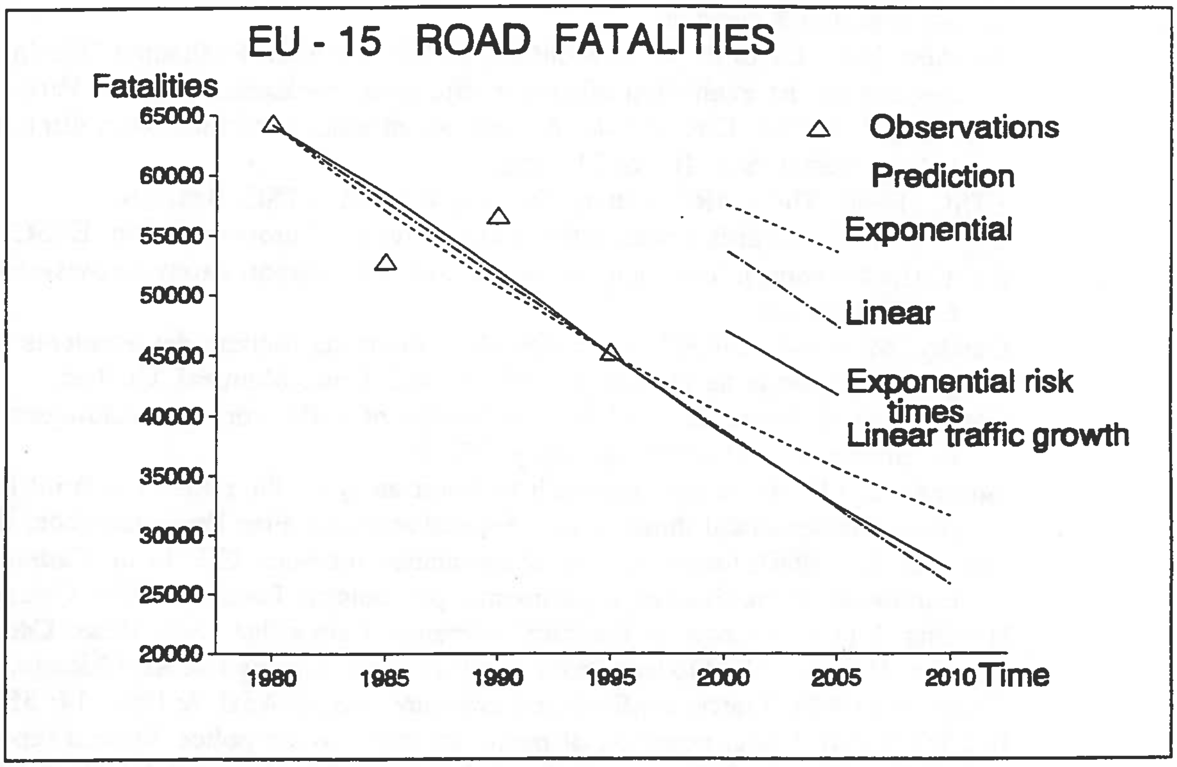


Figure 7. The development of fatalities in the EU.

Moreover, in view of the fact that in the EU between 1980 and 1995 the fatalities would have been reduced by 25,000 if the risk of the UK, Sweden, Finland and Netherlands would have applied to the EU as a whole, it must be possible to reduce the EU-fatality rate by 56% from 1995 to 2010 as predicted by the exponential risk reduction. Combined with a less than linear traffic growth the 45,000 fatalities of 1995 in the EU are then reduced by at least 18,000 in 2010. Since this assumes nothing else than an as effective policy as in the past 15 years, a somewhat more ambitious target in round figures would asks for a reduction of 20.000 fatalities by 2010 from 1995 on ward to an achievable level of 25.000 fatalities in 2010 in the EU and its further reduction thereafter.

Generally the targets will be related to the officially reported accidents frequencies, which as mentioned before are much lower than the actual frequencies. However, also the extrapolation are generally based on these official data and thus will include the underreporting and the possible trends in the underreporting of the actual accidents frequencies. Nonetheless, if the targets are aimed to quantify the actual to achieve reductions in the frequencies of accidents, one needs to monitor and evaluate the developments in such a way that the official frequency data are corrected for the possibly in time changing underreporting percentages.

Literature

Asmussen, E. (1982). Concepts and methodologies for integrated safety programmes. SWOW, Leidschendam

Biechler, N.B.; Lacomte, C. & Muhlrad, N. (Eds.) (1985). Evaluation "85. International meeting on the evaluation of local traffic safety measures. ONSER, Paris.

Box, G.E.P. & Cox, D.R. (1964). An analysis of transformations (with discussion). J. Roy. Statist. Soc. B. 26: 211-252.

ETSC (1994). The CARE system: The way forward. ETSC, Brussels.

ETSC (1966). Towards a road safety strategy for the European Union. ETSC, Brussels.

ETSC (forthcoming). The socio-economic costs of transport safety (provisional title). ETSC, Brussels

Gaudry, M. (1984). DRAG, un modèle de la demande routière des accidents et de leur gravité, applique au Québec de 1956 à 1982. Univ. Montréal, Québec.

Glanz, W.D. & Bauer, K.M. (1985). Validation of traffic conflicts techniques in the USA. In: Biecheler et al.(1985) op. cit. p: 352-362.

Guttman, L. (1954). A new approach to factor analysis: the radex. Ch. 6 in: Lazersfeld, P. (Ed.). Mathematical thinking in the social sciences. Free Press, Glencoe, Illinois.

Guttman, L. (1966). Order analysis of correlation matrices. CH. 14 in: Cattell, R.B. (Ed.). Handbook of multivariate experimental psychology. Rand McNally, Chicago.

Hacking, I. (1965). Logic of statistical inference. Cambridge Univ. Press, Cambridge.

Harman, H.H. (1970). Modern factor analysis. Univ. Chicago Press, Chicago.

Hauer, E. (1982). Traffic conflicts and exposure. Accid. Anal. & Prev. 14: 352-362.

IRTAD (1994). Under-reporting of traffic accidents to the police. Special report. OECD-RTR, BASt/Norwegian Road Administration, Bergisch Gladbach/Oslo.

Kaiser, H.F. (1962). Formulas for component scores. Psychometrika, 27: 83-87.

Kaiser, H.F. & Caffrey, J. (1965). Alpha factor analysis. Psychometrika, 30: 1-14.

Koornstra, M.J. (1991). The structure of system safety. SWOV-report, D-91-1, SWOV, Leidschendam.

Koornstra, M.J. (1992). The evolution of road safety and mobility. IATSS Research Vol.16, no.2: 129-148.

Krzansowski, W.J. (1988). Principles of multivariate analysis. Clarendon Press, Oxford.

Lawley, D.N. & Maxwell, A.E. (1971). Factor analysis as a statistical method. (2nd ed.). Butterworth, London.

Mc Donald, R.P. (1962). A general approach to non-linear factor analysis. Psychometrika, 27, 27: 397-415.

Morrison, D.F. (1976). Multivariate statistical methods (2nd. ed). McGraw Hill, New York.

Oppe, S. & Koornstra, M.J. (1990). A mathematical theory for related long term developments of road traffic and safety. In: Koshi, M. (Ed.). Transportation and traffic theory, 11th Proc. Elsevier, Amsterdam.

Sanders-Kranenborg, A. (1985). Towards a dynamic system approach to road safety. In: The way ahead. P: 63-74. SWOV, Leidschendam.

Solomon, H. (1960). A survey of mathematical models in factor analysis. Part III in: Solomon, H. (Ed.). Mathematical thinking in the measurement of behavior. Free Press, Glencoe, Illinois.

Van de Geer, J.P. (1971). Introduction to multivariate analysis for the social sciences. Freeman, San Fransico.

Exposure Data and the Assessment of Risks:

Use and Needs Within and Across the Transport Modes in the EU

final draft ETSC REVIEW dd. 2-9-'98 of MK

Acknowledgements

ETSC gratefully acknowledges the contributions of members of ETSC's Transport Accident Statistics Working Party to this review:

Drs. Matthijs. J. KOORNSTRA (Chairman and principal author)
Dr. Jeremy BROUGHTON (co-author of sections on road transport)
Mr Jean-Pierre CAUZARD
Ir. Ruddy DIELEMAN
Prof. Andrew EVANS (co-author of sections on rail transport)
Ir. Cees GLANSDORP (co-author of sections on sea transport)
Mr Lasse HANTULA
Prof. Niels JORGENSEN (co-author of sections on combined transport modes)
Dr. .... ? KOPPEL
..? Frank TAYLOR (co-author of sections on air transport)
Mrs Mary WARD (WP Secretary, editor of the review)

ETSC is grateful for .... etc.

Contents **Page**

1. Introduction

The EU member states devote considerable efforts to collecting information about transport accidents and the number of travellers who are killed and injured in them. These accidents are an undesirable consequence of people's need to travel, and it is important to develop policies for improving safety by reducing the number and severity of accidents. In order to understand how best to do this, we need to investigate

$$\text{RISK} = \frac{\text{Number of accidents, casualties or fatalities}}{\text{Volume of travel}}$$

Thus, it is important to collect information about the volume of travel, which can be compared with the existing information about accidents and casualties. The resulting risk assessments are then used to improve transport safety by:

- monitoring casualty trends and evaluating policies which have been introduced to improve safety, in order to provide a sound basis for developing new policies (for example, have past changes in the numbers of accidents and casualties been achieved by reducing the level of risk, or has the volume of travel changed?)
- comparing the levels of risk of different types of travel (for example by transport environment (e.g. rural/urban) or by transport mode)
- setting priorities, i.e. identifying those transport situations with high levels of risk for high severity outcomes of accidents in order to formulate policies and concentrate resources to reduce the high levels of risk, especially for high severity outcomes of accidents.

The safety policy for each mode of passenger transport is the same: research, develop and apply measures that have the potential to reduce the accident risk and/or the severity of the accident outcome. The various ways of measuring the volume of travel are referred to collectively as 'exposure data' because they measure travellers' exposure to the risk of injury or death. In addition to measuring the level of transport safety, this type of information also plays a central role in many other aspects of transport planning such as deciding whether to invest in new roads or railways.

2. How exposure data are gathered and their availability

This chapter examines how exposure data are gathered or how relative shares of exposure for groups of travellers or transport means as well as for transport conditions can be estimated and what its feasible uses are. Typical examples of its use in risk evaluations are given and illustrated in chapter 3 and 4. Here the availability, the estimation methods and merits of exposure data and the limitations of making inferences from them are discussed for each mode.

2.1. Road transport

There are two principal methods of collecting safety-relevant exposure data for road transport:

(a) surveys of traffic (i.e. vehicles), and
(b) surveys of travellers (i.e. people).

Different methodologies are used for the two types of survey. A third method does not collect exposure data, but infers the relative exposure for groups of road users from accident data for involved pairs of these groups. The latter methodologies are called:

(c) methods of induced exposure.

Each method has its merits, but also shows limitations of making inferences from them (see also : OECD-IRTAD, 1998). Combinations of the three methods are sometimes needed. Often one method may not contain information on exposure for sub-categories, where combined methods may allow for a disaggregation of exposure data. The last section of this chapter discusses the use of combined sources of exposure information.

2.1.1. *Surveys of Traffic*

Traffic counts have been made for many years for local purposes, e.g. to investigate whether the construction of a new road would be justified. Several European countries now carry out more extensive counts to monitor trends in the national and regional traffic. In most of these countries these counts are carried out systematically at a series of counting sites chosen to be nationally representative. Thus, there are sites on all types of road in each region, and counts are usually classified by the type of vehicle. The count data are then combined with detailed information about the road network to provide national and regional estimates of traffic volumes. Counts are only made for a sample of links on the road network, and are often of limited duration, so statistical theory is required to establish confidence limits for the estimates. Broadly speaking, the precision of the estimates increases with the number of observations - and the cost of the survey.

A few European countries have no national system for counting traffic, and rely instead on sales of fuel for road vehicles to estimate their national traffic volumes (see annex 2). The average fuel efficiency of the vehicle fleet (i.e. average number of kilometres travelled per unit of fuel sold) is established periodically by survey, and this figure is used to convert the total of fuel sold into the total distance travelled. Using fuel sales data is much cheaper than collecting national traffic counts, but has several drawbacks. It is sensitive to the estimate for the average national fuel efficiency and indeed the actual efficiency varies continually with factors such as the weather and the purchase of new vehicles. The total distance travelled cannot be divided among the types of road or vehicle. A significant proportion of the fuel sold in some countries is used to travel in another, after the purchasing vehicle has crossed an international border: this is an increasing problem as travel between the countries of Europe increases. It is possible to adjust the national travel estimates if sufficient additional data are available, e.g. from border surveys.

The use of national traffic data is not without its difficulties either. Most countries have many minor rural roads with little traffic, yet the total traffic on these roads forms a significant fraction of the national total: it is difficult to achieve an effective but affordable survey of traffic on these roads. Cyclists tend to prefer these quieter roads, so pedal cycle traffic can be poorly measured; some automatic traffic counters have difficulty registering cycles, which adds to the problem.

2.1.2. *Surveys of Travellers*

Surveys of traffic provide no information about the travel characteristics of different groups within the population, and surveys of people are essential to collect this type of information. Local surveys often stop vehicles and interview occupants, but this approach is unnecessary and inefficient with a national survey. Instead, a representative sample of people is inter-viewed in their homes about their travel patterns. This can include travel by all modes, but non-road modes are poorly represented since travel in Europe is predominantly by road at present.

The National Travel Survey (NTS) of Great Britain is a good example of this type of survey. It used to consist of yearlong surveys at irregular intervals, the first being in 1965, but it has run continuously since 1988. The survey is based on households, about 3200 households including about 8000 people are surveyed each year, with equal numbers each month. Each survey begins with a visit to the household and an extensive interview about the household's characteristics and use of transport facilities. Each household member is asked to keep a travel diary for seven days, recording details of all personal trips made during that time. These diaries are checked by the interviewer during a final visit. The information collected provides a good picture of the trips made by these families, including:

- the modes and vehicles used,
- the times, costs and distances involved,
- the age, sex and social characteristics of the travellers,
- the journey purpose and any links with other transport modes.

The information is invaluable for understanding the use of transport facilities made by different sectors of the population. It is possible with a continuous survey to discern seasonal and cyclical variations, as well as broad trends in patterns of demand.

The main problems with this approach concern cost and response. A survey with a sample that is sufficiently large to provide reliable estimates of the main transport statistics is expensive. Estimates of the more detailed statistics can be rather imprecise because of the limited sample size. A survey that is sufficiently detailed to collect the necessary information, including travel diaries, is difficult for respondents to complete; for example, travel diaries tend to be completed less fully for the last day than for the first. As with most types of survey, response rates tend to be lower among young people, yet they are involved in disproportionately many road accidents.

2.1.3. *Methods of Induced Exposure*

There are several methods to obtain induced exposure estimates. The reader is referred to the exposition of Haight (1971) and the literature review of Mengert (1982). Induced exposure methods do not give information on the absolute level of exposure or annual mileage, but estimate the relative exposure for categories of road users from accident data. When only the total exposure is known (e.g. from fuel data), and detailed exposure data are not gathered or are impossible to obtain from traffic of travellers surveys, the method has the advantage that shares of exposures can be estimated for all kinds of subgroups which can be defined as parties in accidents without using no other data than accident data. Without the use of induced exposure methods, exposure information for many sub-groups would remain unknown.

One method, originated by Thorpe (1964), discussed by Waller, et al (1973) and recently reviewed by Stamatiadis & Deacon (1997), assumes that relative exposures for subgroups of road users are reflected by the their shares of non-guilty road users in accidents between road users or by their corrected shares with respect to the same shares for a reference group (generally the total group). Although not seldom used also recently (Preusser et al. 1998a, 1998b), this method has some weaknesses, related to the underlying basic assumption that road users at-fault in accidents are randomly selected road users (see: Lyles et al. 1991). These induced exposures tend to be different when derived from fatal and from slightly injured accidents, because the more severely injured party tend to be more often registered as at-fault (e.g. in German accidents between cars and motorcycles the killed motorcyclist is manyfold more often registered as at-fault than the injured motorcyclist). However, corrected by a reference group these differences may be less. Haight (1973) modified the method by assuming that the ratio of single accidents for two groups reflects the ratio of their relative responsibility shares in multi-party accidents between these groups. Nonetheless, when instead of accident totals for each subgroup the numbers of accident between all pairs of subgroups are used (e.g. for 10 sub-groups there are 45 pairs) Thorpe's and Haight's methods tend to give both differences in the relative exposures of subgroups, indicating that the basic assumption of either method may be questionable (for discussions see articles in Accid. Anal. & Prev. Vol. 5, 1973) .

The other, more analytic model for induced exposure, proposed by Koornstra (1973a), does not assume that ratios of non-guilty subgroups in accidents reflect relative exposures, nor that ratios of single accidents reflect relative responsibility shares in multi-party accidents, but that in average both parties in road traffic encounters contribute to the extent of their risks to the outcome of accidents. The model predicts the numbers of multi-party accidents for all pairs of sub-groups by a risk parameter and an exposure parameter for each of the two sub-groups involved in the multi-party accidents. The risk and exposure parameters for each subgroup are simultaneously estimated from the (symmetric) data matrix of the accident numbers for pairs of subgroups involved. The risk parameters are assumed to be proportional to the usual risk values of the subgroups and the product of exposure parameters proportional to the frequency of road traffic encounters between the subgroups. Since the number of parameters (for 10 sub-groups: 20 parameters) is smaller than the number of data-elements (for 10 sub-groups: 55 data-elements) the fit of the model can be tested and thereby also assess the validity of the model. The model has been shown to fit for data of several kinds of subgroups (Koornstra, 1973b; Wass, 1977), but not all kinds (e.g. not for subgroups using different road modes). Its exposure and risk parameters are shown to be highly correlated with actually observed mileage and risks for several kinds of subgroups (for example, age and gender groups of car drivers; see also Mengert, (1985) for a critical evaluation).

Also this induced exposure model has its limitations, because its exposure parameter theoretically relates to the frequency of encounters in road traffic. Although a multiplicative function of annual traffic volumes for parties may estimate the relative frequency of encounters between them, the frequency of encounters also depends on the type of road infrastructure. This model also raises the question what the relevant exposure to risk is for collisions between different road modes. For example: the model assumes that risk of pedestrians with their majority of pedestrian-car collisions depends more on the relatively large car exposure than on their relatively small own exposure. The validity of its risk and exposure estimates for subgroups, therefore, can be questionable if the accidents between subgroups concern different road mode combinations and/or accidents that occur on rather different mixtures of road types for different subgroups.

Anyhow the advantage of induced exposure is the low costs, since accident data are already gathered. Its main problem is that the validity of induced exposure estimates can be questioned and thus must be in some way assessed. Given relative exposure values that are reliably derived from accident data, it is possible to split a known total of mileage for all drivers (e.g. from fuel data) in absolute exposure values for each group of drivers. All kinds of categories that apply to registered aspects of accidents can be used, while several of these aspects can hardly be obtained from surveys. It has, for example, been used for the estimation of risks for drivers with and without passengers (Preusser, et al., 1998b) and when the categories would concern the colours of cars, one even could estimate the relative exposures and risks of drivers per car colour.

2.1.4. *Combination of methods*

Different limitations are inherent to each of the methods. Traffic counts are easily related to road types, but it is hardly possible to disaggregate traffic counts into sub-groups of road users that do not differ in externally observable characteristics. Travellers often do not know on which road type they are travelling or which part of the road trip is located within an urban region. Therefore, surveys of travellers do not give reliable information on exposure for different road types (or different speed limits or different authorities), but can contain exposure information for categories that are not externally observable. Induced exposure estimates are limited by the categories that apply to multi-party accidents and by the specifications of variables for parties in the registration.

Data from several sources can be combined. For example, the mileage of 18-20 year old male drivers can be estimated from the total car mileage (from traffic surveys or estimated from fuel consumption) and the proportion of car mileage driven by 18-20 year old males (from the travel surveys or from induced exposure values). The mileage of car passengers can be estimated from the total car mileage and the ratio of car passenger mileage to car driver mileage. The level of detail that is practicable for these estimates is limited by the accuracy which can be expected from the sample size and by the feasible categories in each method.

Several combinations of methods are possible in order to obtain disaggregated exposure estimates for sub-groups. It is not always possible to obtain exposure cross-tables from combinations of two methods. For example, exposure per road or/and vehicle type from traffic surveys and exposure per age category from traveller surveys do not allow to construct an exposure cross-table of road or/and vehicle types and age categories. However, from the exposure data per road type and the multi-party accidents between two age categories per road type the combination of traffic surveys and induced exposure can estimate such an exposure cross-table for road or/and vehicle types and age categories. The totals for each age category and each vehicle type in such a cross-table ought to fit the totals for each vehicle type from a traffic survey and for each age category from a traveller survey. Reliability of exposure estimates can be enhanced very much by combining the three independent sources of exposure information. Moreover combinations of the three methods allow the estimation of detailed exposure estimates that are not obtainable from one method alone or from two methods.

2.2. Rail

There are no standard international conventions for collecting and measuring exposure to railway accidents, casualties or fatalities.

Railway fatalities are classically divided into passengers, staff and other persons (third parties). The UIC (Union Internationale des Chemin de Fers) gives numbers of fatalities on the 15 Railway systems of the EU subdivided in these groups. For the EU rail data from 1970 to 1996 18½% of fatalities are to passengers, 11% are to staff, and 70½% are to other persons. The percentage of other persons has been moving upwards over time, but there are wide variations in the percentages for other persons between the 15 Railway systems of the EU (ranging from an exceptionally low 33% in Great Britain to 93% in the Netherlands). This variation is probably more due to different reporting conventions for third party fatalities than to real differences between the EU countries.

In the UIC data, the only exposure measure provided is the number of passenger-kilometres, which is certainly a suitable measure for passenger fatalities, but only for them, and, as stated above these represent a minority of all railway fatalities. However, some other data on other exposure measures are available (Railway Gazette International 1997 Yearbook). For the EU-countries (except Luxembourg) data are given on route-kilometres, rolling stock, freight tonne-km and number of staff as well as passenger-km. In Great Britain, Railtrack uses different exposure measures for different kinds of casualties in their casualty targets. For passengers the number of passenger journeys is used, for staff the number of staff in critical occupational groups (e.g. people working on or about the track), and for third parties the national population.

2.3. Air

In aviation very detailed world-wide statistics on regular air traffic and accidents are produced every year. It are probably reliable data, since the number of flights, passengers carried, hours flown, distance flown, etc. are recorded as well as the numbers of fatalities, seriously injured and those with only minor or no injuries. Also noted are any third party injuries, that is those on the ground. The major countries collect their own data and use it in a variety of ways, the rest report to ICAO (the International Civil Aviation Organization of the UN).

Comparisons are made between countries, areas of the world and year by year. The occurrence of accidents and incidents is to be related to exposure data in order to assess risks and to obtain an indication of the urgency and potential benefits of certain countermeasures.

In aviation, data is available, or gathered on accidents, in varying levels of details, including information on relevant conditions, like weather, maintenance records etc. No such systematic data collection is available for unscheduled, uneventful flights. With such data it is possible to calculate accident rates, for example, number of accidents per departure or per flight hour. Also, when combined with weather data, accident rates as a function of outside conditions could be calculated and analysed. However, there is enough available in the operational world to obtain the relevant exposure measures, such as totals on number of departures per airport and the total number of flight hours per airline. These data are published by the local airport authorities and the international organisations, as ICAO, airline organisation IATA, and airport organisation ACI.

2.4. Sea

Waterborne transport concerns transport over seas and in-land waterways. Due to the lack or scarcity of relevant data with regard to accidents and exposure of passenger transport on in-land waterways, only passenger transport over seas can to some extent be considered.

For maritime passenger transport world based accident data are not being available with the exception of the casualty database of LMIS (Lloyds Marine Information Services). This database is gathered using the global agent network that has been built up by LMIS. However in many cases LMIS is unaware of accidents in some sea areas and consequently the data in the database are misleading to obtain a complete picture of all accidents. Risk analysts need to supplement the Lloyds accident data with local data coming from different sources (mainly the Coast Guards, Admiralty Courts and Maritime Safety Agencies).

Exposure data related to maritime passenger accidents are scarce. More than in any other mode the threat of maritime accidents, except for ferries, concerns the environmental damage and economic costs. The maritime exposure data in relation to accidents of different vessel types take different forms. Statistics are frequently given in terms of lost vessels in percentage of numbers of vessels that are operational or in percentage of Gross Tonnage. IMO (.........?...........) has a keen interest in the safety of oil tankers and in association with LMIS the number of serious accidents with oil tankers are being compared with the number of tanker years sailed for a number of size classes. These data are of great importance in the maritime domain, because the environmental and other costs dominate the total costs of maritime accidents (ETSC, 1996).

Fatalities are not normally given in those statistics although in some cases the number of fatalities is published in casualty returns form Lloyds or insurance companies. In Watson (19..) there is a table that provides an insight in the magnitude of fatalities in this century, but this table does not include ferry disasters.

The data gathered generally do not permit an analysis per area. However, in COST 301 (19..) an attempt has been made to analyse different European areas, such as the Atlantic Approaches, the Baltic, the Mediterranean and the North sea. The table in annex 1 (taken from ....), provides some data regarding disasters with ferries in European waters from the decade of 1985 to 1994. From this table it follows that 6 out of 29 ferry disasters are accompanied with occurrences of (sometimes massive) fatalities. Thus about 80% of the ferry disasters are without fatalities, while fatalities mainly occur when ferries capsize. Five out of 29 in ten years capsized (=17%), one without fatalities and the other four capsized ferries account for 1110 fatalities out of a total of 1408 fatalities for ferry disasters (=79%) in European waters. Only one fire disaster and one collision disaster of ferries account for the other fatalities. Only about 6% are ferry disasters that are due to collisions, which is quite different from most other passenger transport modes (about 70% of the accidents in road traffic are collision accidents).

The available data and their relations are used to determine different exposure measurements. In COST 301 the ship miles and encounter frequencies, obtained from the combination of ship miles and their route structure in European waters, are both used as exposure measurements. The encounter frequencies in relation to collisions and ship miles in relation to nearly all other types of accidents. On the basis of the voyage records that contain data regarding the vessel and the port of departure and the port of destination (for European waters about 1.5 million voyage records in one year are available) and a route structure the number of ships on each link (as part of a route) for European waters is determined. This route structure and the ships allotted to it lead to the number of ship miles sailed, whereby the accident rates per million miles sailed are determined. The route structure is also used to calculate the number of encounters. An encounter is a penetration of a ship in the domain of another vessel. This domain is taken to be a circle with a diameter of one mile. The encounters are classified in passing, overtaking and crossing encounters and the relevant number of encounters is used as exposure in the collision rates for these three categories.

Since fatalities do not play a large role in global shipping their risk values are not being widely discussed. Also in COST 301 no special attention was given to fatalities. In a recent study, initiated after the disaster of the ESTONIA, the fatality risk of ferry transport is compared with the fatality risks of other modes of transport (2 ...., 19..). In this study the following exposure parameters are used:

-vehicle hours	and	-vehicle miles (sometimes km, generally nautical miles)
-passenger hours	and	-passenger miles (sometimes km, generally nautical miles).

In some cases the fatality risk per exposure time, defined as the number of fatalities per million exposure hours or mortality rate (MR), defined as the number of fatalities per 100,000 inhabitants are being used if a comparison with other activities is made. Such values, for example, are used to assess the danger of sea environment for fishers in relation to shore based jobs.

Summarizing, the following exposure measures in the maritime domain are being used:

-number of ships
-ship years or hours
-ship miles
-passenger miles
-total GT of ships exposed
-ship encounters
-passenger hours
-inhabitants (e.g.: MR for coastal and sea jobs of fishers)

2.5. Combined transport modes

It is of interest to compare travel modes in cases where a traveller has a clear choice between travel modes for the same trip between points A and B.

One main case in this respect is daily journey-to-work trips in urban areas. In this case the interesting comparison is between door-to-door trips by different modes of transport. From a safety point of view it is of interest to be able to evaluate the safety effects of a change in the modal split, i.e. it is interesting to compare the risks associated with journey-to-work trip alternatives such as: Walk - train - walk;
Walk - bus - train - walk;
Bicycle - train - walk; etc.

Generally the travel distances per mode are different. On average the trip by train will be longer than the trip by bus simply because the bus network in an urban area will generally be much denser than the train network. Bus travel will in general contain some detour distance compared to car travel. So trips that fulfil the same travel need may be different. What is of special interest here is that the walking mode is involved in almost all trips. In fact, for journeys to work the risk as a pedestrian often is a major part of the total risk. Therefore, it is very important to have good data on the walking distances and accidents of pedestrians.

It is well known that pedestrian risk on urban streets is dependent on the volume of motor traffic. Therefore, it would be of interest to measure pedestrian activities in different urban environments such as e.g. rural, suburban, dense urban, etc. In cities where bicycle traffic is of importance similar studies as those for pedestrians would be useful.

A special problem related to urban trips is the risk associated with change between means of transport. It is known that in some cities collisions at bus stops between other vehicles and pedestrians are of some importance. Such accidents with bus passengers getting on and off the bus constitute an important part of all accidents related to urban bus passengers, but are registered as pedestrian accidents and not as bus passenger accidents. Therefore, in connection with change of travel mode it is of some importance to have data on the number of passengers entering and leaving busses and trains as well as their accidents in their periods of mode change. This will be a useful piece of exposure and accident information for the risk comparison between trips using several travel modes. If a change in modal split is substantial the accident data may change so much due to a changed traffic environment that risks may change. This, however, does not reduce the need for the exposure data and for data on passengers entering and leaving busses and trains. In a given urban area a detailed study of the safety effects of a change in modal split will require a local travel survey with enough response in order to obtain the geographical distribution of the modal trips and their combination frequencies. From such data and detailed local accident data it is possible to estimate the overall safety effects of a given change in the modal split.

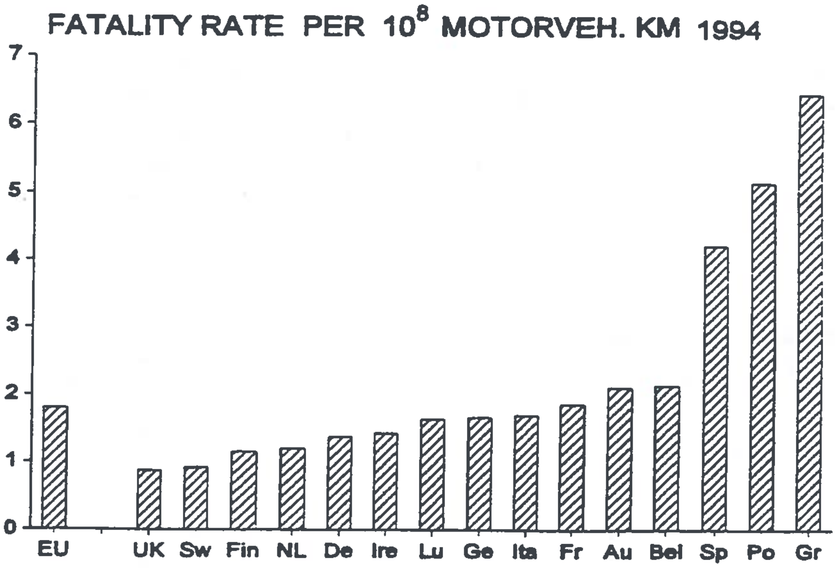
It should be kept in mind that travel on roads not only produces a risk to the traveller, but also to other road users. Pedestrian travel produces very little risk to others, while bus kilometres with the lowest risk for its passengers produces a much higher risk to others. The risk to other parties from a bus or other vehicle does not relate to its number of passenger kilometres, but to exposure as the number of encounters with the bus or other vehicle, which depends on the bus or other vehicle kilometres as well as on the kilometres of other parties in the traffic environment of the bus or other vehicle. For the assessment of risk to other (groups of) road users, therefore, one also needs information on the exposure of the (groups of) other road users per traffic environment.
Another type of trips that combines modes are long and medium long distance trips, where the choice between transport by planes or high speed trains or coaches can be relevant. Apart from the walking involved, the relevant data for the different exposure to risk can be reliably obtained from the data that pertain to the separate modes, because generally special circumstances that invalidate their use need not to be considered in these cases. Clearly the risk of the total trip increases if the share for the most risky mode is increased and decreases if the share of the safest mode becomes larger. However, the influence depends on the risk definition as risk per travel distance or risk per travel hours. Since long distance and home-work trips generally are not performed for the spending of (leisure) time, it seems most appropriate to use travel distances as the relevant exposure to risk in these cases.

3. Illustrations of use for risk assessment within the modes

This chapter contains case study type examples for some EU countries, the EU or European region which illustrate the benefits of exposure data and how beneficial it is to have information on what is risky and where it is risky. The risk figures in the examples given are mainly fatality risks, because fatalities are almost completely registered and more or less identically defined (for road fatalities death within 30 days after the accident). Injury accidents are in road traffic to different extents not registered in different countries and injuries are differently defined in the different EU countries. Definitions of injuries are also different for different modes. It makes comparisons of road injury risks between different countries and injury risk between different modes to a large extent meaningless, but a comparison of road injury risks within some countries and casualty risks for the maritime domain are presented in this chapter.

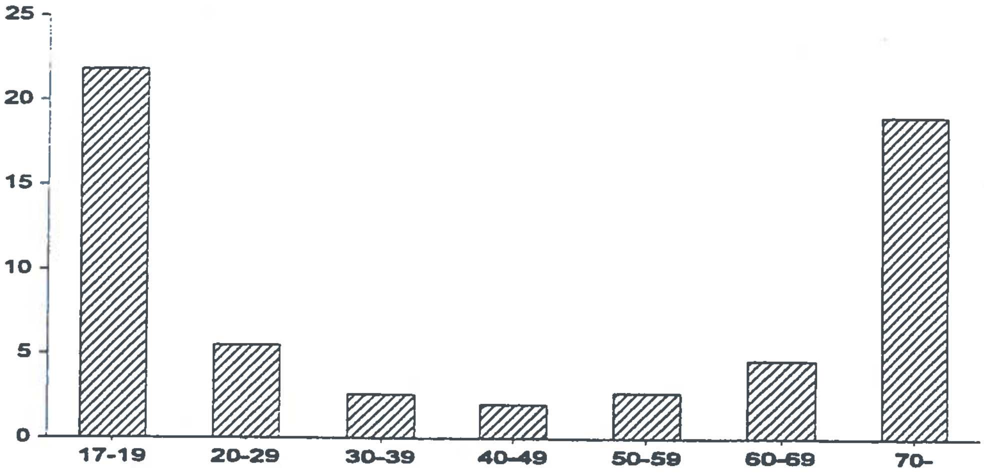
3.1. Road

Detailed exposure information is widely used to compare the road risks of different groups of travellers, as a first step in developing effective countermeasures. Generally the effectiveness of countermeasures can not be evaluated without the use of exposure data. An example of the use of national exposure data is shown below, where the motor vehicle kilometres in the countries of the EU are used for the comparison of their road fatality risks (FERSI, 1997).



For Greece, Portugal (before 1995) and Luxembourg the annual motor vehicle kilometers are unknown, their rates are estimated from the known rates per motor vehicle and the linear relation between rates per kilometer and per vehicle for the other EU countries.

An example from more detailed exposure data is the risk of car drivers per age class, where it is generally found that the fatality rate per kilometre driven falls steeply with age until the age of about 50 to 60, after which it begins to rise. This is shown by the next graph for Great Britain.



Fatality risk per billion km. for car drivers in Great Britain 1989-'91

A similar graph can be made for fatality risks for age categories of car passengers, where the relevant exposure is car passenger kilometres per age category obtained from traveller surveys. When corrected for the risk contribution from the age of the driver (positively correlated with passenger age) the passengers below the age of 60 show an almost constant fatality risk (teenagers somewhat higher: lower belt-use level and more risky driving with passengers than without), but for car passengers above the age of 60 also a sharply rising fatality risk is observed (Koornstra, 1996). Thus it can be deduced that it is mainly the driving behaviour of young (unexperienced) drivers that causes their high fatality risk, while the high fatality risk of the elderly is mainly caused by their increased physical vulnerability and not so much by their possibly reduced driving capability. Without detailed exposure information such inferences could not be made.

Another example of the use of such detailed exposure data highlights the different risks of different roads with different layouts and different mixtures of road users, as shown in the next table for the more or less comparable road types in the Netherlands and Germany.

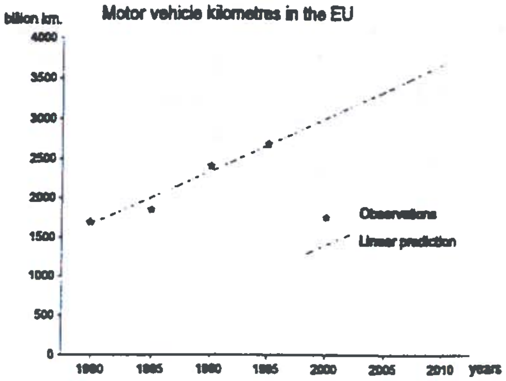
Road Type	Speed limit Neth.	Speed limit Ger.	Mix fast slow	Crossing opposite traffic	Injury rate 10^6 km Neth.	Injury rate 10^6 km Ger.	Fatality rate 10^8 km Neth.	Fatality rate 10^8 km Ger.
calming area	30	---	yes	yes	0.20	-----	0.3	---
residential roads	50	50	yes	yes	0.75	1.75	1.0	1.7
urban arteries	50/70	50/>50	yes+no	yes	1.33	1.37	2.3	2.1
rural roads	80	100	yes	yes	0.64	0.44	3.6	2.8
rural arteries	80	100	no	yes	0.30		1.8	
rural motor roads	100	100	no	no/yes	0.11	0.26	1.0	0.8
motorways	100/120	no	no	no	0.07	0.15	0.4	0.5

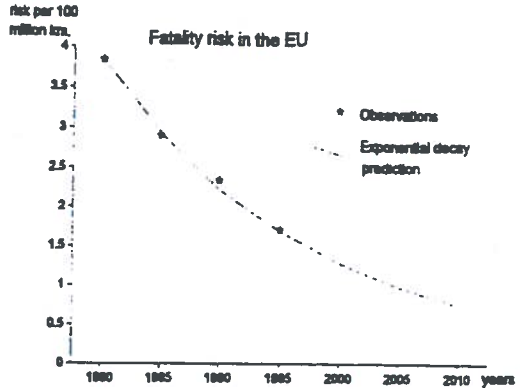
Risks per motor vehicle kilometres on road types in the Netherlands '94 and Germany '93

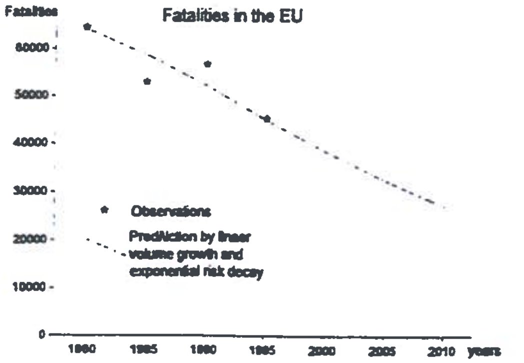
This table with injury and fatality rates per road type clearly shows that the risks are a function of allowed speeds and traffic complexity. It shows that conditions of either low speeds (calming areas) or low traffic complexity and highly predictable infrastructure (motorways) must be fulfilled in order to obtain relatively low risks, otherwise the road risks are manifold increased. The highest injury risks are on roads with a high traffic complexity and moderate speeds (residential roads and urban arteries with slow and fast traffic), while the highest fatality risks are observed if traffic complexity and speeds are high (rural roads with slow and fast traffic).

Exposure information is also used to compare changes over the years, to measure improvements in road safety and to help understand the reasons for changes in the casualty statistics. In Great Britain, for example, the pedestrian casualties have fallen fairly rapidly in recent years, but results from travel surveys show that this has partly been caused by a reduction of walking (reference ?).

Fatality rates per motor vehicle kilometres tend to decrease over the years in an exponential way, while the growth of motor vehicle kilometres tends to follow a S-shaped curve with an almost linear growth in the mid part of the S-shaped curve. This has been shown to be the case in many countries (Koornstra, 1992). It also is applied to the developments in the EU, where for the mid part of the S-shaped growth curve a linear growth for vehicle kilometres and an exponential decay for fatality risk are fitted to the observations from 1980 to 1995, as shown in the next figures.





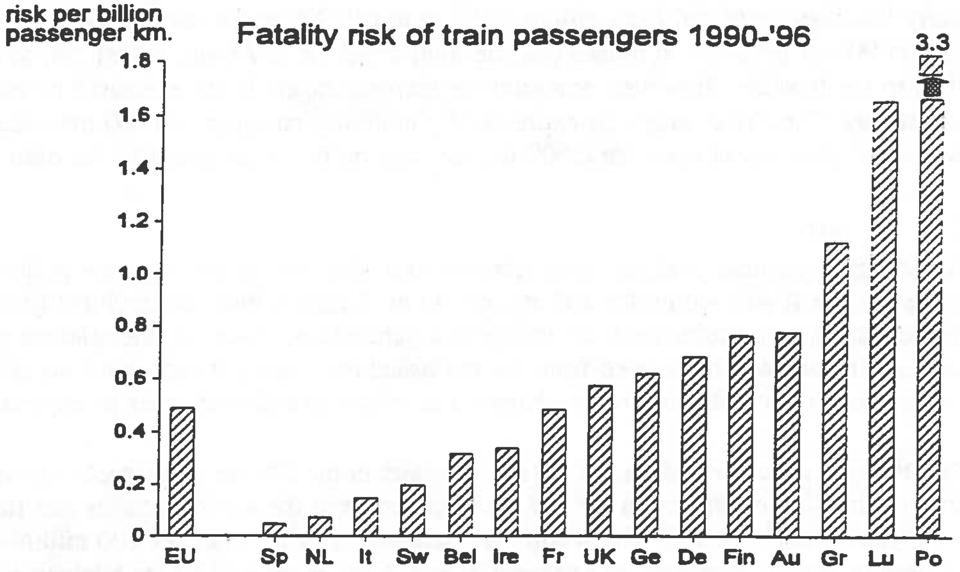


Extrapolated decay of risk with some reasonably accurate estimates of further traffic growth can be used for predictions of the fatalities in the future under the condition of equal effectiveness of road safety policies. This is illustrated for the EU in the left figure. Since the constant 5% of annual risk decay is larger than the decreasing annual growth percentage of motor vehicle kilometres, it shows that the overall trend in the road fatalities of the EU is decreasing. The expected number of road fatalities in the EU for 1998 is about 42.500 and the expected fatality risk per 100 million motor vehicle km. about 1.43 or 1.1 per 100 million passenger km.. Road fatalities in the EU have shown a maximum in the early seventies, because before the oil crises in '72/'73 annual growth percentages of motor vehicle kilometres has been larger than the 5% annual risk decay in the EU.

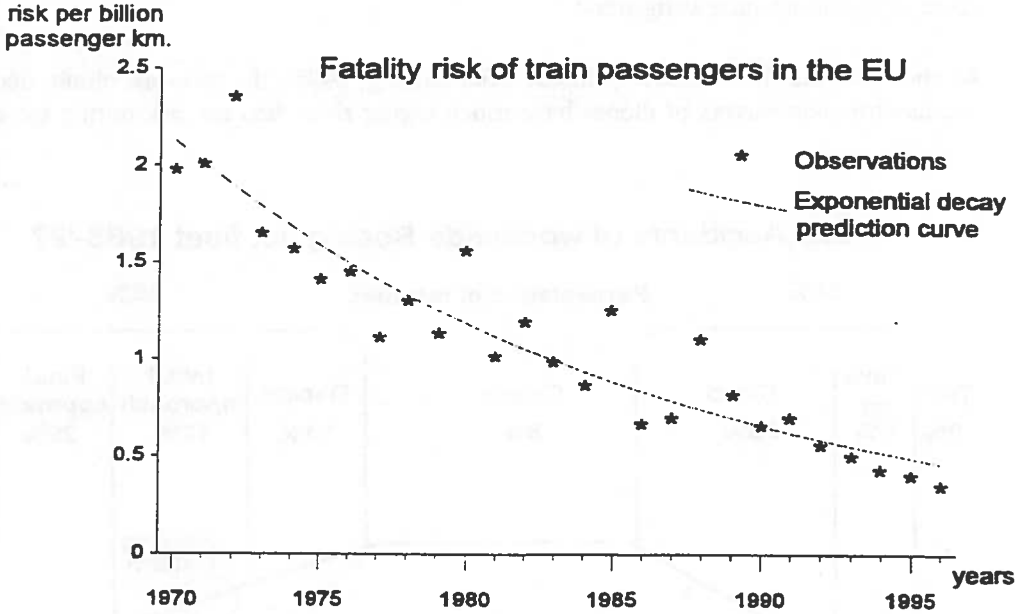
These types of information are especially useful when trying to understand the past as a basis for the prediction of future developments or the setting of realistic road safety targets. Research has also shown that a weighted sum of annual exposure and annual fatalities closely predicts the annual numbers of injured road users in several countries (Koornstra, 1992), so that the number of fatalities as well as the number of road injuries in a country can be forecasted by reasonable accurate predictions of exposure and fatality risk. These forecasts are not only useful for the preparation to set a target for future fatality and casualty reductions. Once forecasts have been made or targets have been set, exposure data collected in subsequent years will contribute to the monitoring of progress towards the forecasts or targets: for example, if progress proves to be slower than predicted, has this been caused by unexpectedly rapid growth in the volume of travel or by unexpectedly slow progress with reducing the level of risk?

3.2. Rail

The average annual fatality risk per passenger kilometres for travellers of the railway systems in the countries of the EU over the period from 1990 to 1996 differ very much between the countries. The average annual EU risk is 0.49 per billion passenger km. over 1990 to 1996, but the mean risk of the safest two (Spain and the Netherlands) and the most risky two (Luxembourg and Portugal) differ by a factor 8 to 10 from the average risk of train passengers in the EU. However, the consistently high risk for Portugal may be regarded as outlier. The next graph shows these national differences of the annual fatality risks per 10^9 passenger kilometres for the period of 1990 to 1996.



The average fatalities per year for train passengers in the EU decreased from almost 400 in the early seventies to around 100 in the last three years. For 1970 to 1996 the rail passenger kilometres in the EU (all 15 from 1970 onwards) increased from about 200 billion to about 270 billion. It means that in the EU the fatality risk for rail passenger decreased from 1970 to 1996 with an average decay of just over 5½% per year. This is shown in the graph below.



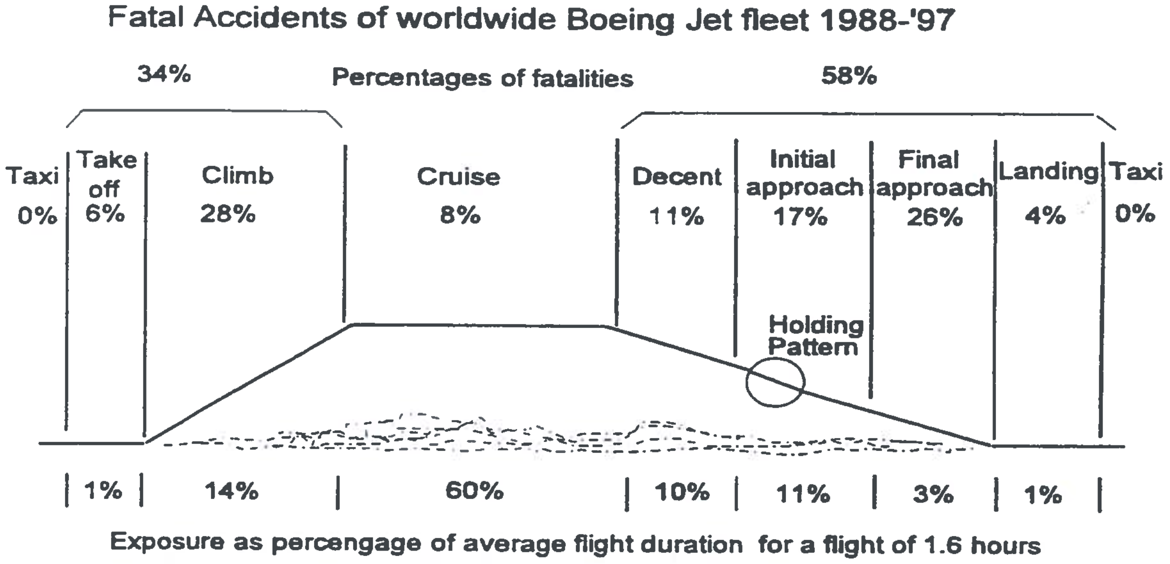
The risk curve shows that the expected risk per 10^9 passenger km for the late nineties in the EU is about 0.4, which for 270 billion trian passenger km. means about 108 expected fatalities per year.. Most years have a somewhat lower risk then the curve predicts, because some years have higher risk due to exceptional rail disasters. Due to recent disaster of the high speed train in Germany, the actual EU risk for 1988 also may be higher than 0.4 per billion passenger km., but that still is the best recent estimate of the expected risk. The average of rail staff fatalities decreased from about 350 in the early seventies to about 35 in the mid nineties. The corresponding average for third party fatalities decreased from around 1300 to nearly 700 in the late eighties, but increased to almost 900 in 1993-'96. It means that the train travel has a 9 times higher risk to other persons than to the traveller. However, exposure for non-passengers is not measured by passenger kilometres. Their risks might be expressed by mortality rates per 100.000 inhabitants of the EU, which for their recent rates are 0.009 for rail staff on the trains and 0.24 for third party fatalities.

3.3. Air

Air transport accident statistics are presented in a wide variety of ways, but published risks do not related to the flights within the EU and not all air fatalities from unscheduled flights are reported in the statistics of international air transport organisations. However, the relevant risks for the EU can and in here will be derived from the published data. Since it here concerns people and not cargo, the derived risks are for passengers and related to different types of exposure.

Due to large annual variations in aircraft disasters in the EU the most stable trends in the risk of air passenger transport within the EU are obtained from the world statistics and the average share for flights whithin the EU. The worldwide passenger fatality risks per 100 million air passenger kilometres also decreases in an exponential way from about 0.24 in the beginning seventies to just below 0.5 for the last three years (ICAO, 1998) with an average decay of about 6% per year. The corresponding risk of fatal accidents per 100 million flight km. decreased from 0.5 to just below 0.2 in the recent years (ICAO, 1988) with an average decay of almost 4% per year. Thus the annual fatality risk per 100 million passenger km. for today can be estimated as 0.045 and the updated fatal accident risk per 100 million flight km. as 0.19. In contrast to road and rail transport the annual growth of passenger air transport in the last decades has not been less than the fatality risk decay (both 6%). Therefore, the number of fatalities from air passenger transport shows no decreasing and no increasing trend.

As shown in the figure below (adapted from Boeing, 1998), the take-off, climb, decent, approach and landing manoeuvres of planes have much higher risks than the risk during the cruise flight.



The safety procedures and ground communications for these plane manoeuvres in areas of the airports, therefore, are of crucial importance. The level of the risks can differ markedly by global regions for airports of destination and depart, if there are regional quality differences in these procedures and ground communications. That the risks over the decade of 1983 to 1992 indeed mainly differ by global regions of airports and not so much by the home country of the flight operator has been shown in a study of Ho (199.).

This study shows not only that the European region (without the former USSR) and the North-American and South-West Pacific regions have approximately equal risks, but also that these three regions have just less than half the risk of all other regions together. Since flights within and from/to the three safer regions account for just over 65% of all landings and takeoffs for scheduled passenger flights (IATA, 19..) the worldwide fatality risks for air passengers can be differentiated into risks for these safer regions and the rest.

Flights within and from/to the European region (without the former USSR) accounts for almost 25% (20% within and 5% intercontinental flights; see IATA, 19..) of all passenger flights in the world, but the fatality risk per 100 million passengers for the safer regions also applies to all flights within and from/to the EU region. Thus, because 65% times the European risk and 35% times twice that risk equals the worldwide risk, it is possible to estimate the recent air passenger risk per 100 million passenger kilometres for the European region from that worldwide risk by its proportional factor of 1/(0.65+ 2*0.35)=0.74, thus as 0.74*0.045=0.033. The same correction holds for the risk of fatal accidents per 100 million flight km. as 0.74*0.19=0.14.

The updated key-figures and exposure measures (codes p,q,r and x,y,z) for air passenger transport presented below are obtained from a diversity of sources (references.........?). They apply to all scheduled flights of commercial operators and to the additionally estimated number of non-scheduled flights (of mainly charter operators), but not to general aviation (incl. private planes).

Type of exposure	All flights (incl. intercontinental) worldwide	European (ex. USSR)	National and continental flights within EU region
Passenger planes	20,000	5,000	3,600
Flights per plane year	1000	1000	1,250
Passengers per flight	100	100	80
Flight duration	2.5 hours	2.5 hours	1.6 hours
Flight distance	1500 km.	1500 km.	720 km.
p. Passengers per year	2,000 million	500 million	360 million
q. Passenger km. p. y.	3,000 billion	720 billion	260 billion
r. Pass. hours p. year	5 billion	1.25 billion	567 million
x. Flights per year	20 million	5 million	4.5 million
y. Flight hours p. year	50 million	12.5 million	7.2 million
z. Flight distance p. y.	30 billion km	7.5 billon km	3.24 billion km

Referring to the above shown figure, the difference in risk per flight between flights of 1.6 hours. within a global region and all flights within and from/to that region with an average duration of 2.5 hours will be small, since only the duration of to the cruise flight (accounting only for only 8% of the risk in a flight of 1.6 hours) is different for the intercontinental flights. For the same reason the risk per flight distance will be much higher for short flights than long flights. Taking the index for the accident risk of the illustrated flight of 1.6 hours as unity, the next table shows the varying risk indices of four typical flights for accident risk per flight, flight duration and flight distance.

Flight duration	ground distance	non-cruise time	non-cruise risk	cruise time	cruise risk	accident risk index per flight	flight hour	flight distance
1 hour	360 km.	0.64	0.92	0.36	0.030	0.950	1.520	1.900
1.6 hours	720 km.	0.64	0.92	0.96	0.080	1.000	1.000	1.000
2.5 hours	1500 km.	0.64	0.92	1.86	0.155	1.075	0.688	0.516
7 hours	5750 km.	0.64	0.92	6.36	0.530	1.450	0.331	0.182

Thus the fatality risk per passenger kilometres for flights within the regions of the EU (average 1.6 hours.) is estimated to be higher than the same risk for all flights within and from/to the EU (average 2.5 hours) by a factor 1.0/0.516 (for shorter flight distance) times 100/80 (for less passengers per flight), which yields 2.42 x 0.033=0.08 as the fatality risk per 100 million passenger km for flights within the regions of the EU. These updated risks, the resulting expected fatalities and the fatality risks per 100 million air passenger hours as the most relevant figures for comparison with other modes ans activities are summarised in the next table.

	All flights (incl. intercontinental) worldwide	European (ex. USSR)	National and continental flights within EU region
a. Fatalities/100 million pass. km.	0.045	0.033	0.08
b=qxa Expected Fatalities '98	1350	250	207
c=b/r Fatalities/100 million pass. h.	27	20	36.5

One may define risks that relate to other exposure measures. The fatal accident risk per 100 million flight km. for flights within the EU is estimated as (1.00/0.33) x 0.14=0.42 in a simialr way as for the above table. These risks and several alternative risks are given in the next table, where the codes for the rates relate to the ones of previous tables.

	All flights (incl. intercontinental) worldwide	European (ex. USSR)	National and continental flights within EU region
d. Fatal accidents/100 million flight km.	0.19	0.14	0.42
e=b/z Fatalities/100 mill. flight km	4.5	3.3	6.4
f=b/x Fatalities/ 1 million flights	67.5	50	46
g=e/d Fatalities/ Fatal accidents	23.6	23.6	15.2
h=f/g Fatal accidents/ 1 million flights	2.9	2.1	3.0

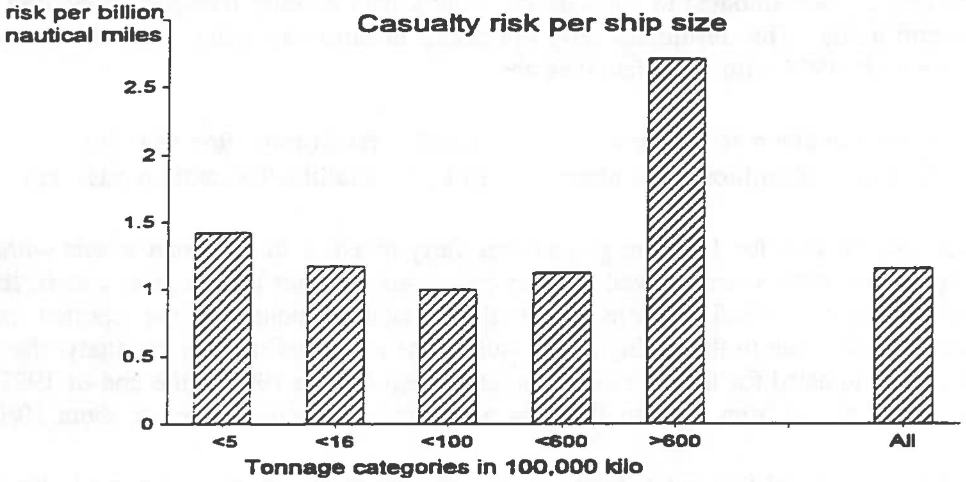
3.4. Sea

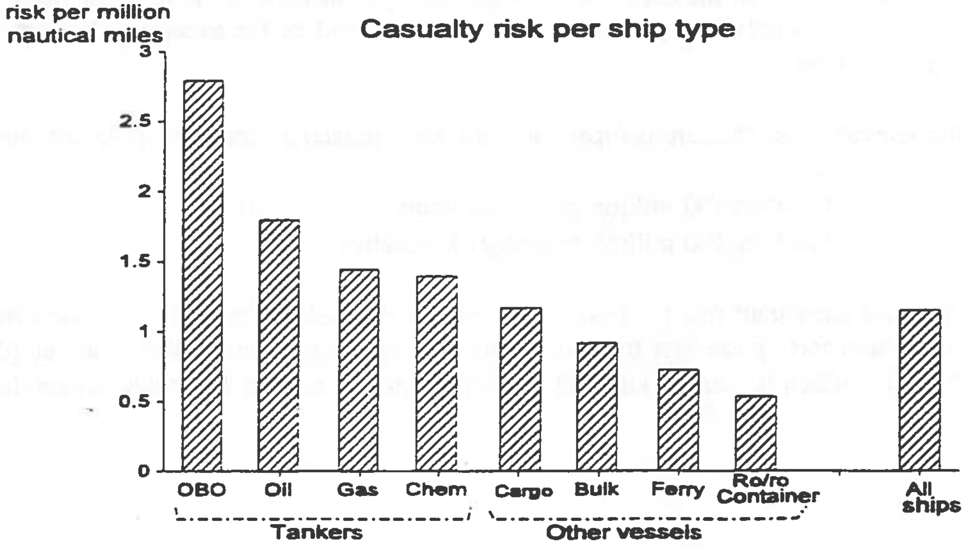
Risk statistics for maritime transport are often given in terms of lost vessels in percentage of the numbers of vessels that are operational (EU-waters: 0.5%) or as a percentage of Gross Tonnage (EU-waters: 0.4%) (reference... ?). A typical risk value for tankers is their collision rate as 0.3 per 100 tanker years sailed. Typical risk values for all types of tanker accidents are about 2.5-3 per 100 tanker years sailed (reference... ?). On the basis of damage characteristics it is possible to determine the penetration of tanks and to calculate the spill of oil. For European waters also accident rates per 10^6 nautical miles are determined for types of ship accidents (reference ..?) as:

meeting collisions	0.279	crossing collisions	0.155	overtaking collisions	0.061
stranding	0.483	ramming	0.070	foundering	0.105

Such accident risk and the regional exposure are of great importance for the size of the oil abatement or rescue and assistance fleets which are required by coastal states to abate the consequences of oil tanker or other ship disasters. However, here the concern is risk of persons.

Casualty risks per million nautical miles for ship size and ship types are shown in the next graphical presentations (reference...?).


Casualty risk per ship size


Casualty risk per ship type

The following table shows how exposure as encounters (see section 1.4) is used in the calculation of the effects of a vessel traffic service (VTS) (reference 4...?) often in combination with a traffic separation scheme by the collision rate (CR) per 100.000 encounters of different types..

Type	CR Total	CR (VTS)	CR (no VTS)	effectiveness
meeting	0.589	0.310	0.636	48.7%
crossing	4.381	3.888	4.500	86.4%
overtaking	0.640	0.104	0.765	13.6%
all	0.817	0.533	0.871	61.2%

It demonstrates how useful it is to have the relevant detailed exposure data for the assessment of risks in the evaluation of the effectiveness of countermeasures. The use of encounter frequency as exposure could also be relevant for other modes, especially in road transport, but there hardly is any research on this type of exposure in the other modes.

Up to recently one hardly could present any results on fatality risks of passenger transport in European waters. However, as a direct result of the ESTONIA disaster in 1994 a study (reference..?) was initiated to compare the fatality risks of ferry transport in relation to other transport modes. The results for ferry operations in European waters from this study over the decade 1985-1994 with 1408 fatalities are:

fatalities/million ferry hours	0.842	fatalities/million ship km.	2.61
fatalities/100 million pass. hours	14.8	fatalities/100 million pass. km.	0.458

Since also the data for 1984 are given (three ferry disasters in European waters without fatalities), while the last three years showed no ferry passenger fatalities in European waters, the exceptional ferry disaster of the ESTONIA in 1994 with 850 fatalities dominates the reported risk estimates in a selective way due to the timing of the study. The estimated risks in the study, therefore, must and can be updated for the 14 year observation period from 1984 to the end of 1997 (in stead of the 10 year period from 1985 to 1994) by a corrective reduction factor of about 10/14=0.714.

The lower values of the updated risks are not the result of a downward trend in the risks, as observed for the fatality risks in other modes, but estimate by the absence of any observable trend the constant risks from the data over a longer period than used in the referred study. The updated estimates are thus only less (or not) selectively dominated by the exceptionally high number of fatalities for 1994.

So the relevant risks that are comparable with other passenger transport risks, become updated as:

fatalities/100 million passenger hours	10.5
fatalities/100 million passenger kilometres	0.33

and because a constant risk for ferries can only be inferred, the annually expected number of fatalities from ferry passenger transport in the EU-waters is 1408/14, that is about 100 per year for the 30.3 billion passenger km. that ferries within and to/from EU countries produce nowadays.

4. Illustrations of use for risk comparisons across the modes

In this chapter mainly fatality risks, but also fatal and serious injury risks, for the different road modes and the other modes are compared. Definitions of injuries are different for different modes, but a comparison of fatal and serious injury risks is not meaningless, because all definitions of serious injury imply a hospital treatment of 24 hours and longer. Due to the under-reporting of serious injuries in road accidents, a comparison of fatal and serious injury risks asks a correction for road traffic. Since the average under-reporting of serious injuries in road accidents of the EU has been estimated (ETSC, 1977), that correction is applied. The comparison of the fatality risks for travellers that combine different modes for their journeys also is discussed in this chapter.

4.1. Comparison of risks between road modes

The following table gives the risk for road users (passengers and drivers or pedestrians) of different road modes per 100 million passenger (or road user) kilometres and 100 million passenger (or road user) hours for Great Britain and the Netherlands.

Country	Great Britain		the Netherlands	
Travel by	10^8 hours	10^8 km.	10^8 hours	10^8 km.
Bus or coach	1	0.04	0.8	0.03
Car	15	0.4	15	0.40
Foot	20	5.3	8.5	2.25
Bicycle	60	4.3	27	1.95
Motorcycle	300	9.7	200	5.90
Moped			200	8.73

Sources: TRL and SWOV

The corresponding figures are not known for many countries of the EU, but the British and Dutch road traffic risks are the lower ones in the EU (see section 3.1.). Their average risks of total road traffic is half the estimated recent risk for road traffic in the EU.

4.2. Comparison of risks between passenger transport modes

The following table gives the recent fatality risks for the different passenger transport modes per 100 million passenger or road user kilometres and 100 million passenger or road user hours for the EU, estimated for the road modes by twice the average of the specified risks in the previous table and for trains, planes and ferries within the EU or EU regions by the risks of chapter 3.

Mode		10^8 person km.	10^8 person hours
Road	total	1.1	33
	bus/coach	0.08	2
	car	0.8	30
	foot	7.5	30
	cycle	6.3	90
	motorcycle/moped	16.0	500
Trains		0.04	2
Ferries		0.33	10.5
Planes		0.08	36.5

Fatality risks per kilometres and hours for each mode in the EU

Comparable figures for all modes are given by Collings (1994) for Great Britain. When the adjustments to the EU region and updates for the fatality risks of the modes are taken into account, the risks given by Collings and the ones in the table above are almost identical.

Travelling by train is the safest mode in the EU when the fatality risk is expressed per passenger kilometre and expressed per passenger hour, the latter equals the bus or coach. So trains and bus or coach have the lowest fatality risk per passenger hour of all modes. Travelling by bus/coach is the safest road mode in the EU, either expressed by fatality risk per passenger hour or per passenger kilometre, but the fatal accident risk per vehicle kilometre is similar for busses and cars.

Travelling by plane within the EU has the same fatality risk per passenger kilometre as travelling by coach. However, flying in the EU region is less safe in terms of passenger hours spend in the mode, due to the relatively high speed of planes. The fatality risk per passenger hours for flying in the EU region is in average about 18 times higher than for travelling by train or coach, and turns out to be about 10% higher than the fatality risk for all road traffic in the EU.

Travelling by car is per distance has a 10 times higher fatality risk than travelling by bus, but its fatality risk also is also almost 10 times lower than for walking. Travelling by two-wheeled motor vehicles is the most risky mode by both measures, its fatality risk per distance is 20 times higher than for travelling by car. All road modes together show that road transport is the most risky mode. The fatality risk for road traffic is 27.5 to 3.33 (per distance) or 16.5 to 0.9 (per hour) times higher than for the other passenger transport modes.

The risk of death and serious injury from road transport are once again a factor much higher than for the other modes, because serious injuries occur relatively more often in road transport. The ratio of registered serious injuries to fatalities in 1995 vary from almost 12 for Germany to 4 for France and Portugal with an average ratio of 8 for the EU, but that ratio of 8 must be corrected for about 30% of the serious injuries in the EU that are not registered by the police (ETSC, 1997). Moreover, that ratio tend to increase over time. Thus the ratio of serious injuries to fatalities for the road mode in the EU is at least 11½. For the other modes these ratio's are around 1.3 for ferries, 0.5 for planes and 2 for trains (ETSC, 1997). The lower ratios of the other modes are explained by the higher fatal impact of disasters for planes, trains (accidents with very high kinetic energy) and ferries (accidents with massive drowning) than for road accidents.

Since all definitions of serious injury imply a clinical treatment of 24 hours, a comparison of fatal and serious injury risk for the different modes in the EU is a meaningful one. Thus from the fatality risks and the given ratios for serious injury to fatalities the risks of death or clinical treatment from travelling by the different modes in the EU can be estimated. These comparable risks are presented in the next table.

Transport mode	Risk of death or clinical treatment 10^8 person km	 10^8 person hours
Road	13.8	413
Train	0.12	6
Ferry	0.76	24
Plane	0.12	55

Risk of fatal and serious injury by travel in the EU

The risk of death or clinical treatment for the road traffic is 115 to 18 (per distance) or 69 to 7½ (per hour) times higher than for other modes. This risk per distance for trains and planes is equal.

4.3. Comparison of risks between intermodal trips

The scarce studies on suburban/urban home-work trips (see: Jorgensen, 1996) have shown that in several cases it is safer for the traveller to be a car driver than a bus or train passenger, because travel by car avoids the high risk activity of walking or cycling that is necessary before and after the travel by train or bus. But in a social context bus or train travel is safer, because one car driver inflicts more accidents per kilometre on other road users than walking or cycling and a number of car drivers thus manyfold more than an additional bus or train for that number as passengers. The presented risks of each mode up to now are the traveller's own risk and do not contain the risks to other travellers or persons. For ferries and for planes to a lesser extent the latter risk are small, but not for several road modes and trains.

Based on the own risks per distance in section 4.2. the next examples of risks for the traveller in combined mode trips for typical distances of home-work journeys are given in the next table.

Typical home-work trips by combined modes					Total trip km.	fatality risk per 100 million km.
walk ½ km	+	bus 8 km	+	walk 1½ km	10	1.56
walk ½ km	+	bus 10 km	+	walk ½ km	11	0.75
cycle 3 km	+	train 12 km	+	walk 1 km	16	1.68
walk ½ km	+	train 15 km	+	cycle 2 km	17½	0.97

The same trip distances per car, assuming 100 metre walking for access to the car and home-work trips without car distances on the safer motorways (usually about 20% of the car kilometres with half the risk of their total kilometres), would have given fatality risks of about 0.95. Since walking and cycling for the average of the EU are not so much different in risk, one can conclude that the share of walked and/or cycled distances before and after a trip with a bus or a train generally must not exceed 15% of the total trip distance, otherwise the whole trip by car is safer for the traveller. This percentage, however, is about the average for EU countries, but will be different for different countries and for different suburban or urban environments within a country. The individual choices for public transport in home-work journeys with not too long bus or train distances generally are for the safety of the travellers in home-work trips better replaced by choices for car travel. However, this does not take into account that the risk for other road users than the traveller becomes manifold increased when the car instead of public transport is used.

Jorgensen (1996), who studied in detail the risk of trips that combine land transport modes for the dense urban and suburban areas of Copenhagen, gives for different modes in these areas fatality risks that are differentiated into ones own risk per distance as road user or passenger and the risk per distance of the traveller to other road users or persons. They are presented in the next table.

Travel mode	Dense urban area own risk	Dense urban area other's risk	Suburban area own risk	Suburban area other's risk
Pedestrian	9.8	0.1	2.0	0.03
Bicyclist	4.5	0.1	2.8	0.1
Car occupant	1.3	1.4	1.0	1.1
Bus passenger	0.05	0.5	0.05	0.5
Train passenger	0.02	0.16	0.02	0.16

Fatality risk per 100 million passenger km. in and around Copenhagen

For realistic weighted averages of dense urban and suburban distances the own risks per mode of the traveller for the Copenhagen region are different for the ones that are presented for the average of the EU in section 4.2., except for walking. For the Copenhagen region the fatality risk of car occupants is about 25% higher and that risk of train or bus travellers about 40% lower, which contributes to relative safer trips that include public transport in the Copenhagen region than for the same average trip in the EU, both in comparison with the trip by car. The previous examples for home-work trips by combined modes, when based on these detailed dense urban and suburban risks for the city of Copenhagen with the last 4 km as dense urban distances and compared to the same trips by car, yield the following risks:

	Combined mode trips or car trips	fatality risk per 100 million km.		
	suburban and last 4 km urban	own	other's	total
1a	walk ½ km + bus 8 km + walk 1½ km	1.61	0.42	2.03
1b	6 km. suburban + 4 km. urban by car + 100 m. walk	1.21	1.21	2.42
2a	walk ½ km + bus 10 km + walk ½ km	0.58	0.46	1.04
2b	7 km. suburban + 4 km. urban by car + 100 m. walk	1.19	1.20	2.49
3a	cycle 3 km + train 12 km + walk 1 km	1.15	0.15	1.30
3b	12 km suburban + 4 km urban by car + 100 m. walk	1.14	1.18	2.32
4a	walk ½ km + train 15 km + cycle 2 km	0.59	0.15	0.74
4b	13½ km suburban + 4 km urban by car + 100 m. walk	1.12	1.17	2.29

In all cases the car trip has a higher total fatality risk than the combined mode trips (ranging from 4 times to 20% higher), because the use of car in these trips causes a manyfold higher risk for other road users than the trips that combine walking and/or cycling with train or bus. Nonetheless the cases in the Copenhagen region where walking and/or cycling distances are larger than about 20% of the total trip distance (instead of more than 15% for the average in the EU), show that the own fatality risk of the traveller can be lower by car than by train or bus travel and walking and/or cycling to and from the train stations or bus stops. It exemplifies how optimized safety can be different for the individual traveller, who would base the mode choice on the minimum of the own risk, and for community authorities, who ought to minimise by their transport policies the total risk for all persons (sum of the risks for the traveller and for other persons). The underlying personal choice dilemma between lower own risk and higher risk to others in short trips by car compared to trips by modes that include public transport, may contribute to the understanding of why policies that promote public transport for short trips have not been very effective.

Also the before and after transport for long distance trips by planes can sometimes cause that the before and after transport to the airport by car becomes safer for the traveller than by combinations of walking and bus or trains. However, most trips by plane require less walking on streets than 15% of the distance for the before and after transport by bus or train to the airport. It generally implies that journeys with air transport and transport by car or taxi to and from the airports are less safe for the traveller than the same plane trip combined with bus or train travel to the airports and walking to and from the bus stops or train stations in home and destination places.

From the last table in section 4.2. it also follows that long intermodal trips within the EU, where the average ground distance by plane covers 720 km., have per distance in average the same fatal and serious injury risk as the same trips by train or twice the fatality risk of the same trip by train or coach. Since the approach, landing, take-off and climbing manoeuvres of planes contribute the most to the risk of air transport, one rather replaces for one's own safety the train (or coach) for the plane in journeys less than 720 km. This also because the before and after transport to train or coach stations generally is much shorter then to airports. Although flights longer than 720 km have a lower risk of fatal and serious injury than train travels, only flights longer than about 1600 km ground distance have in average a lower fatality risk than the journey by train. This follows from section 3.3, where the fatality risk of 0.08 for flights of 720 km. must be corrected by 0.516 for flights of 1500 km. to 0.08x0.516=0.041 per 100 million passenger km., while that risk for the train remains for all distances 0.04. Thus also a flight of 1500 km. in the EU still has a higher fatality risk, but in some countries the train has much higher fatality risks (section 3.2.). The plane may thus be safer when the train covers long distances in countries with very high railway risks.

If there is a choice for a part of a trip between ferries and planes (or ferries and trains in case such a connection exist), then a choice for the ferry contributes to a much higher intermodal trip risk, provided that the total trip distance and/or the walking distance within the total trip is not much enlarged by a choice for the plane (train connections without a ferry generally are always safer).

5. Comparison of passenger risks with other personal risks

Comparison of risks for transport and other activities requires a common type of exposure to risk. Such risks can be expressed per inhabitant as mortality or incidence rates. But different amounts of time are spend to different activities, which implies that comparisons of risks for different activities should be based on exposure as time spend on each activity. Comparisons of risks caused by transport and by permanent threats, such as floods, diseases and disasters, can only be based on risk per inhabitant. Therefore, mortality rates and incidence rates of death or clinical treatment for EU inhabitants caused by transport and other main causes of death or clinical treatment are also used in this chapter. Older studies have shown that transport risks per hour generally are much higher than risks per hour of other activities and that mortality rates for transport are much higher than for natural disasters (Schwing & Albers, 1980) and for cancer or coronary heart diseases up to the age of about 50 (Hartunian et al, 1981), but transport risks have been decreasing over time.

5.1. Risk comparisons between travel and other activities

A recent study for Great Britain (Evans, 1997) compares accidental fatality risks per hour for transport modes with the ones for employment and home activities. Using the transport risks per hour for the EU from section 4.2. and the risk per hour for the other activities in Great Britain, the ratios of the accidental fatality risks per time of persons spend in different transport modes and in home activities or types of employment activities can be obtained as ratios that may apply to the EU regions. The next table gives the risks per 100 million hours and their ratios in round figures.

Activity		risk	road	train	ferry	plane
Transport		---->	33	2	10½	36½
			risk ratio transport/other activity			
Employment	all work	0.84	39	2½	12½	43½
	banking and finance	0.17	194	12	62	414½
	chemical industry	1.01	33	2	10½	36
	construction work	4.70	7	½	2	7½
	all railway work	5.50	6	½	2	6½
Home activities		2.60	12½	1	4	14

Fatality risks per 10^8 hours for activities and the risk ratios for transport

Home activities may be differentiated for age classes in view of the fact that the fatality risk for home activities of elderly are much higher than this risk for all ages, but due to the higher physical vulnerability of the elderly this also applies to all transport fatality risks.

The table above may apply to the EU when it is assumed that the levels of the risks for the other activities in Great Britain are the same for the EU. This might be wrong, but the actual risk ratios for the average EU country will not differ too much from the presented ones. For individual EU-countries the road transport risks differ much more than the other activity risks and thus at least the first column of ratios in the table will be markedly different for each EU-country. Anyhow, the magnitude of the presented ratios are such that the conclusions for the EU are clear even if an uncertainty margin of 50% is taken into account. The main conclusions for the EU are:

a) the risks per hour for road, ferry or plane travel are manifold higher (probably over 40 to about 4 times) than the risks per hour spend on work or home activities. Only the risk for time spend in train travel is similar to the risk for time spend at home, but also train travel is probably more risky than all work activities;

b) Although there are rare work activities that are extremely risky, the comparison shows that road, ferry or plane travel are more risky (probably over 7 to about 2 times) than the most risky types of normal work activities (e.g. construction work). Only being on a train is safer than being at work in these rather risky jobs.

5.2. Comparisons of risks caused by travel, disasters and diseases

Transport risk also can be compared with other permanent risks, such as risks from the permanent threats of diseases, natural or industrial disasters (e.g. floods or a melt down of nuclear plants). The comparison with transport risks then only can be based on exposure to risk as risk per life time in a region, thus by rates per 100.000 inhabitants as mortality rates or incidence rates.

In order to be able to compare the mortality rates (MR) for modes of transport with the MR's for disasters and diseases, the MR's for passenger transport are also needed. These MR's for the passenger modes in the EU follow from 375 million EU-inhabitants and from the annually expected recent fatalities of passenger transport within the EU for EU citizens. These fatalities and MR's are presented in the next table together with the corresponding annual passenger kilometres.

Mode	Billion km.	EU fatalities	MR
road user	3860	42.500	11.333
train passenger	270	108	0.029
ferry passenger	30	100	0.027
air passenger	240	190	0.051

Passenger kilometres, fatalities and mortality rates of EU-citizens

This table summarises the updated passenger km. and expected annaual fatalities for the road, trian and ferry modes within the EU or within the relevant regions for the EU from the sections in chapter 3, but here 8% of the 260 passenger kilometres and 207 fatalities for air transport are subtracted as related to non-EU citizens, becuase the MR's relate to the inhabitants of the EU. The very high MR for road users, clearly is also caused by the fact that 88% of all passenger transport of EU citizens within the EU is road passenger transport.

With respect to the 15 countries of the EU many fatalities are caused by several river floods and some sea floods since the latest world war, the one with highest number of fatalities has been the flood in 1953 in the Netherlands with 1835 fatalities. Although the total number of fatalities from floods since 1945 in the 15 countries of the EU is not exactly known, it certainly exceeds not the three thousand. Assuming a constant flood threat since 1945 in these countries the average annual expected fatalities from floods is about 60. For the 375 million inhabitants of the EU it would mean a mortality rate per 100,000 inhabitants (MR) of about 0.016.

Due to the flood prevention measures taken, which may have reduced the risk for floods over time, this estimate for a constant MR for floods could be an overestimate for its recent MR. A recent source (Jorissen, 1998) gives, when related to 15% of the 375 million inhabitants in the EU regions that can be endangered by floods, the theoretically to achieve MR's of 0.0173 for sea floods (a MR of 173 in 10.000 years) and 0.0014 for river floods (a MR of about 1.73 in 1250 years). So the empirical estimated MR for floods is lower than the theoretical value of 0.0187. So the empirical estimate of the MR for floods indeed is a fair estimate, thus about 0.016.

Other natural disasters, such as earth quakes and hurricanes, and disasters of nuclear plants that result in fatalities are so rare in the countries of the EU that their fatality risks hardly can be estimated empirically. Worldwide hundreds of nuclear plants are in operation since 25 years and only the Tsjernobil disaster has resulted in fatalities for inhabitants of a large area around the plant. Its actual number of fatalities will never be known, but it can be assumed that 1500 fatalities is an underestimate. On the other hand the nuclear plants in the EU are of a much safer type and have shown no fatal disasters up to now. Nonetheless taking a nuclear plant disaster to result in 1500 fatalities and the risk of such a disaster for all plants in the EU to be less than once in 25 years, one can estimate the maximum annual MR of a nuclear plant disaster in the EU with 375 million inhabitants to be (1500/25)/375 million, that is a MR (per 100.000) of smaller than 0.016. Since flood and nuclear plant disasters are the major types of natural and industrial/technological disasters for the inhabitants of the EU it can be concluded that natural or industrial/technological disaster in the EU have an MR of about or less than 0.016.

The major types of fatal diseases in the EU during the lifetime as active road user are cancer and coronary heart diseases (death by strokes, as the other main fatal disease, occurs for 80% after the age of 75). The mortality rates per 100,000 inhabitants (MR) for these diseases in the EU are given by the WHO (199...?), while the also relevant MR's for EU inhabitants younger 45 year for these diseases can be derived from the age class distributions for these diseases (Hartunian, 1981).

In order to compare the MR's for modes of transport with the mortality rates for diseases of EU inhabitants youger than 45 years, the corresponding MR's for passenger transport are also needed. About 60% of the EU inhabitants are younger 45 years and when the same percentage of annual passenger fatalities in the EU are younger than 45 years the MR remains the same as for the total EU population. The percentages of fatalities younger than 45 year for train and ferry can indeed be taken to be the same as for the population, but since less children and teenagers travel by plane the percentage of fatalities for air passenger youger than 45 is estimated to be about 55%. The road risks of youngsters are much higher than for all ages, which causes that the percentage of road fatalities below the age of 45 is 72% in the EU. The MR's for persons below the age of 45 in passenger transport thus become for air transport 0.051 x 55/60, that is about 0.047, and for road traffic 11.333 x .72/.60, that is 13.60, while the MR's for plane and train transport remain the same as for the total population of the EU.

The next table compares the MR's for transport modes, given in the previous table and derived by the estimated corrections for persons youger than 45 years, with the calculated MR for disasters and the MR's for cancer and coronary heart diseases, the latter taken or for EU inhabitants younger than 45 derived from the literature.

Cause	population	MR	road	train	ferry	plane
transport	all ages	---->	11.33	0.029	0.027	0.051
	< 45 year	---->	13.60	0.029	0.027	0.047
			ratios of transport MR / other MR			
disasters	all ages	0.016	708.1	1.813	1.688	3.188
cancer	all ages	337.0	0.034	<0.001	<0.001	0.001
	< 45 year	13.5	1.007	0.021	0.020	0.034
coronary	all ages	90.0	0.126	0.003	0.003	0.006
heart	< 45 year	7.7	1.766	0.038	0.035	0.060

Mortality rates of transport, disasters, and diseases of EU inhabitants and their rate ratios

The MR for road passenger transport of all ages is about 420 to 220 times higher than for the other passenger transport modes, not only because of its fatality higher risk but also because 88% of all passenger transport in the EU is road transport. All the transport modes have higher MR's than the MR for disasters, but the road MR is more than 700 times higher than the MR for disasters. However, the MR for cancer and coronary heart diseases for all ages are respectively about 30 and 8 times higher than the MR for road transport and more than 300 to more than 1000 times higher than the MR for passengers of the other transport modes. Nonetheless, the cumulative frequency of death before the age of 45 by these diseases is lower than by road transport (this also holds for the frequency per age class up to the age of 35), because the corresponding MR's relate to the same population of EU inhabitants younger than 45 year. This is also shown by the respective MR ratio's of 1.007 and 1.766 for this comparison.

Since the mean age of death by road accidents is about 32 and by cancer or coronary heart diseases above 65, not only the MR of road transport is higher for EU inhabitants below the age of 45 than the corresponding MR's for these diseases, but also for the EU inhabitants of all ages together the years lost of expected life years by road transport accidents are higher than the lost years of expected life years by any disease.

Moreover, the incidence of death or clinical treatment from road transport has a incidence rate per 100.000 inhabitants (IR) that is 12.5 higher than the MR of road transport. This IR is comparable to the incidence rates per 100.000 inhabitants for death or clinical treatment (survival without later death by the same disease) caused by cancer or coronary heart diseases, which respectively are about twice and one and a half times than their MR's. This is summarised is the last table.

Cause of incidence	Death or clinical treatment all ages	 < 45 y.
road transport	142	170
cancer	670	27
coronary heart	135	12

Incidence rate per 100.000 EU inhabitants

It follows that road accidents are the second cause of death or clinical treatment for inhabitants of the EU, preceded by cancer and followed by coronary heart diseases. For the population of the EU younger than 45 the frequency of death or clinical treatment is for road accidents 6.3 times higher than for cancer and 14.2 times higher than for coronary heart diseases, which also causes that the annual economic loss from road fatalities and serious injuries in the EU is higher than the annual economic loss of death or clinical treatment from these diseases.

6. Conclusions and recommendations

6.1 Conclusions

In case exposure to risk is measured and fatalities and serious injury or incidences of clinical treatment are registered per major type of causation, it is possible to express and useful to compare fatality risks or incidence risks of serious injury or clinical treatment for those individuals who survive the incidence.

Apart from the different types of exposure measures and the needs for the gathering of some types exposure data, it must be noticed that in the EU there exist no consistently defined and completely registered data on the numbers of serious injuries from accidents in the different transport modes. This also holds for fatalities in waterborne passenger transport and partially for air transport by unscheduled commercial flights within the EU. It causes that risks for passenger transport on inland waterways in the EU are unknown and that for the other types of passenger transport some fatality risks and most serious injury risks only can be approximately estimated, provided the necessary exposure data are available.

The collective time spend in a region is the only exposure measure that is common to all different types of risks. Therefore, one can always compare risks of death per 100,000 inhabitant as mortality rates or risks of clinical treatment as incidence rates per 100.000 inhabitants. Comparing the risk of death caused by floods and transport in a region or risk of death or clinical treatment cuased by a disease and transport, there is no other more relevant exposure measure than the collective time spend in the area, which means that the number of inhabitants in the region must be the exposure measure and thus mortality or incidence rates the expression for the comparable risks of death or clinical treatment.

In such comparisons for the EU it turns out that the mortality rate for road traffic or other modes of passenger transport is higher than the mortality rate for natural or industrial/technological disasters. For road transport the mortality rate is even more than 700 times higher than for such disasters in the EU.

Similar mortality rate comparisons also show that all EU inhabitants younger than 45 have a higher mortality rate for transport than for any type of disease (cancer, coronary heart diseases etc.). Because road accidents have a much higher incidence rate for clinical treatment (annually half a million serious injuries from road accidents in the EU) than individuals that survive a coronary heart disease, road transport accidents are the second important cause of death or clinical treatment for the EU inhabitants of all ages. Due to the low average age of road fatalities (32 years) compared to death by cancer or coronary heart diseases (mean age over 62 years) the total of life years lost and the total economic loss by transport accidents are higher than for any disease.

It is appropriate for comparisons of risk in transport and other activities to use the time spend on the activity as the exposure measure.

In such comparisons, for example, road transport in the EU shows a fatality risk per hour that is probably about 40 times higher than for all employment activities together and probably about 12 times higher than for home activities. Also passenger transport by ferries and planes in EU region show much higher fatlity risks per hour than employment or home activities. Even highly risky jobs, such as construction work, have lower fatlitity risks per hour than passenger transport by road, plane or ferry travel. Only train travel has a fatality risk per hour that is lower than for these risky jobs, but the fatality risk of being a train in the EU is probably still about 2 times higher than being at work in all types of work together. Only home activities have about the same fatality risk per hour as travelling by train, while train travel is the mode with the lowest fatlity risk per travel hour (together with bus or coach travel) in the EU.

One rather uses a more relevant measure for exposure than activity time in risks comparisons of passenger transport modes (e.g. driving vs. rail etc.). In this case exposure as passenger kilometres per year is preferred for the calculation of comparable risks of travellers, because it concerns decisions on how to travel distances and generally not on how to spend amounts of time.

In these risk comparisons for the EU the fatality risk for motorised two-wheelers is the highest of all modes, being in average 20 times higher than for car occupants. Also walking and cycling are rather risky transport modes, having in average a 9 to 8 times higher fatality risk per distance than car travel. All road traffic together has the highest fatality risk per passenger (or road user) kilometres of all passenger transport modes. The risk of fatal and serious injury risk per distance for road travel is even 115 times higher than for train or plane travel and over 10 times higher than for ferry travel.

The passengers of trains, bus or coach and planes within the EU have the lowest fatality risks per passenger kilometres. For the average passenger trips in the EU, bus travel has a 10 times higher fatality risk than car travel and the average air travel distance within the EU has the same fatality risk per passenger kilometres as the average travel by coach in the EU.

Trips by train in the EU have in average half the fatality risk of trips by planes within the EU, covering in average a ground distance of 720 km, but the fatal and serious injury risk for trains and flights of 720 km. ground distance are equal. The risks of plane passengers are mainly due to the dangers in the take-off and landing of planes and the cruise part of the flight takes only a small percentage of the total flight risk. It causes that trips by plane shorter than 720 km. have a higher fatal and serious injury risk per passenger kilometres than train trips. Only flights within the EU for longer ground distances than 1600 km. have per passenger kilometres a lower fatality risk than trips by train with a fatality risk that is independent of the distance. However, railway fatality risks differ markedly between the countries of the EU and train travels over long distances in countries with very high railway fatality risks per passenger kilometre can become more risky than flying.

Although ferries seldom have fatal accidents, the fatality risk per passenger kilometre for ferries in the EU waters is 4 time higher than for planes and 8 times higher than trains within the EU, mainly due to their risk of capsizing with drowning of many ferry passengers.

With appropriate and reliable exposure information it is also possible to compare the risks of trips with different combinations of modes. It turns out that the average home-work trip in the EU by bus or train must contain less than 15% of the total trip distance for the walking or cycling to and from the bus stops or train stations in order have a lower fatlity risk for the traveller than a door to door home-work trip by car. This percentage will vary for different suburban and urban regions in the EU, but probably always must be less than 20%, otherwise the fatality risk of the traveller for the whole trip by car becomes lower.

Nonetheless, most home-work trips that combine walking and/or cycling with train or bus travel, are from a societal point of view a better alternative than the same trips by car, because the use of the car inflicts more risk on other road users than walking and/or cycling and a number of car drivers manyfold more than trains or busses with that number as additional passengers. Almost the majority of car trips are for trip distances less than 10 km, but their replacement by walking and/or cycling in combination with (or without) bus or train travel, can cause a higher risk for the traveller (certainly much higher without bus or train). The choice between car and walking and/or cycling combined with public transport thus constitutes an individual dilemma between societal and personal risks. Although the use of cars for short trips reduces the risks of drivers compared to risks of travellers who combine walking and or cycling with public transport for the same short trips, the use of the car also has a higher total risk (the sum of the risk for the traveller and the risk of other road users) than walking and/or cycling and the use of bus or train, which poses thus no societal dilemma for policies that promote public transport.

Transport safety policies can not do without exposure information, because risks are indispensable for a sound evaluation of policy alternatives. For example, in the maritime domain it is shown that the passenger risk of ferries is mainly caused by capsizing and not by collisions or other causes, because capsized ferries are for 80% responsible for the fatality risk of ferry passengers. With regard to road safety, as another example, it is shown that the lowest fatality risks are observed on motorways and on roads in traffic calming areas. The highest injury risks are on main rural and arterial urban roads with level crossings (9 to 6 times higher than on motorways or roads in traffic calming areas).

Exposure information in varying details is needed for the risk assessments and comparisons of different transport modes in the EU or EU countries. However, for most transport domains several EU countries and the EU do not gather the needed kinds of exposure information and no European standards for the gathering of exposure information are agreed.

In the EU the national authorities for air and rail transport have already the needed data, but they are not documented for the EU (for rail by the UIC, not by the EU and for air no complete documentation of exposure from unscheduled flights within the EU is available). For waterborne passenger transport on European waters and on in-land waterways there hardly are exposure data gathered on passenger transport, although in principle easy obtainable from the voyage records of the passenger ships. The needed exposure information for ferry and air passenger transport within the EU are derived form specific studies or estimated in this report in order to obtain approximate risks values for ferry and air passenger transport, but for passenger transport on inland waterways of the EU the risks can not even be estimated.

For road transport a few countries do not gather the minimal needed exposure information, but total exposure sometimes is only derived from the annual fuel use. Some countries gather exposure information from irregular traffic counts and/or from traveller surveys on a six or five year basis. Only a few countries gather the detailed exposure information annually from traffic counts on randomly selected roads and traveller surveys during the whole year. Nonetheless approximate estimates of exposures and/or risks for the different road modes in the EU and for road traffic as a whole for each of the EU countries (some tentatively) are derived in this report and summarised in the above conclusions.

Risks in transport generally relate to one's own risk per distance travelled in journeys by a particular mode as defined by exposure as annual passenger or road user kilometres for that particular mode. However, for the understanding of these risks and their changes over time it must be noticed that the kilometres travelled by other parties that are involved in the accidents are important as well. For example: if risks for pedestrians increase over the years it may be more related to the growth of car kilometres than to an increase in unsafe walking.

In the maritime and road transport domains somtimes exposure and risks for outcomes of collisons are expressed by the estimated frequency of encounters. The frequency of encounters between parties are dependent on the kilometres of each party. However, the frequency of encounters also can be dependent on the transport infrastructure (e.g. kilometres on rural roads have more encounters than the same kilometres on motorways that have no head-on and crossing encounters).

It is to be expected that exposure to risk as frequency of encounters will have more explanatory and predictive power in many evaluations of risks than exposure to risk as travel distances or traffic volumes. However, research on exposure to risk as frequency of encounters is almost absent.

Relative exposure measures for subgroups of road users also can be deduced from the numbers of multi-party accidents. Although much cheaper to obtain than exposure measures from traffic counts and traveller surveys, the validity of induced exposure values can be questioned, while there hardly is research on the relation between induced exposure and obtained travel kilometres for subgroups.

6.2 Recommendations

It is recommended that national and EU health policies recognise the relatively high mortality rates and incidence rates for clinical treatment of passenger transport to a larger extent in their priority setting, while also relatively more priority for transport safety is needed in the transport policies of the nations and the EU.

Transport policies should make more use of exposure data for risks assessments in order not to be contra-productive with respect to the safety of transport and transport safety policies ought to be based on detailed risks evaluations in order to be effective.

Transport safety policies and policies for intermodal passenger transport have to recognize that there are large differences between the risks of different transport modes and within the rail and road modes also between the countries of the EU. It is strongly recommended that relatively much more priority is given to the improvement of road safety, because road transport is not only the most risky mode, but also the mode for 88% of all passenger transport within the EU. It also is recommended that the EU in its project on European Rail Traffic Management Systems assists the EU countries with relatively very high railway risks in the improvement of their railway safety.

The priority setting for transport safety must recognize the relative low fatality risks of train and bus passengers and within road transport the very high fatality and serious injury risks of motorised two-wheelers as well as the relatively high fatality and serious injury risks of cycling and walking. Therefore, it is recommended to discourage the use of motorcycles and mopeds by all means available and to give more priority to the improvement of the safety of pedestrians and cyclists within the policies and research for road safety.

An improved safety of walking and cycling is also needed for the optimisation of the safety for trips with public transport modes, because of the relatively high risk of the necessary walking and/or cycling in the before and after transport for a trip with a bus or train.

If for environmental and congestion reasons public transport is promoted for home-work trips, then this only can be individually acceptable to persons that usually travel their relatively short home-work trips by car when the safety of walking and cycling also is effectively improved. Otherwise a change from car to public transport may result in an increase of the fatality risk for the total of short home-work trips of the travellers due to the necessary walk and/or bicycle distances to and from train stations or bus stops in short home-work trips by public transport.

Passenger transport policies of the nations and the EU ought to promote the use of (high speed) trains instead of planes in long distances trips, because the fatal and serious injury risk per distance of plane travels in the EU with a ground distance of less than 720 km. is higher than for trains, while only flights that cover longer ground distances than 1600 km. have a lower fatality risk per distance than trains. However, these critical distances may vary within the EU, becuase some EU countries have markedly higher passenger fatality risks on their railways than the EU average.

The annual fatalities of passenger transport within the EU are not well documented on the EU level for waterborne transport in EU-waters and inland waterways of the EU and partially also not for air transport by unscheduled flights within the EU. It makes the valid assessment of their fatality risks in the EU troublesome. Initiatives of the EU to improve this situation are in place.

Moreover, the risks of serious injury for passengers in different modes within the EU and within countries are hardly to assess and to compare in valid way, because the data on serious injuries are not consistently gathered and serious injuries are differently defined in modes and countries. Since beside fatalities, the numbers of serious injuries in each passenger transport mode are an important aspect of passenger safety, it is recommended that standards for the collection of serious injuries are established on the EU level (e.g. the obligation of hospitals in the EU to report to the police the cases with clinical treatment of longer than 24 hours that are caused by transport) and that collection of data on serious injuries for each mode is annually completed for the EU according to these standards in cooperation with the national authorities.

Due to the lack of detailed exposure information on kilometres travelled in several countries and the absence of standards for the collection of that exposure information for each mode, even the assessments of the fatality risks for nearly all passenger transport modes in the EU (exept for railways) can only be approximately estimated. Therefore, it also is recommended that standards for the collection of exposure information are established on a EU-level for the different transport domains in cooperation with the relevant national authorities, and that the exposure information according to these standards for each transport mode is annually obtained from all EU countries.

The detailed annual exposure information on road transport for each EU country should be based on traveller surveys for randomly selected households over the whole year, reporting for a week on all travels of their persons of all ages (also of children), and on random samples of regular traffic counts on all road types for the different vehicles (including cyclists) and pedestrians, because this has been shown to be the most reliable methodology in the few advanced EU countries that have detailed exposure information on road passenger transport.

It is recommended to initiate research on exposure to risk as frequency of encounters and on the validity of exposure to risk by methods of induced exposure as well as on the possible differences and relations between the different exposure measures (for road: frequency of encounters, induced exposure and travelled kilometres) in order to enhance the validity and the understanding of risk assessments.

Lastly it is recommended to initiate research on differentiated risk assessments of the own risk of traveller and the societal risk of travel (risk to other persons than the traveller of a particular mode) for each mode and for the different modes within road traffic (the own risk of the traveller by a particular mode and the risks of that road mode to users of other road modes), in order to be able to define policies for modal and intermodal passenger transport which contribute to the reduction of the total risk (for travellers in particular modes or particular combinations of modes and for travellers in other modes or other citizens).

References

To be included or completed by other WP-members

- the incomplete references COST 301(19..) and Watson (19..) and/or original reference numbers 1, 2, 3 and 4 or unknown references from Cees on sea
- some other references ? from Frank on air, additional to the incomplete ones for Ho (19..), Boeing (19..), ICAO (1998) and IATA (199.)
- some references, additional to the incomplete ones for Evans (1997) and UIC (1998), from Andrew on rail.

Boeing. (1998.). Fatal Accidents Worldwide Commercial Jet Fleet 1988-1997. Boeing commerical Airplane groups. .... ?

Collings, H. (1994). Comparative Accident Rates for Passengers by Mode of Transport. In: Transport Statistics Great Britain. Dep. of Transport, London.

ETSC. (1997). Transport accident costs and the value of safety. ETSC. Brussels.

Evans, A.W. (1997). ..... ?

FERSI. (1997). Road Safety Research and Policy in Europe. Mission paper of the Forum of Road Safety Research Institutes. Secr. FERSI, TRL, Crawthorne.

Haight, F.A. (1971). Indirect Methods for Measuring Exposure Factors as Related to the Incidence of Motor vehicle Traffic Accidents. DOT-HS-041-1-049. State Univ., Pennsylvania, PA.

Haight, F.A. (1973). Induced Exposure. Accid. Anal. Prev., 5: pp. 111-126.

Hartunian, N.S., Smart C.N. & Thompson, M.S. (1981). The Incidence and Economic Costs of Major Health Impairments. A comparative analysis of Cancer, Motor Vehicle Injuries, Coronary Heart Desease, and Stroke. Lexington Books, Lexington, Massachusetts.

Ho, H. (199.). ....? . PhD thesis, Cranfield Aviation Safety Centre, Cranfield University, Bedfordshire.

IATA. (19..). World Air Statistics, Section III IATA Industry Statistics. ....?

ICAO. (1998). Fatal accident rates for passengers on world scheduled services. ICAO journal, ...?

Jorissen, R.E. (1998). Flood protection, safety standards and societal risk. In: Jorissen & Stallen, P.J.M. Eds. (1998) pp.19-36, referred.

Jorissen, R.E. & Stallen, P.J.M. Eds. (1998). Quantified societal risk and policy making. Kluwer Academic Publishers, Dordrecht

Jorgensen, N.O. (1996). The risk of injury and accident by different travel modes. Int. Conf.: Passenger safety in European Public transport. ETSC, Brussels

Koornstra, M.J. (1973a). A model for estimation of collective exposure and proneness from accident data. Accid. Anal. & Prev. 5: pp. 157-173.

Koornstra, M.J. (1973b). Empirical results on the exposure-proneness model. Accid. Anal & Prev. 5: pp. 175-189.

Koornstra, M. J. (1992). The Evolution of Road Safety and Mobility. IATSS Research, 16: pp. 129-148

Koornstra, M.J. (1996). Sustainable road safety and the new road user standard. (in Dutch: Duurzaam veilig wegverkeer en de nieuwe normmens. Bijdrage aan conferentie: De nieuwe normmens. Pov. Org. Verkeersveiligheid Zuidholland, Den Haag.)

Lyles, R.W. , Stamatiadis, P. & Lighthizer, D.R. (1991). Quasi-induced exposure revisited. Accid. Anal & Prev. 23: pp. 275-285.

Mengert, P. (1982). Literature review on induced exposure models. Project memorandum. Task 2. HS-270 PM-223-US-4A. US DOT, TSC, Cambridge, MA.

Mengert, P. (1985). Analysis and testing of Koornstra-type induced exposure models. Report # FR-45-U-FAA-86-01. US DOT, TSC, Cambridge, MA.

OECD-IRTAD. (1998). Methods and Necessity of Exposure Data in relation to Accident and Injury Statistics. Special IRTAD Report by Nilsson.G. International. Road Traffic and Accident Database, OECD Road Transport Research Programme. VTI, Linkoping/OECD-IRTAD, Paris..

Preusser, D.F., Williams, A.F., Feguson, S.A., Ulmer, R.G. & Weinstein, H.B. (1998a). Fatal crash risk for older drivers at intersections. Accid. Anal. & Prev. 30: pp. 151-159.

Preusser, D.F., Ferguson, S.A. & Williams, A.F. (1998b). The effect of teenage passengers on fatal crash risk of teenage drivers. Accid. Anal. & Prev. 2: pp. 217-222.

Stamatiadis, N & Deacon, J.A. (1997). Quasi-induced exposure: methodology and insight. Accid. Anal. & Prev. 29: pp. 37-52.

Swing, C.R. & Alberts, W.J. (Eds). (1980). Societal Risk Assessment. How Safe is Safe Enough ? Plenium Press, New York-London.

Thorpe, J.D. (1964). Calculating relative involvement rates in accident without determining exposure. Aust. Road Res., 2, pp. 25 36.

UIC. (1998). Sécurité dans les transports ferroviaires des Reseaux de l'U.E.. Centre de Statistique de l'UIC. .... ?

Waller, P.F., Reinfurt, D.W., Freeman, J.L. and Imrey, P.B. (1973). Methods for Measuring Exposure to Automobile Accidents. Paper 101st meeting of the American Public Health Association, San Francisco.

Wass, C. (1977). Traffic Accident Exposure and Liability. ROC, Rungsted.

Watson, M. H. (19..). Disasters at Sea. .... ?

WHO. (199..?). 1995 World Health Statistics Annual. World Health Organisation, Geneva.

Annex 1: Ferry disasters in European waters, taken from (2),

Date	Name	Year of built	GT	Cause	Fatalities
1/1-31/12/85				no disaster	0
30/01/86	Svalan	1965	131	Explosion	0
30/01/86	Toran	1966	132	Explosion	0
14/04/86	Isla de Cubagua	1961	3733	Water ingress	0
11/06/86	Freccia de Messina	1959	122	Fire	0
01/02/87	Midnat sol Norge	1949	2098	Capsized	0
06/03/87	Herald Free Enterprise	1980	7951	Capsized	193
04/01/88	Bird of Paradise	1960	1268	Foundered	0
24/03/88	Italia Express	1963	3504	Explosion	0
21/10/88	Jupiter	1961	6306	Collision	0
19/07/89	Nereus	1964	2505	Wrecked	0
13/12/89	Menorca	1972	292	Fire	0
28/12/89	Zakinthos	1979	1559	Foundered	0
07/04/90	Scandinavian Star	1971	15750	Fire	158
29/04/90	Espresso Trapani	1983	2719	Capsized	15
14/12/90	Rosso	1968	2307	Water Ingress	0
10/04/91	Moby Prince	1968	6187	Collision	140
00/09/91	Krila Dalmacije	1968	130	Damaged	0
00/09/91	Krila Istre	1968	130	Damaged	0
12/11/91	Adriatic	1973	931	Fire	0
12/11/91	Argolys	1947	234	Fire	0
24/11/91	Freccia delle Isole	1966	133	Damaged	0
24/11/91	Freccia d'Oro	1960	131	Damaged	0
12/12/91	Reggio	1960	3713	Submerged	0
29/05/92	Istanbul	1973	3445	Fire	0
06/10/92	Ionion	1972	3277	Stranded	0
27/12/92	Tiburon	1986	135	Stranded	0
14/01/93	Jan Heweliusz	1977	3015	Capsized	52
17/08/93	Delfine XVI	1983	127	Stranded	0
28/08/94	Estonia	1980	15556	Capsized	850

Annex 2: Measurement methods of road traffic exposure in the EU countries

Country	Traffic Counts*	Traveller Survey	Fuel use
Austria	regular	irregular	no
Belguim	regular	no	no
Denmark	regular	irregular	yes
Finland	irregular	every 6 years	no
France	regular	irregular	yes
Germany	regular	irregular	yes
Great Britain	regular	permanent	no
Greece	no	no	no
Ireland	regular	irregular	no
Italy	regular	first nov. 1998	yes
Luxenbourgh	no	no	no
The Netherlands	regular	permanent	no
Portugal	planed every 5 year	no	yes
Spain	regular	no	yes
Sweden	regular	every 5 years	yes

*)Traffic counts generally apply always to motorways, mostly also to a more or less random selection of rural roads and acces roads to cities, but sometimes not to urban roads.
Traveller surveys sometimes do not include the journeys of persons below 12 years.

EXPOSURE DATA FOR THE ASSESSMENT OF RISKS:

USE AND NEEDS WITHIN AND ACROSS THE TRANSPORT MODES IN THE EU

ETSC review of Transport Accident Statistics WP

$$\text{RISK} = \frac{\text{Number of accidents, casualties, fatalities}}{\text{Volume of travel}}$$

The review thus concerns travel exposure and travellers risks

Rail transport

Exposure data: UIC all 15 EU-countries

Problems: a) Reporting differences
b) own and others risks

Air transport

World-wide exposure estimates from
ICAO, IATA and national airports
for commercial airlines

Problems: a) unscheduled flights
b) estimates for European region
c) no exposure data for private flights

Waterborne transport

No systematic gathering of exposure data
Studies on European waters (COST 301)

Problems: a) no EU-inland data
b) main data on freight transport
c) relevance of vessel km, passenger km or ship encounters

Combined transport

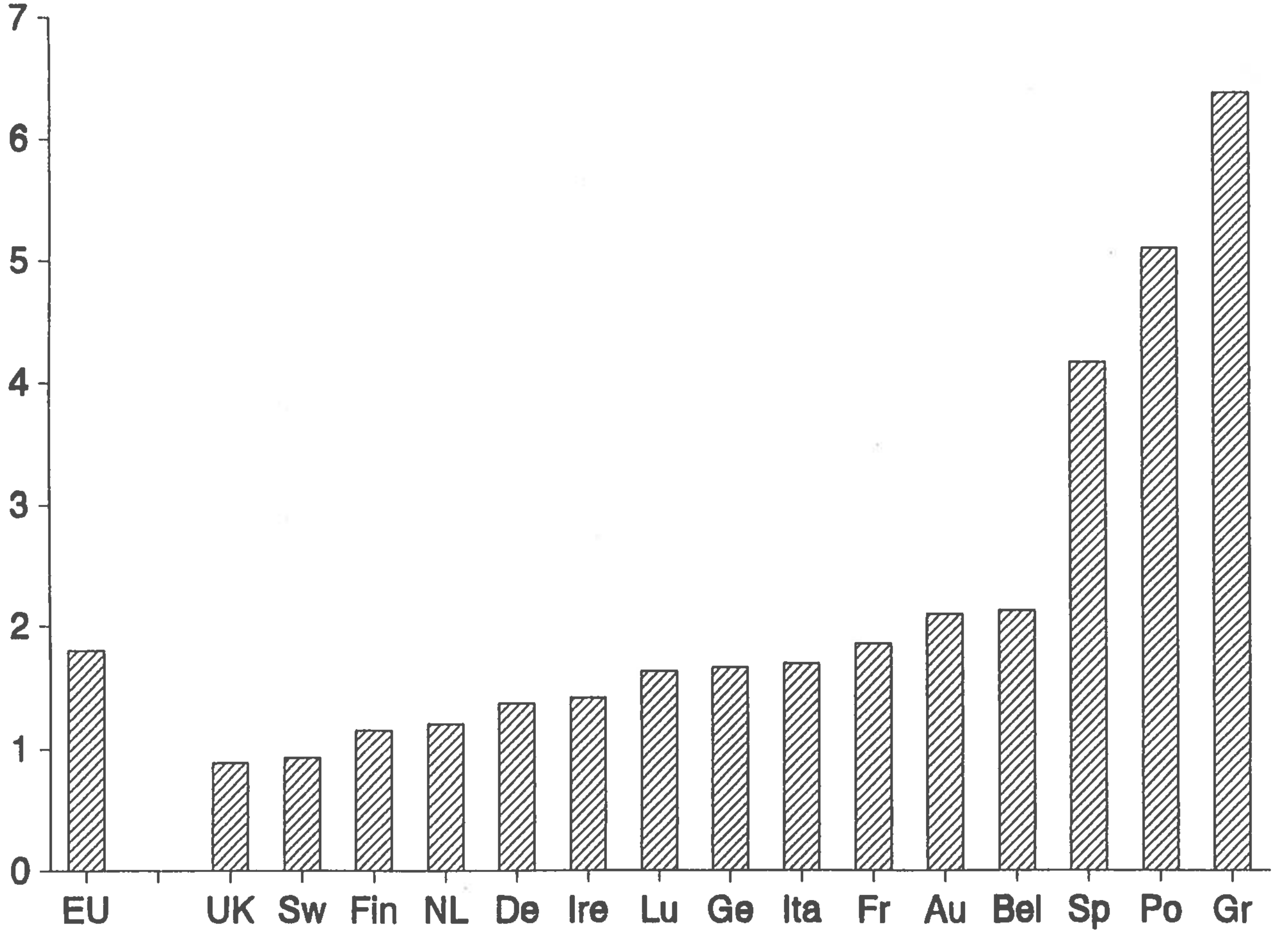
Only additional problems
a) additional data needs
b) own and others risk

Illustrations of use for passenger risks

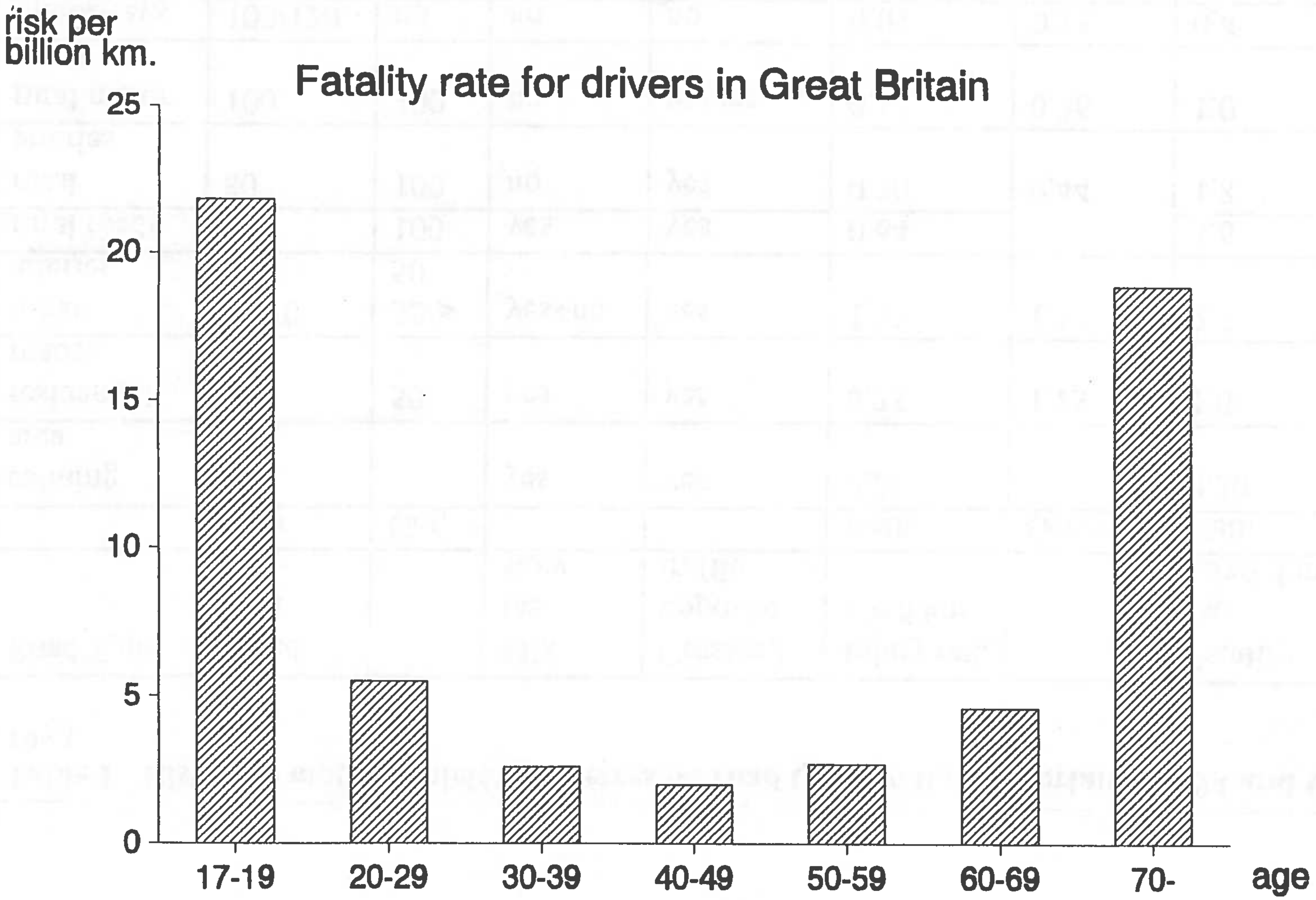
a) per mode
b) in comparisons across modes
c) in comparisons of intermodal trips
d) in comparisons with other activities
e) in comparisons with disasters and diseases

Conclusions

Recommendations



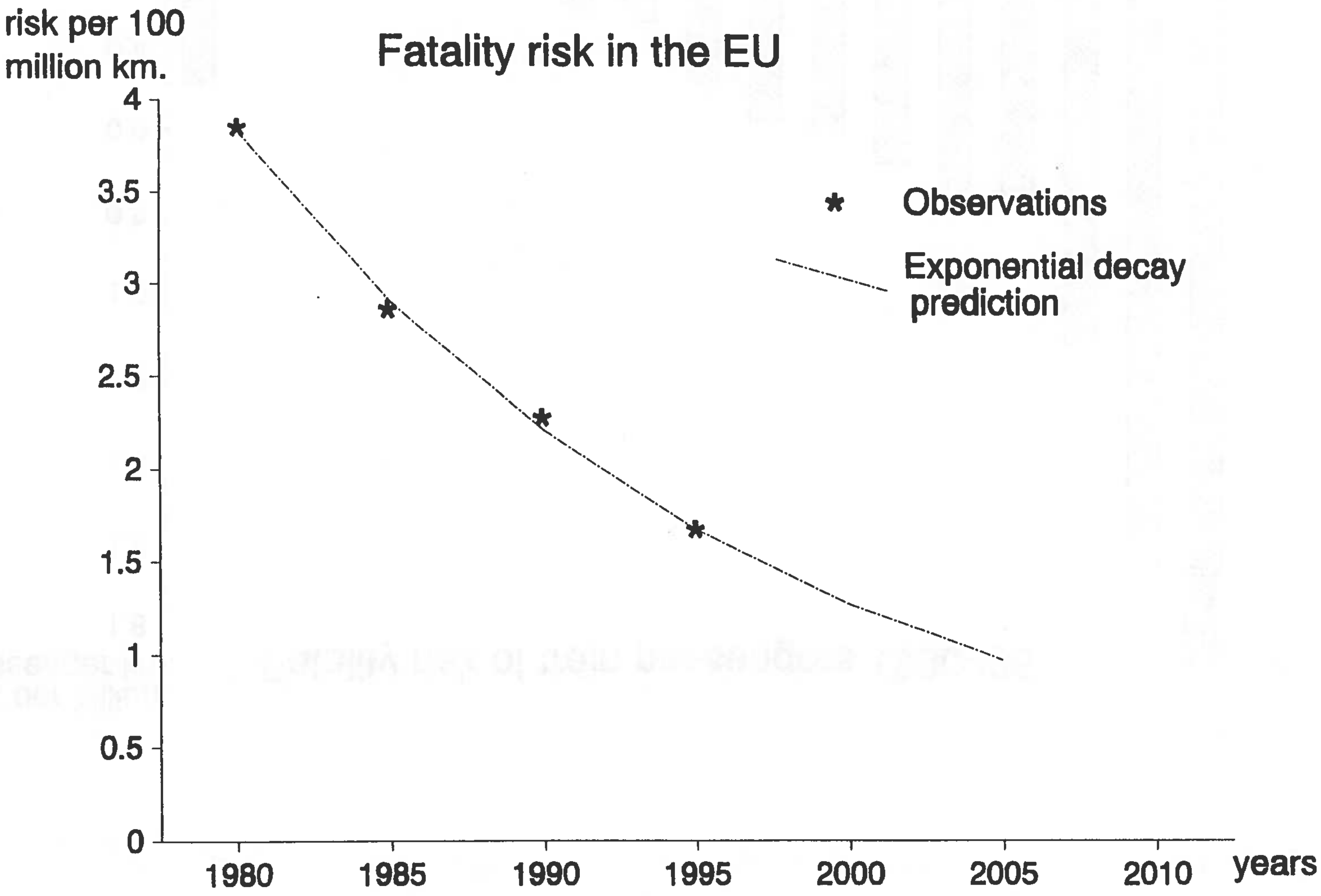
FATALITY RATE PER 10^8 MOTORVEH. KM 1994

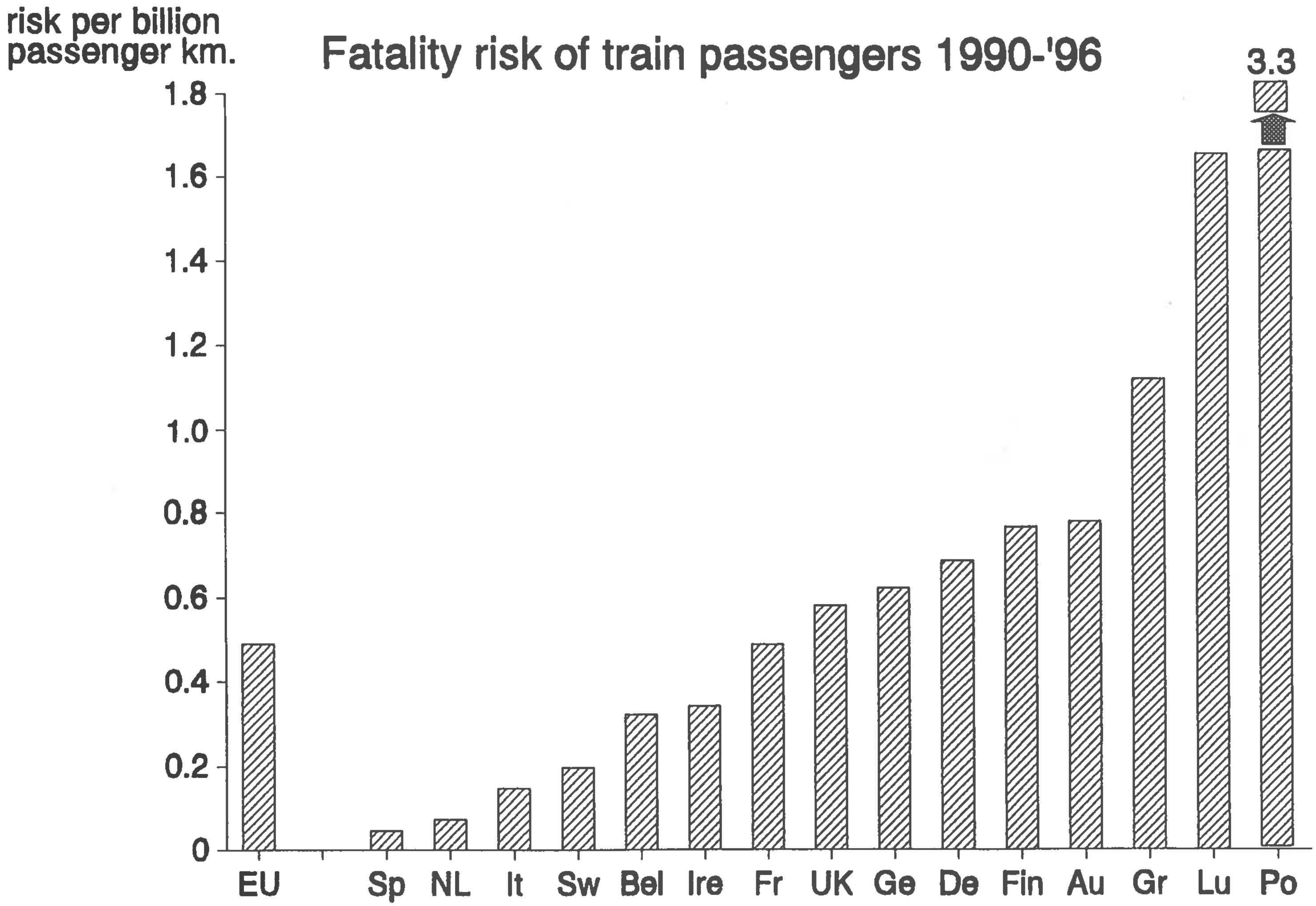


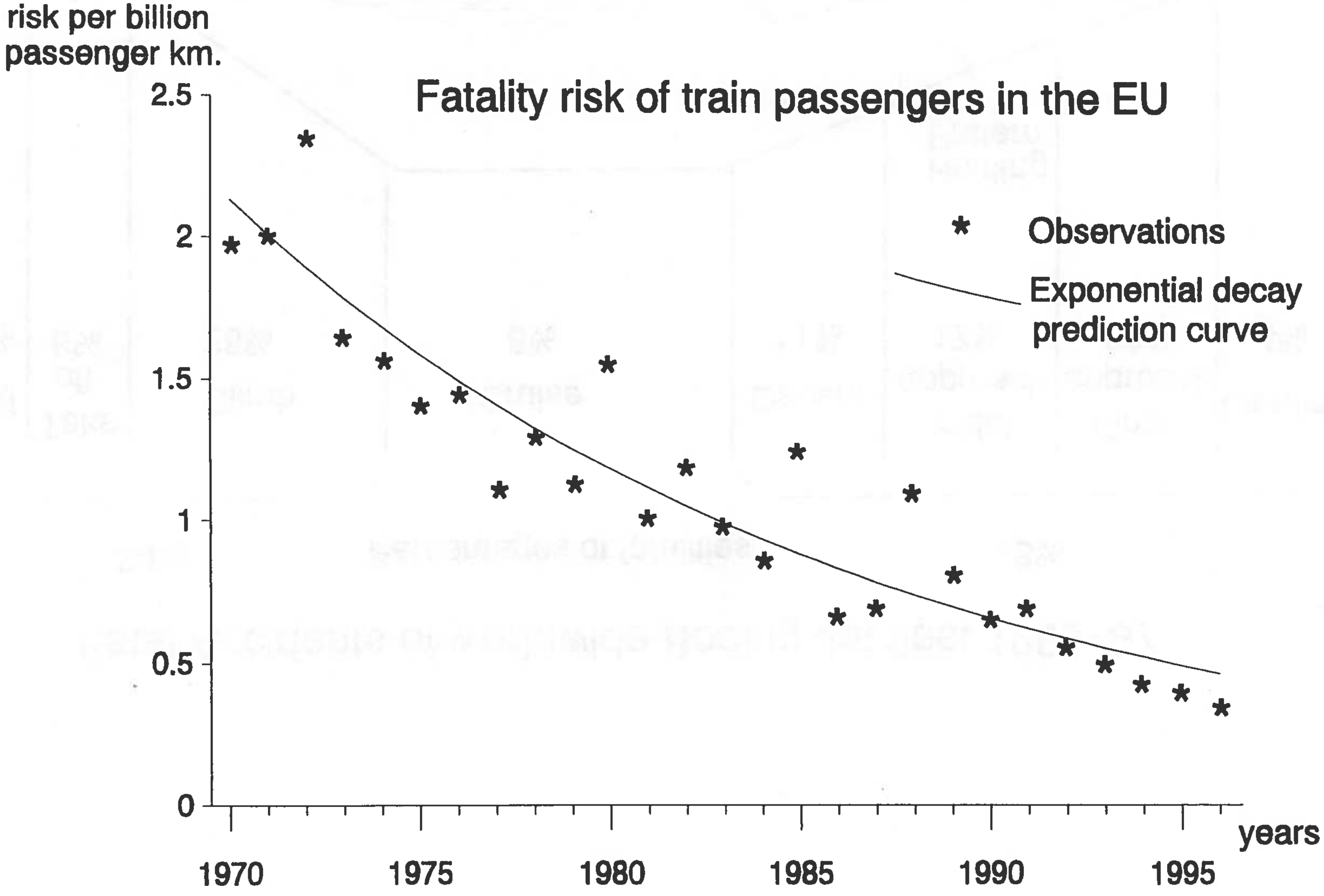
Fatality rate for drivers in Great Britain

Table 1 **Risks per motor vehicle kilometres on road types in the Netherlands 1994 and Germany 1993**

Road Type	Speed limit		Mix fast slow	Crossing opposite traffic	Injury rate 10x6 km		Fatality rate 10x6 km	
	Neth.	Ger.			Neth.	Ger.	Neth.	Ger.
calming area	30		yes	yes	0.20		0.30	
residential roads	50	50	yes	yes	0.75	1.75	1.0	1.7
urban arteries	50/70	50/> 50	yes+no	yes	1.33	1.37	2.3	2.1
rural roads	80	100	yes	yes	0.64	0.44	3.6	2.8
rural arteries	80	100	no	yes	0.30		1.8	
rural motor roads	100	100	no	no/yes	0.11	0.26	1.0	0.8
motorways	100/120	no	no	no	0.07	0.15	0.4	0.5


Fatality risk in the EU
risk per 100
million km.
4
3.5
3
2.5
2
1.5
1
0.5
0
1980
1985
1990
1995
2000
2005
2010
years
* Observations
Exponential decay
prediction


Fatality risk of train passengers 1990-'96


Fatality risk of train passengers in the EU

Fatal Accidents of worldwide Boeing Jet fleet 1988-'97

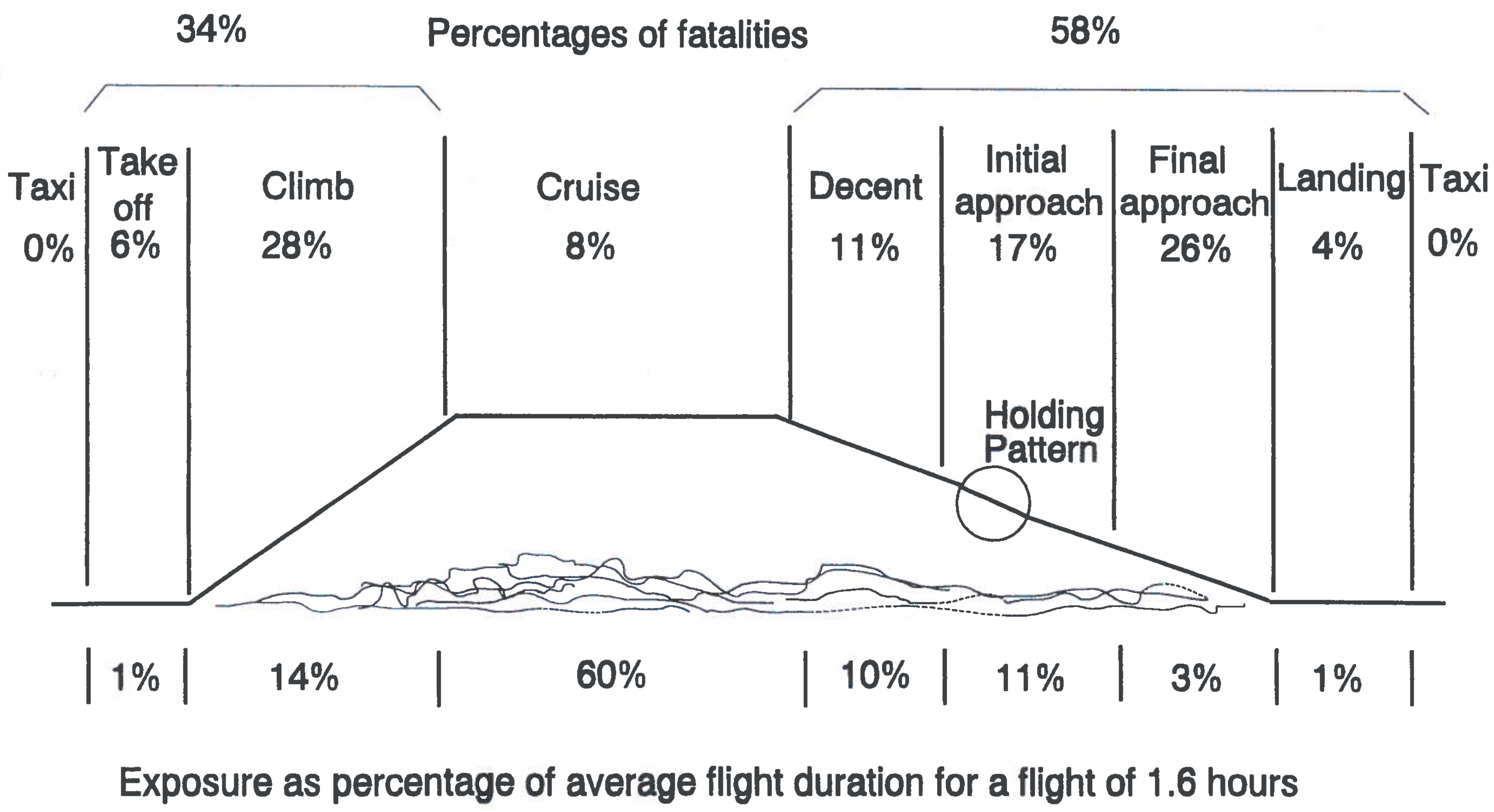
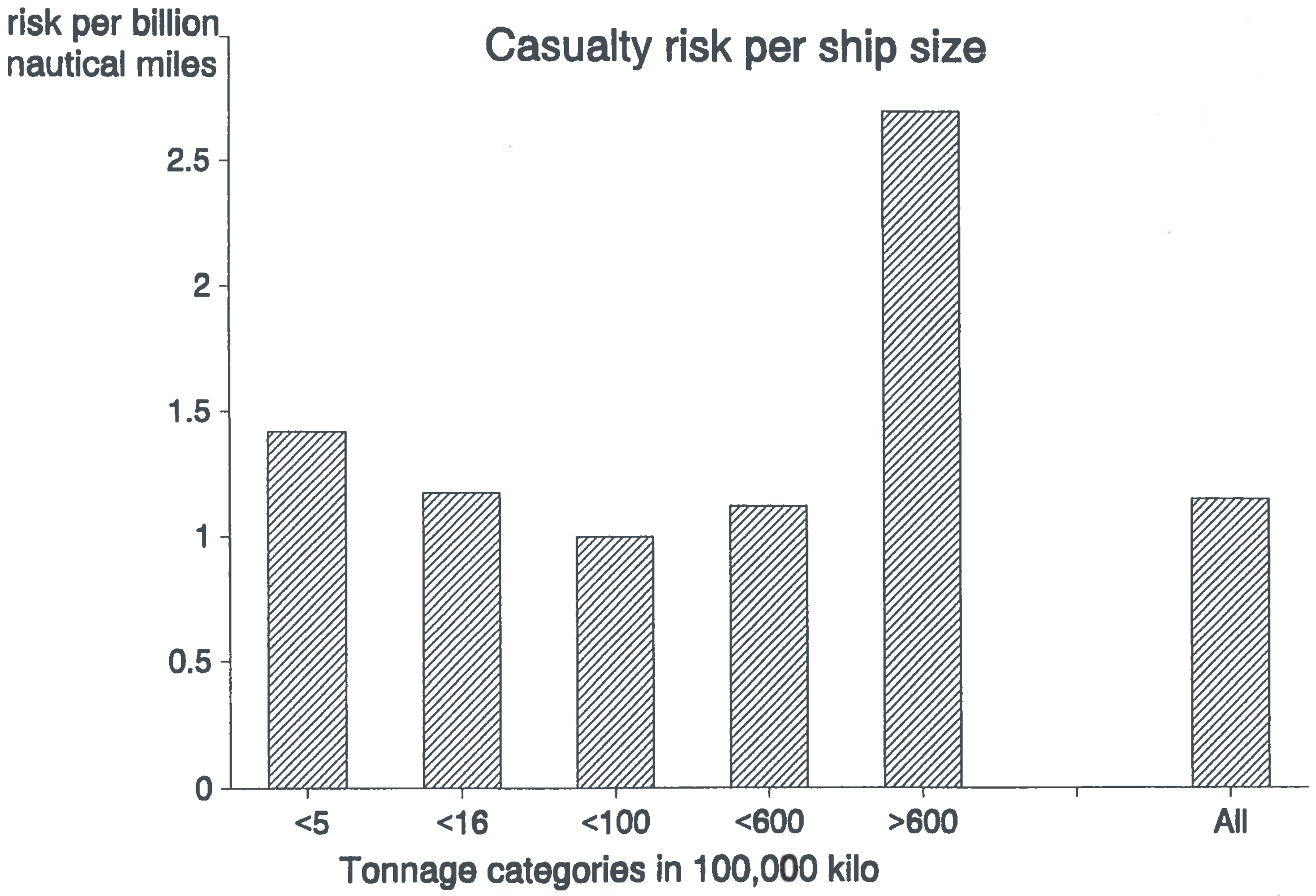


Table 4

		All flights (incl. intercontinental)		National and continental flights within EU region
		worldwide	European (ex. USSR)	
a. Fatalities/100 million pass. km.		0.045	0.033	0.08
b=q×a	Expected Fatalities '98	1350	250	207
c=b/r	Fatalities/100 million pass. h.	27	20	36.5



Casualty risk per ship size

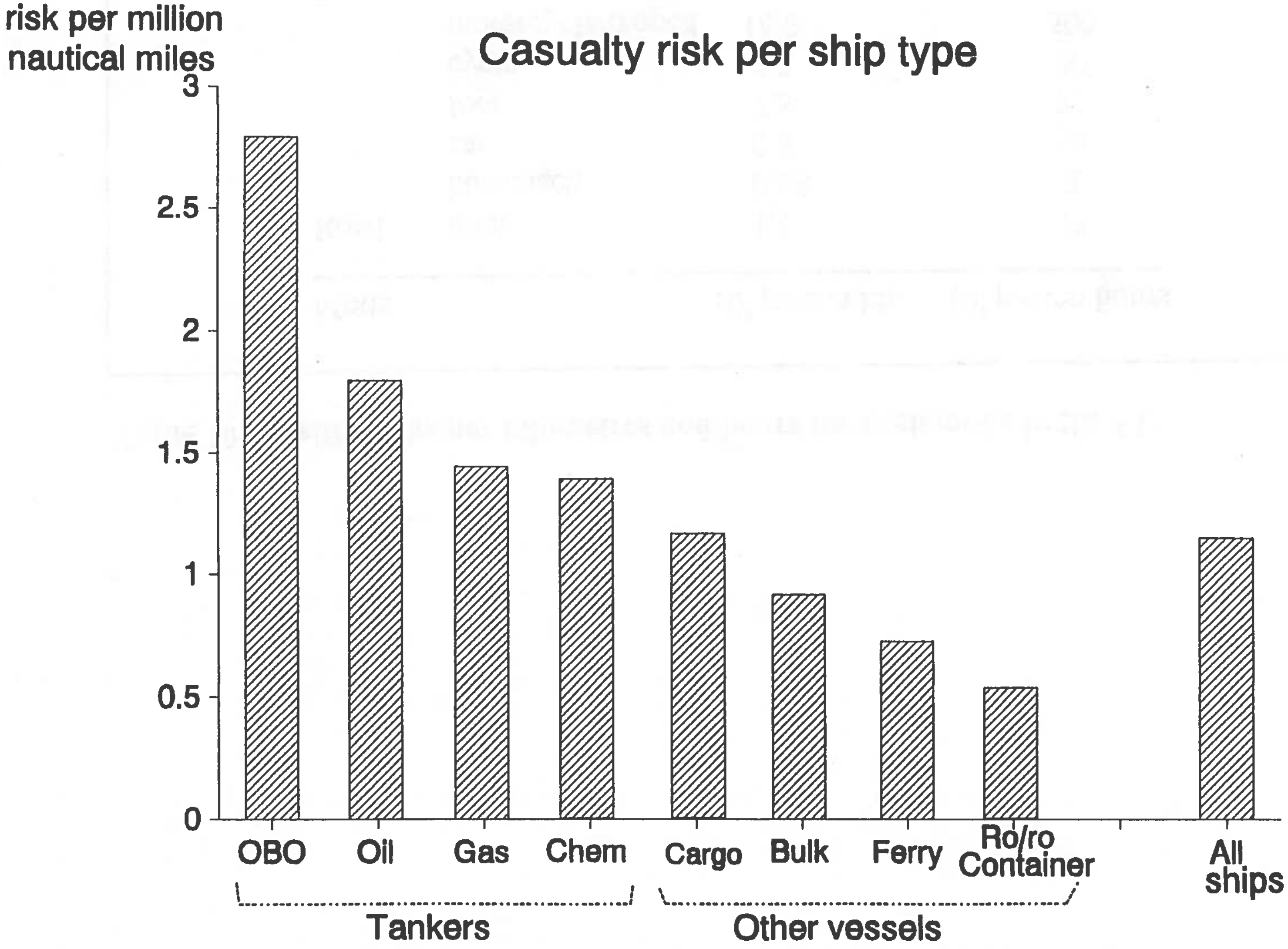

Casualty risk per ship type

Table 10 Fatality risks per kilometres and hours for each mode in the EU

Mode		10^8 person km.	10^8 person hours
Road	total	1.1	33
	bus/coach	0.08	2
	car	0.8	30
	foot	7.5	30
	cycle	6.3	90
	motorcycle/moped	16.0	500
Trains		0.04	2
Ferries		0.33	10.5
Planes		0.08	36.5

Table 12

Typical home-work trips by combined modes					Total trip km.	fatality risk per 100 million km.
walk 0.5 km	+	bus 8 km	+	walk 1.5 km	10	1.56
walk 0.5 km	+	bus 10 km	+	walk 0.5 km	11	0.75
cycle 3 km	+	train 12 km	+	walk 1 km	16	1.68
walk 0.5 km	+	train 15 km	+	cycle 2 km	17.5	0.97

Table I1 Risk of fatal and serious injury by travel in the EU

Transport mode	Risk of death or serious injury	
	10^8 person km	10^8 person hours
Road	13.8	413
Train	0.12	6
Ferry	0.76	24
Plane	0.12	55

Table 14 Fatality risks per 10^8 hours for activities and the risk ratios for transport

Activity		risk	road	train	ferry	plane
Transport		---->	33	2	10.5	36.5
			risk ratio transport/other activity			
Employment	all work	0.84	39	2.5	12.5	43.5
	banking and finance	0.17	194	12	62	414.5
	chemical industry	1.01	33	2	10.5	36
	construction work	4.70	7	0.5	2	7.5
	all railway work	5.50	6	0.5	2	6.5
Home activities		2.60	12.5	1	4	14

Table 15 **Passenger kilometres, fatalities and mortality rates of EU-citizens**

Mode	Billion km.	EU fatalities	MR
road user	3860	42.500	11.333
train passenger	270	108	0.029
ferry passenger	30	100	0.027
air passenger	240	190	0.051

Table 16 Mortality rates of transport, disasters, and diseases of EU inhabitants and their rate ratios

Cause	population	MR	road	train	ferry	plane
transport	all ages	---->	11.33	0.029	0.027	0.051
	< 45 year	---->	13.60	0.029	0.027	0.047
			ratios of transport MR / other MR			
disasters	all ages	0.016	708.1	1.813	1.688	3.188
cancer	all ages	337.0	0.034	<0.001	<0.001	0.001
	< 45 year	13.5	1.007	0.021	0.020	0.034
coronary	all ages	90.0	0.126	0.003	0.003	0.006
heart	< 45 year	7.7	1.766	0.038	0.035	0.060

Table 17 Incidence rate per 100000 EU inhabitants

Cause of incidence	Death or serious injury all ages	< 45 y.
road transport	142	170
cancer	670	27
coronary heart	135	12

Corridor Risk Assessment

Analyze historical data and trends to identify operational rail corridors that may benefit from the implementation of Positive Train Control.

Sherry Borener
USDOT Volpe Center

Study Background

"Railroad Communications and Train Control" FRA 1994 Report to Congress

- Cost / benefit does not support nationwide requirement
- Significant potential benefits exist for research and application of PTC systems

PTC Functional Description

Reviewed prototype PTC systems and created a general PTC system description

Identified system functions that could play a role in reducing railroad accidents

PTC Definition

- Ability to <u>enforce authorities</u> (T.O. & CTC) and signals (ABS) - speed limit control
- Ability to <u>ensure safe authority issuance</u>
- Ability to <u>enforce temporary and permanent civil speed restrictions</u>
- Ability to <u>enforce braking curve envelope</u>

Accident Record Review
RAIRS 19[illegible] - 1995

- Accident records were examined for all 1574 accidents potentially PTC preventable accidents (PPAs).
- Accident scenarios (as reported in the narrative) were evaluated by a subject matter expert and were dropped if not considered truly preventable by a PTC system.
- Accident records were also dropped if geographic or rail data were incomplete or missing.
- Resulted in 819 PPAs".

Example Accident Rating Scheme

PTC Preventable Accident (PPA) Evaluation Scheme

TRAIN CONTROL PREVENTABLE ACCIDENTS BY CAUSE CODE

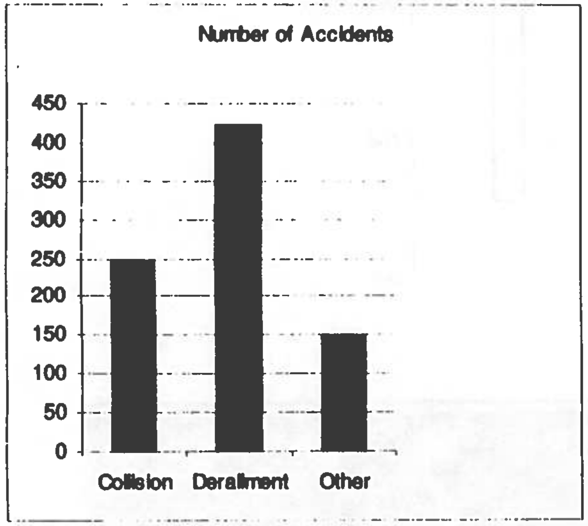
BLOCK SIGNAL TERRITORY	NON BLOCK TERRITORY
Y= Preventable	y= Preventable
N= Non preventable	n= Non preventable
C= Preventable depending upon circumstances	c- Preventable depending upon circumstances

CAUSE CODE	ATC	INT-ATS	CON-ATS	PTS	ITCS	PTC
T002 Washout/rain/slide/flood/snow/ ice damage to track [slide/flood] *Installation of slide fences/ high water detectors required*	C-n	C-n	C-n	C-c	C-c	C-c

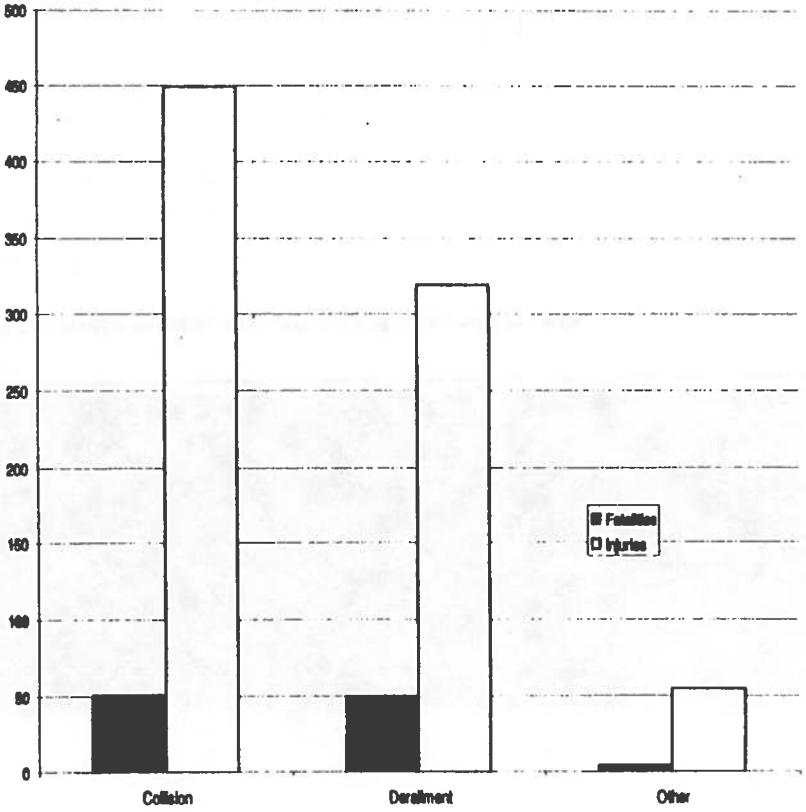
RAIRS Data Summary
1988 - 199[illegible]

Total accidents during study period	22,594
Total Geo-located mainline accidents	17,366
PTC Preventable Cause Codes	1,574
Met review analysis criteria	819

Number of Collision, Derailment and Other
[illegible] and Consequences



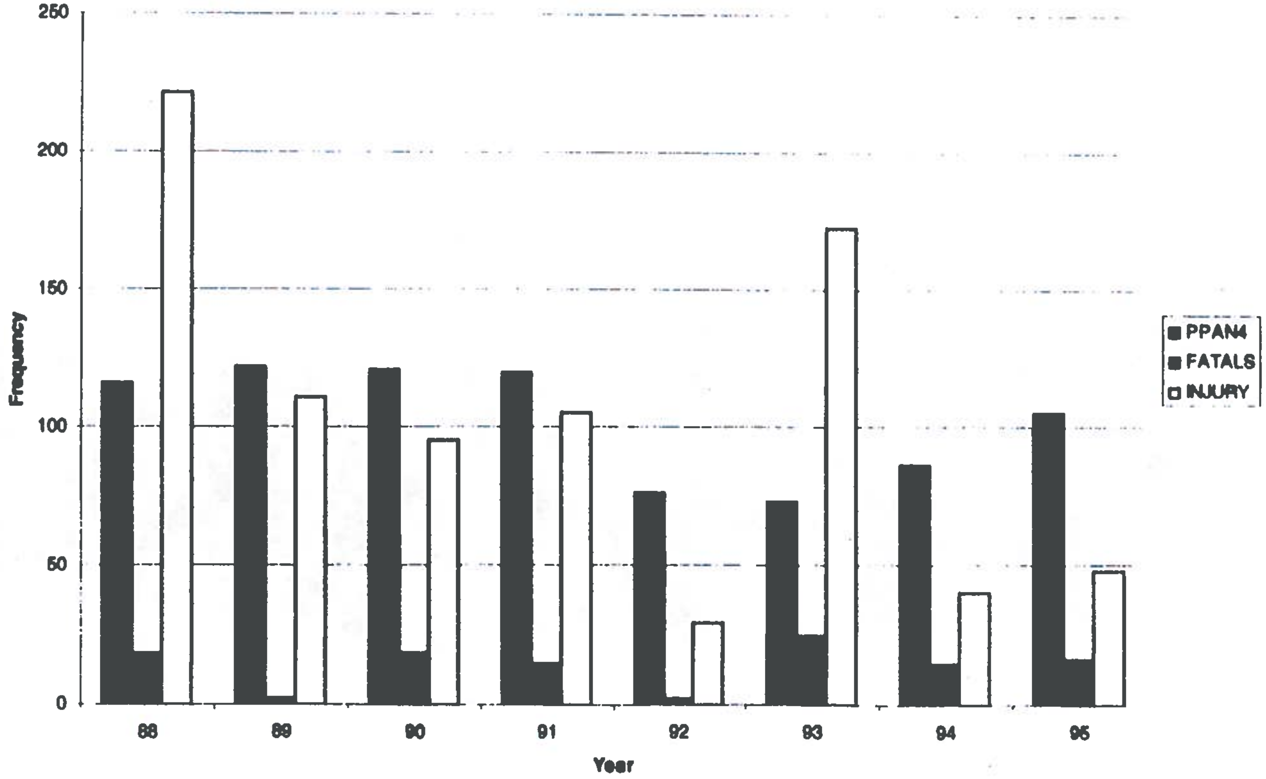
Number of Accidents



Fatalities and Injuries

PPA Characteristics Level 4

PPA Level 4 Number of Incidents,Fatalities and Injuries



GIS Platform Development

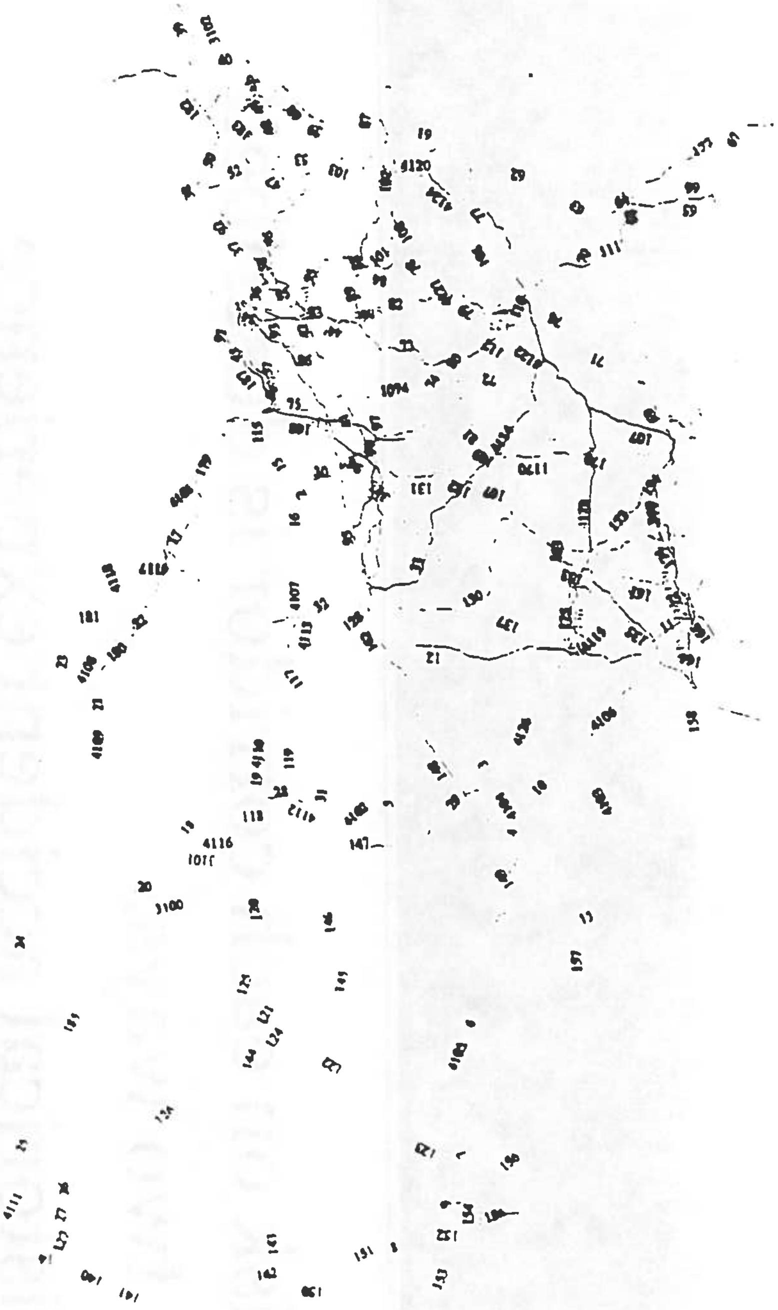
- Adapated and created a 1:100,000 GIS representing the mainline US rail network (ratio 1cm : 1kilometer (.62 miles)
  - » Flow data: railroad provided data on gross tons of freight shipped annually between stations
  - » Feature data locations of signals, switches, grade crossings
  - » Linearly referenced data on speed restriction, signaling/control methods
  - » Accident locations
  - » Topography and population characteristics

GIS Analytical Approach

Created uniform segments (routes) to represent normal operational characteristics, ending at control points.

Developed characteristic variables such as Length Weighted Average Speed.

Employed in *Poisson* regression model, and forecast.



4120
1094
4116
1011
3100
147
4107
4113
131
12

Corridor Based Risk Assessment

- Risk on each corridor is described in two ways:
- Historical accident experience
- Predicted accident experience
  - Comparison of historical and predicted rates


Seattle-Tacoma PTC Accidents
SEATTLE
AUBURN
TITLOW
PIONEER
WEST TACOMA
PUYALLUP
SUMNE
PPA Typ
01 Deraillmer
02 Head on c
03 Rear end
04 Side colli
05 Raking cc
08 RR grade
09 Obstructi
12 Other
Other type
0 1 2
Miles

Predictive Model

- Regression Model
  - *Poisson (probability model) assumes that accidents are random in time and a function of exposure and track/location-specific factors.*
  - *Dependent Variable - Occurrence of a PPA*
  - *Independent Variables*
  - Speed, Curvature, Type of Signal or Control Method, Traffic Mix (freight/passenger), Total Traffic Volume

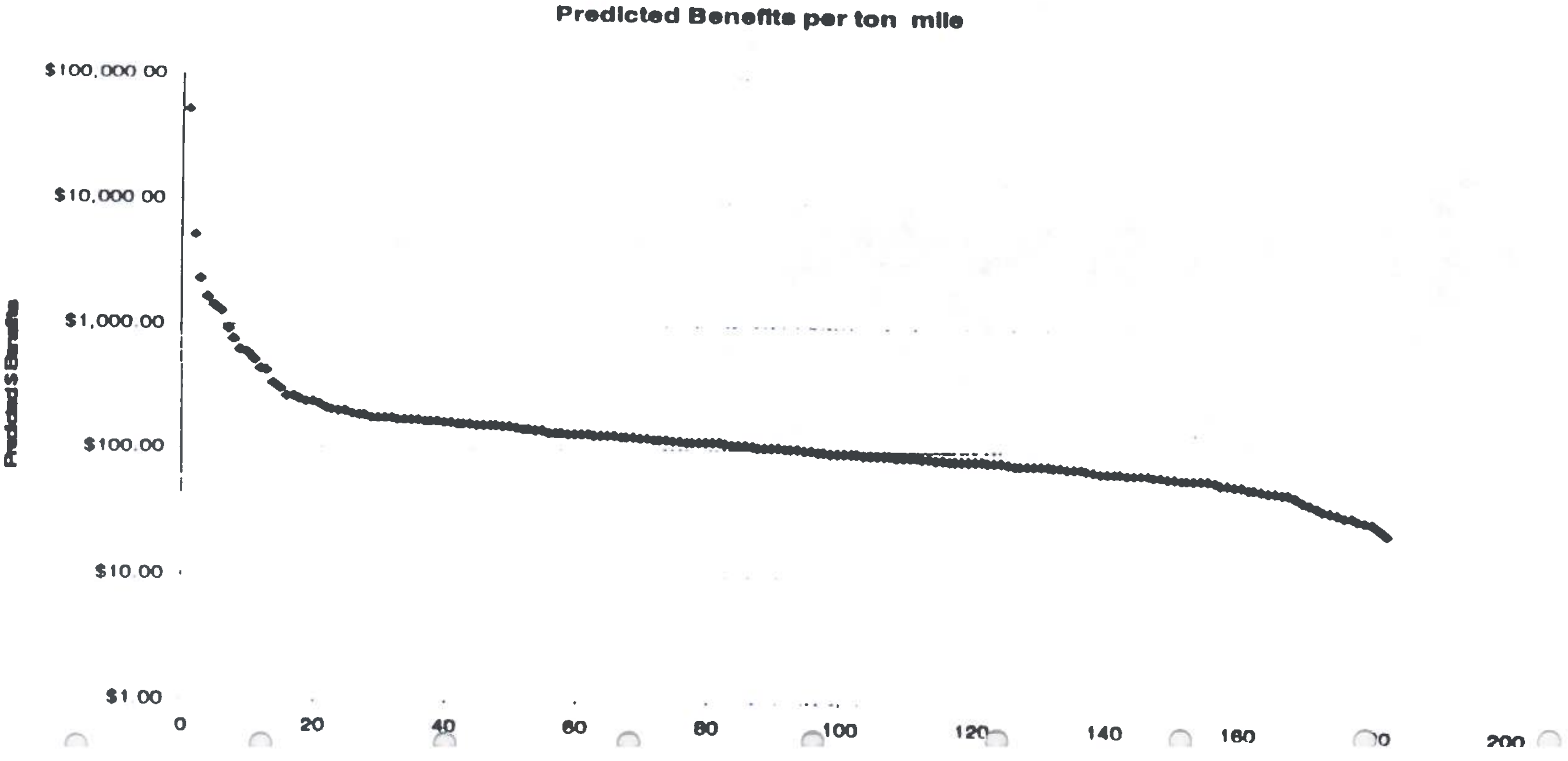
Consequence Estimates

- All estimates based upon average consequences in the PPA dataset.
- Fatalities:

Fatalities = Freight Fatalities in Freight Accidents +Passenger Fatalities in Passenger Train Accidents

#PPA fatalities$_i$ =μ_i (Total passenger fatalities/passenger train accidents * passenger/total tons segment$_i$ + Total freight fatalities/freight train accidents * freight/total tons segment$_i$)

Predicted Benefits per Ton Mile



Benefit Assignment Methods

- Fatalities are expressed as a willingness to pay of $2.7 million per avoidance
- Injuries are expressed as a willingness to pay of $100,000 per avoidance
- Total damages are multiplied by 1.5625 (reflecting FRA and AAR's estimate of under reporting)
- Total evacuations are costed at $1,000 for each person

DRAFT

EXPLAINING CHANGES IN THE YEARLY INCIDENCE OF MOTOR VEHICLE FATALITIES, 1982-94, WITH REGIONAL MODELS: DEMOGRAPHIC, ECONOMIC, ALCOHOL-RELATED EFFECTS

September 1998

David Skinner
Sherry Borener

Phone: (617) 494-2696
FAX: (617) 494-2696
E-mail: skinner@volpe.dot.gov

John A. Volpe National Transportation Systems Center
U.S. Department of Transportation
55 Broadway, Kendall Square

EXPLAINING CHANGES IN THE YEARLY INCIDENCE OF MOTOR VEHICLE FATALITIES, 1982-94, WITH REGIONAL MODELS: DEMOGRAPHIC, ECONOMIC, ALCOHOL-RELATED EFFECTS

David Skinner

John A. Volpe National Transportation Systems Center

Abstract--This working paper examines general factors and their mechanisms involved in causing changes in the yearly incidence of motor vehicle fatalities for the years 1982 to 1994.The factors are demographic change, sustained economic growth, a economic downturn, 1991-92, alcohol consumption, and differential growth by region in population and economic activity. The approach taken is to first use standard epidemiological variables: age, location, time of day, and the passage of time. Subsequent analyses are planned to include crash-related variables from Fatality Analysis Reporting System (FARS). There was a decline in nighttime fatalities absolutely and relatively to daytime fatalities over the study period. 'Daytime' was defined as the period 6:00 a.m. to 6:00 p.m.; 'nighttime', as the remainder of the day. The changes in nighttime fatalities were found through regression analysis to be positively associated with changes in a variable serving as a proxy for beer consumption, shipments (wholesale) of malt beverages. This relationship is interpreted as associated with alcohol awareness and driving safety programs. Likely declines in nighttime fatalities were also influenced by the decline of 15-to-29 year olds by about seven million (11 percent) from 1982 to 1994. Other factors examined in this paper were the sustained economic expansion during the study period; the exception to that expansion, the economic downturn of 1991-92; and significant changes in the entire age structure of the United States population, notably the aging of baby boomers into the safer driving 35-to-54 age group.

Yearly 'changes' in fatality incidence are described as being of two types: (1) trends consisting of small consecutive increases or decreases occurring over a number of number of years; and (2) shocks, a one year drop in absolute number of fatalities followed the next year by an increase back to the previous incidence level. The two types may be sufficient to provide explanations of what appear to be cycles in the fatality time series. A shock during this period is interpreted as the result of an economic event, the downturn of 1991-92 which had a similar effect, although not as drastic, as the 1982 recession. The slow upward trend in daytime fatality series since 1982-83 through the late 1980's resulted in the growth in, and rebound of, daytime fatalities. Nighttime fatalities follow a different path, a steady declined, interpreted as mentioned as resulting from alcohol programs and awareness as evidence by changes in alcohol consumption. Total fatalities from 1992 through 1994 increased because the daytime fatalities were increasing faster than nighttime fatalities were declining, a simple net effect.

Methodologically, the partitioning total motor vehicle fatalities into 'daytime' and 'nighttime' was found to analytically preserve the different causal mechanisms at work in determining total incidence.[3] These mechanisms were identified by a pooled time-series, cross-section, regional regression model. The 13 years of observations were disaggregated for the United States into State, division (U.S. divided into nine areas), and regional (U.S. divided into four areas) levels. Differential fatality change was present along lines one might expect from population shifts and relative changes in economic growth. Changes in the yearly incidence of daytime fatalities were best modeled by gross state product (GSP) and retail sales. Changes in the yearly incidence of nighttime fatalities were associated with a variable serving as a proxy for beer consumption, the shipments of malt beverages at the wholesale level. Changes in VMT were not found to be strongly associated with changes in either nighttime or daytime fatalities. Changes in GSP and retail sales were, however, associated with changes in VMT.

The regional regression models used, the partitioning of total fatalities into nighttime and daytime, and the results of this study can help in assigning the relative contributions that safety programs and external factors have in changes in the yearly incidence.

Keywords: highway safety, accidents, motor vehicle crashes.

RESULTS[1]

A summary of this working paper is presented below. Four different types of factors were found to affect the yearly incidence of motor vehicle fatalities in the thirteen-year, study period 1982 to 1994. These factors included standard epidemiological variables: age, location, time of day, and the passage of time. As well, economic activity and alcohol consumption played a major role. This approach -- of first examining the most general of factors -- was purposely taken. Subsequent analyses are planned to include more crash-related variables from the Fatality Analysis Reporting System (FARS), notably alcohol use. The methods and results are discussed in detail within the working paper.

The total yearly incidence of fatalities was partitioned into 'daytime' and 'nighttime' fatalities. Daytime was defined as the period 6:00 a.m. to 6:00 p.m.: nighttime, the remainder of the day. The influence of two factors was to reduce the yearly incidence of nighttime fatalities. Those factors were alcohol programs and awareness and probably relatedly the reduction in the absolute

---

[1] RESULTS section presented before INTRODUCTION in this draft to facilitate reading.

numbers of the 14- to-29 year old population cohort. a high risk driving group.

However. daytime fatalities increased because of a strong. and generally continuously so. economy. This growth more than offset the decline in nighttime fatalities in most years of this study. After 1992. this was particularly true. Another factor that probably caused daytime fatalities to increase was the shifting of population to more temperate parts of the countries. This factor is less quantifiable. The population shift over time may be causing increases in at least daytime fatalities because it is occurring in areas with strong regional economic growth. As well. those areas are more temperate and there is less seasonally-related declines in exposure during winter months. The effects of each of the four factors on the yearly incidence of fatalities are summarized below.

Change in the absolute amount and proportion of daytime/ nighttime fatalities
In 1982. motor vehicle fatalities during the nighttime were 27,840, representing 63 percent of all fatalities. Daytime fatalities were 16.105 and 37 percent of total fatalities. ('Daytime' is defined as 6:00 a.m. to 6:00 p.m.; 'nighttime' as the remainder of the day.) At the end of the thirteen-year period analyzed in this paper. 1994. nighttime fatalities had declined to 21,703. representing 53 percent of all fatalities. Daytime fatalities increased to 19.013, 47 percent of all fatalities. The respective decline and increase in these series were steady without any meaningful inversion during the period. as shown in Table 2.

Different causal mechanisms at work for daytime and nighttime fatalities
Regression analysis associated percentage changes in yearly nighttime fatalities with a proxy for beer consumption. Daytime changes showed no such association. Percentage changes in economic activity were associated with daytime fatalities but not with nighttime. Changes in vehicle miles traveled (VMT) were not significantly associated with either nighttime or daytime.

The interpretation made of these regression results is that daytime fatalities are increasing because of strong. sustained economic growth over this period with the exception of an economic downturn in 1991-92. Nighttime fatalities are declining because of (1) program effects notably those involving alcohol. and relatedly because (2) the high risk age group. those 15 to 29. have declined in absolute numbers steadily over the study period. As well. the baby boomers have moved into the safer age groups.

The net effect of a larger increase in daytime fatalities over the slowing decline of nighttime fatalities has caused total fatalities to increase after 1992. The year 1992 represented a relative low point in the total fatality series because the economic downturn 'shocked' downward the growth in daytime fatalities while -- probably -- accentuating the already well in progress decline in nighttime fatalities at least for a while. (Refer to Tables 2. 3. and 4)

Demographic change among ages 15-29

Demographically, the age structure of the United States population around 1994 could not been distributed more optimally for low fatality incidences. At the beginning of the study pe the resident United States population of 15- to 29 year olds was 62.3 million. Some thirteen yea later, this age group declined by 7 million to 55.3 million. Also, the 30- to 34 year old group grew by only 3.4 million. The big growth was among those aged 35 to 54 who grew from 50.5 t 71.6 million -- by 42 percent -- representing an aging of baby boomers into the safer driving years. To show what a shift in age structure means during the study period, a simulation was done using the 1982 age structure with 1994 population and age-specific fatality rates. From thi simulation, there were 1,429 more fatalities than the 40,716 in 1994 that actually occurred as shown in Table 7.

Thus, the demographics have recently been favorable for lower yearly fatality incidences. However, as those interpreting low crime statistics have noted, those under the age of 15 have grown (as shown in Table 5) and will start moving into the 15- to 24 year old group with obviou implications for crime (and motor vehicle fatalities). (Refer to Tables 4, 5, and 6)

Economic effects
The economic effect found in this study was the association of percentage growth (decline) in gross state product and retail sales with percentage growth (decline) in daytime fatalities. And also the downward shock to daytime fatalities in 1992 assumed to have been caused by the economic downturn of 1991-92, even in face of a steady upward trend in the series. The year 1992 appears to be like 1982-83, a decline resulting from an extraordinary event. Two economic variables that showed a strong relationship were changes in gross state product and retail sale both outperforming changes in VMT. While regression analysis did not show any associati with nighttime fatalities, it should remain an open question for more research if there is any economic effect in a nighttime series. In short, economic activity was associated with daytime fatalities but not with those of nighttime. An extraordinary economic decline will cause a decline in daytime fatalities for a year or more. (Refer to Figure 1. Note has not been included in this draft.)

Geographic shift
This factor is harder to quantify. The yearly fatality incidences for daytime and nighttime fatalities were dimensioned to capture regional and local effects. State, division (divided U.S. into nine areas), and regional (divided U.S. into four areas) analyses were done. Differential fatality change was present along lines one might expect from population shifts and differential rates of economic growth within the United States. Striking was the decline in fatalities in the Northeast as shown in Table 8

Net effect on total fatalities
How all these factors net out to determine the yearly incidence of total fatalities is not altogether certain. However, one plausible view is the increase in daytime fatalities because of strong

economic growth causes total fatalities to increase -- or at least plateau -- because the decrease in nighttime fatalities. resulting from highway safety programs (notably alcohol) and reductions in the number of 15- to 29-year olds. was not large enough to offset.

Making an analogy to business cycle research. there is a need for more complete experience to appear in the time series of motor vehicle fatalities. Starting from the beginning of the FARS data, 1975 to the present there are the *appearance* two and one-half cycles. It is more likely that the 'cycles' more likely are the results of shocks and gradual recovery to an equilibrium. With the four to five that is assumed for business cycle analysis it will be awhile. However. some understanding has been gained and can be gained incrementally with additional years. A rush to provide an explanation of change should be avoided. The further maturing of FARS will eventually yield more answers. With more fatality experience likely some conclusions will be weakened while others will be strengthened.

INTRODUCTION

Visual inspection of a time series of motor vehicle fatalities leaves one with the impression of cyclical movement. upward and downward trends. and shocks. Or at the least the impression that yearly incidences are far from random outcomes. There has always been the tendency to attribute upward changes in the yearly incidence of fatalities to more driving; and a downward change. to safety programs.

This working paper examines the reasons for these changes from 1982-94 through the lens of standard epidemiological variables: age. location. time of day. and over time. As well. variables representing economic activity and alcohol consumption are used. Subsequent analyses are planned to include more crash related variables from FARS. And to extend forward and backward in time this analysis. This will further test if the factors found to be important in this study period have an effect in other periods. There is no guarantee that there is anything other than temporal truth because other factors may be important in establishing fatality incidence. In this Introduction some background information to the subsequent analysis is presented. The reader's indulgence of the Introduction is appreciated.

Scope

The analysis done in this paper is on fatalities taken from FARS for the years. 1982-94. Those thirteen years were selected because consistently measured. state economic data was available to the author at the time of study. The fact all the twenty-three years of FARS was not utilized. or that the most recent observations were not used. is not thought to be restricting. A split data technique has implicitly been used.

Conclusions drawn from 1982-94 data can be tested on the unused fatality years. The same data set obviously cannot be used to both develop and test hypotheses. Results also can serve as hypotheses for new data sets. The models. and variable specifications. can be used as well on the unused data and to address different types of questions.

Approach

The approach taken is to first use standard epidemiological variables: age, location. time of day. and the passage of time. (Subsequent analyses are planned to include more crash related variable from Fatality Analysis Reporting System (FARS) particular alcohol usage. An epidemiological approach is used. FARS data is partitioned by time of day (nighttime, daytime). and geographic area (state, division, region). The purpose is to look for 'places' where change, up or down. is present. And to then seek consistent explanations for such change. In this paper. it was deemed a good beginning strategy to structure the fatality data in the traditional epidemiological dimensions of age. time. and location. Clearly, data exploration is occurring but deemed defensible because no comprehensive theory exists for why the yearly incidence of fatalities changes. The belief that it is only from a single cause, as changes in published VMT. is inadequate.

Defining 'change'

To understand changes in incidence there is a need to define quantitative terms what is meant by 'change'. Examining the yearly percent change from 1914 to 1996 of Table 1, 'small' changes might be classified in the 1 to 3 percent per year range. So, defined most changes would be small. 'Medium' might be in the range of 4 to 6 percent. Medium changes would be less frequent. 'Large' changes would be 7 percent and above. Large changes can episodically be associated with major social. political. and economic events. often historic in nature.

Also. any definition must include a temporal dimension. Over what time do a series of small changes become a significant trend? And how to measure change, absolutely. relatively or normalized someway? More thought needs to be given to specifying change. For now. two types are addressed: (1) a trend. consisting of several years of percentage changes in a fatality series generally in the same direction: and (2) a shock. consisting of a one or two years of decline in a fatality series with a return to trend levels.

Historic changes in the yearly incidence of fatalities. 1913 to 1996

Yearly changes in motor vehicle fatalities from 1913 to 1995. as shown in Table 1. can be characterized as 'large'. 'medium'. and ' small' as defined above. The large. double-digit, yearly percentage changes are the easiest to explain. being associated with. as mentioned above. historical events -- social. economic. political in nature. Most double-digit changes are downward. The one notable exception is the end of World War II in 1946 when there was a double-digit increase

The medium-size percentage changes -- those of 3 to 7 percent -- are probably the most difficult to explain. Successive yearly, small changes of 1 to 2 percent which when considered together would appear not to be random fluctuations, are also difficult to explain. There has been a tendency to explain with growth in vehicle miles traveled (VMT). This is shown to be wanting for 1982 to 1994 by the analyses in this paper. In a regression equation, changes in VMT are not highly associated with changes in daytime or nighttime fatalities.

Pre-World War II fatality experience seems to show: (1) growth of the automobile industry and driving; (2) safety efforts to reduce crashes from 'boomtown' rates; (3) boom-and-bust economic cycles of depression-like activity; and (4) World War I. Inconsistent reporting of fatalities and their attributes as well as the lack of explanatory data probably makes full understanding of this period impossible.

A number of analytically interesting years exist in the history of FARS (Fatality Analysis Reporting System). Prior to the study period, the increase from 1975 to 1981, thought to be a rebound from the Oil Embargo and a *de facto* increase in driving speeds even though the legal speed limit remained at the maximum 55 miles per hour. Then, total fatalities declined 10.8 percent in 1982. The worst post-World War II recession occurred late in 1981 and into 1982. There had also been an economic downturn in 1980. The decline was thought to be related to economic factors as well as various safety programs, but no consensus on the proportions attributable to each. There was also a decline in 1992. The year 1992 is referred to as an economic downturn.

Patterns

Referring to Table 1, relative 'high' years, in absolute numbers of fatalities, do precede 'low' years. After 1947, no low year, however, precedes a high year. Fatality levels certainly rebound after a drop, but it takes a number of years to return to levels of a previous high. This suggests that fatality levels can be shocked -- but only downward. The most recent exception to this is 1946 the end of World War II although a couple of other years, 1950 and 1964, came close. As well, the effects of these shocks on fatality levels remain for several years.

The years 1980-81 vs. those at the beginning of this study period, 1982-83, seems transitional. (The term 'epidemiological transition' may not be too strong considering where the trend seemed to be leading from 1975-81 and what happened beginning in 1982-83.) Those years ended the steady increase in fatalities going back to 1975. Thereafter, there is the *appearance* of a downward trend with successive years forming a cycle, with a periodicity of eight years (plus or minus a year).

Actually, any appearance of 'cycles' could come from two types of change: (1) shocks which are associated with economically related events; and (2) trends which are consistent upward or downward movements in the total, or subsets of the fatality series. Two other types of variation are possible but have been avoided: random and seasonality. On the data set of this study, randomness is at least minimized because the subsets remain fairly large. Seasonality is eliminated because annualized data is used.

Origins of interest in incidence changing factors
From time to time, it has been necessary to evaluate highway safety program interventions and other legislative and natural events affecting the number of motor vehicle fatalities. Such cases are the minimum consumption age for alcohol, mandatory restraint use, and higher speed limits on selective roads. It is necessary to control for factors other than those of immediate interest. Some of the control has been implicit using other highly correlated fatality series with the one of interest. The further away in time from the intervention, the harder it is to use an implicit method. Also, it is harder to evaluate a staggered intervention when different states adopt at different times. Understanding the forces and mechanisms involved in change will help with following highway safety interventions over longer periods. [2]

Critical need to understand nature of change
Regardless of its nature, there clearly is change in the yearly incidence. For motor vehicle fatalities in the United States, the difference between 1979 and 1992 is striking: 51,093 deaths in 1979, and 39,250 deaths in 1992. Although this represents an extreme example to emphasize a point and 1979 is outside the study period, a *11,843 different in the yearly incidence of motor vehicle fatalities in 13 years* is worth trying to understand in of itself. The purpose of understanding is operational as well: (1) better explanations to the motor vehicle safety community and general public as to why crash levels change from year to year (as was the case with increases since 1992); (2) improved methods for controlling for 'all other factors' whe evaluating effects of safety programs, interventions, and new technologies; and (3) more knowledge of crash mechanisms to enhance existing, and design new, safety programs, and creating efficient allocation of resources among safety programs.

Importantly, it is hoped that interest can be created for the study of highway safety in academic and public health arenas where such interest does not already exist, and where the application of theories, points of view, and empirical methods may well bring understanding.

Evaluating the effects of highway safety programs is essentially a search for controls to a natural experiments. Good program evaluation is important because implementing resources are so scarce.

Commonality with other unintended fatalities and health-related outcomes
It is hard to link the level of motor vehicle fatalities to other socioeconomic and health outcomes like other unintentional injuries, crime, suicide, and disease. Such efforts may not be the best lines of inquiry. Instructive, however, are the methods used to study suicides and homicides, the range of findings, the lack of consensus, and the recommended policy implications. It seems that

epidemiological and sociological studies have not found commonality among suicides. homicides. motor vehicle crashes. and other unintentional injuries.

There is probably only a general relationship (alcohol use. behavior of younger age cohorts. demographic patterns, stress) among motor vehicle fatalities. other transportation crashes. suicides, and homicide. These interrelationships have been studied without conclusive findings. A common mechanism probably does not exist. At best, and proverbially stated. "different currents in a common stream."

In its strong form. other series representing types of unintended injuries. suicides. crimes. health outcomes can be statistically associated (even if with a lag) with motor vehicle fatality series over significant periods of time. thus suggesting common mechanisms. In its weak form. similar determinants are present: alcohol, male culture, anger, risk taking, and the like.

If some commonality exists there would be benefit to the highway community to enter into joint efforts with other public health efforts. Explanations of incidence change in other health-related fields are not complete. The way total fatalities have been partitioned in this study. and the regression models used. may be very helpful in searching for commonality.

METHODS

Period of study

The period of analyses for this study was 1982-94. This period was selected because state economic data. in constant dollars. was at the time of study only available for those years. By now. it is possible to extend forward to 1996. FARS data is of course available back to 1975.

Repeating what was said earlier. using more years in estimation is not necessarily an advantage. A split data technique has implicitly been used. Conclusions drawn from 1982-94 data can be tested on the unused fatality years. The same data set obviously cannot be used to both develop and test hypotheses. And as hypotheses for anticipating what is to come. It this regard the caveat is given that there may not be any absolute truth only relative to a series of years. The models. and data partitioning structures. can be used as well on the unused data. and to address different questions.

Dependent variables: daytime and nighttime fatalities by state, region. and division level

It would seem that total fatalities should be divided up into sub-entities for study. How to do it is the question. Total fatalities should be divided for the same reason disease would be to obtain homogeneous groups which have a unique set of determinants. 'Total motor vehicle fatalities' is probably more of a category than any thing else just as 'cancer' is.

Fatality data was taken from FARS (Fatality Analysis Reporting System) on CD-ROM. 19[illegible]5. Total fatalities which were partitioned into 'daytime' and 'nighttime', 6:00 a.m. to 6:00 p.m. an 6:01 p.m. to 5:59 a.m. respectively. Fatalities were spatially dimensioned by state. States were easily combined into nine divisions and four regions of the U.S. Other fatality types that were tested were occupant fatalities only, fatalities for 15 to 24 year olds, fatalities involving a driver 64 years of age or older, and fatalities at highway-rail crossings. Nothing is reported in this paper about those efforts, results being immaterial to the subject of change.

Independent variables: gross state product and retail sales
Economic variables were taken from Gross State Product by Industry 1977-94, from the U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Analysis Division.
Economic variables tested besides gross state product and retail sales were the value of some sector variables that comprise gross state product, besides retail sales: agriculture, mining, construction, manufacturing, transportation, wholesale trade, financial, service, government, and amusement. Only construction had significance at the level of gross state product and retail trade in the daytime fatalities equation. It was not reported because it is felt as different time periods are used it will not be as strong because of the volatility of the construction sector.

Independent variable: VMT

Independent variables: shipments of malt beverages
Shipments of Malt Beverages served as a proxy for beer consumption. This variable is compiled by the United States Brewers Association ( ) and is based on reports supplied by individual states. It was assumed that alcohol programs could explain some of the declines in shipments in states. Obviously, there are other reasons why consumption could decline, notably an aging of the population.

Quantifying changes in population
One demographic variable was tested, yearly changes in total U. S. resident population. But percentage changes were not associated with changes in fatalities. It has been difficult to use population in ways to indicate any effect on changes in fatalities in the past. More work needs to be done on the specification of changes in population to show the role demographics have in fatality change

Need for quantifying social forces
One type of independent variable that would be worthwhile to test is those representing social change. Unfortunately not much thought has been given to these. But it is possible that cohort effects exist. Until the effects of these variables are considered, explanations of change run the

risk of being overly attributed to variables that can be specified. economic and demographic.

Regional regression models: pooled time-series, cross-section

Models used have three levels of spatial aggregation. The lowest is the state level. The division level partitioned the United States into nine areas. The region level divides the country into four sections. The models and data could be structure in a fourth level of aggregation. the national level. This level has not been used because aggregation results in only after transforming the variables into percentage change for just twelve observations. Also, national level time series have been explored and it is doubtful that new knowledge will come from further study even as the number of yearly observations increases. The state level is not used because counts for most states are thought to be influenced randomly. It is the division and region level of aggregation that are explored.

Several ideas are tested by the using regional regression models consisting of pooled time series. cross section observations, disaggregated at the region (U.S. divided into four areas). division (U.S. divided into nine areas). and state levels. As mentioned, there are analytical parallels between what has been down in economics for unlocking the causes of the business cycle and analyzing the fatality time series. The thirteen years available represents a short period for time series analysis. But combining with cross sectional observations within each year which exhibited much variation provided a rich data set. it is felt.

To reduce the possibility of a common trend causing indication of statistical association. both independent and dependent variables have been first differenced by working with percentage change from the previous year. As an example. if the economy does have an effect on the yearly incidence of fatalities. percentage changes in. say, gross state product should be associated with changes in fatalities over time. The basis of the association is not a common trend or a dependence of both variables on time.

Models turned out to be parsimonious as two or more variables did not seem to add much explanatory power.

DISCUSSION

This working paper adopts the view that changes in the yearly incidence of motor vehicle fatalities come from internal. as well as external factors Internal forces are defined as: the amount of vehicle miles traveled (VMT) but not necessarily the changes in the average risk of a mile. safety technologies. infrastructure improvements. safety programs. and others. With the exception of VMT. internal factors are difficult to quantify and require implied or induced methods for understanding. For instance, it is hard to specify a variable which would repre the intensity level of highway safety programs. It is unlikely that a dose-response relationship exists. More likely there are long lags before results can be measured.

Shift in daytime/nighttime composition as resulting from safety programs

By defining 'daytime' as 6:00 a.m. to 6:00 p.m. and 'nighttime' as the remainder of the day, 6:0 p.m. to 6:00 a.m., total fatalities are partitioned into two series of analytical interest.[1] A trend is readily apparent, as shown in Table 2. In 1982, motor vehicle fatalities in the nighttime were 27,840, 63 percent of all fatalities. During the Daytime, were 16,105, 37 percent of fatalities. 'Daytime' is defined as 6:00 a.m. to 6:00 p.m. and 'nighttime' as the remainder of the day. At th end of the thirteen-year period analyzed in this paper, 1994, nighttime fatalities had declined to 21,703, 53 percent of all fatalities. Daytime fatalities increased to 19,013, 47 percent of all fatalities. The respective decline and increase are steady from year to year during the period.

The 'daytime/nighttime' partitioning of fatalities is correlated, and closely so, with the decline alcohol related fatalities. (And non-alcohol related fatalities associated with the growth in daytime fatalities.) Clearly the indication in this paper is that nighttime fatalities have declined in no small part because of alcohol safety programs. However, it is also felt that the population decline among those most likely to consume and operate a motor vehicle also played a part. What will remain to be seen is that in a few years when the youngest cohort, those under the age of 15, moves into the higher risk age groups. That is, whether alcohol-related fatalities will continue to decline or decline at a slower rate even though alcohol programs are still having an effect.

The interpretation is that daytime fatalities are increasing because of strong, sustained economic growth over this period with the exception of a downturn in 1991-92. Nighttime fatalities declined because of (1) safety program effects notably alcohol-relate (discussed below); and because (2) the high risk age group, those 15 to 29, declined steadily over the study period. Baby boomers (born from 1946 to 1960) also moved into the safer driving ages, 35 to 54 years old. The net effect of a larger increase in daytime fatalities over the slowing decline of nighttime fatalities has caused total fatalities to increase after 1992. The year 1992 represented a relative low point in the total fatality series, 1982-94, because the economic downturn 'shocked' downward the growth in daytime fatalities while -- probably -- accentuating the already well-in-progress decline in nighttime fatalities. (Refer to Tables 2, 3, and 4)

Alcohol

Regression analysis associates changes in a beer consumption proxy with changes in nighttime fatalities but not with daytime. Changes in economic activity are not associated with nighttime fatalities but were with daytime. Changes in VMT were not significantly associated with either nighttime or daytime

Demographic
During the period 1982-94, there was a significant shift in the age composition of total population in the United States. 'Significant' at least in terms of the yearly incidence of motor vehicle fatalities. A similar impact has been felt in recent crime levels. But there is warning for a younger cohort is soon to move into the higher rate age categories.

Reductions of those aged 15-29
At the beginning of the study period, resident population of 15- to 24-year olds was 41.6 million. Some thirteen years later, this age group declined to 36.2 million. Also, the 25-to-34- years-old age group grew slightly from 39.4 million to 41.3 million persons. The big growth was among those aged 35 to 54 who grew from 50.5 to 71.6 million, representing an aging of baby boomers into the safer driving ages. There was a shift in age structure during the study period. A simulation using the 1982 age structure with 1994 population and age-specific, per capita fatality rates, results in 1,429 more fatalities than the 40,716 that actually occurred (Table 6). In fact, the excess number of fatalities increases monotonically each year (except for 1992) after 1982 until it reaches the 1994 level. Thus, the age composition has recently been favorable to lower fatalities. However, as those interpreting low crime statistics have noted the demographic dividend will begin to change as a larger cohort, aged 14 and under, begins moving into the 15- to 29-year old group with obvious implications for crime and motor vehicle fatalities (Table 5). (Refer to Tables 4 and 6)
Impact of economic activity
A relationship between economic activity and changes in the incidence of fatalities has long been noted. In fact, the origins of the idea may go back to the 1930's and the Depression. Statistical analysis has been done over some time periods. In an anlogous fashion, sociologists have a long standing interest in empirically testing Durkheim's theory (anomie) of a certain type of suicide during times of increased economic activity and/or structural change. To some there was the distinct impression of looking at the business cycle or a manifestation of it. Sections of the total fatality history have the appearance of cycles, with peaks and troughs, and long upward trend, characteristic of periods of sustained economic expansion. Again, this bolsters the analogy to the business cycle.

Where statistical associations are easy to obtain and show the positive variation between variables representing economic activity and total fatalities, or subpopulations thereof. However, no one knows exactly what the economy does beyond changing the amount of driving.

Some changes in fatalities are too large to be explained just by changes in the amount of driving. Hoxie and Skinner (1985) suggested that changes in economic activity also change the risk distribution of miles driven by increasing (or decreasing) riskier, discretionary types of driving.

Without questions the most work has been done on economic explanations related to the business cycle for changes in fatality crash series. There are several reasons for this emphasis, a strong one being the availability of data for both a myriad of economic variables and the now more tha twenty years of fatality experience, which can be subseted along many research-rich dimensio This empirical work in many cases has been well done. However, there are at least two shortcomings: (1) models have been shown not to track well when extended beyond the estimation range (Partyka, 1991); and no consensus explanation of what the economic activity actually does beyond possible changes in VMT.

Partyka (1991) showed as well that models forecasting yearly fatality incidence based on economic activity overestimated actual amounts. It was suggested that the amount of overestimation might be attributed to safety programs (notably alcohol and restraints). There are important implications for content and methodology from this work. Others have urged efforts to understand the economic mechanism.

It is postulated that 'daytime' is up because of steady economic growth before and after 1992. 'Nighttime' is down because alcohol programs have reduced or eliminated drinking before driving. (Declines in shipments of malt beverages also supports this belief for some regions of the country.) Also, the 1992 decline and 1993 increase likely resulted from the 1992 economic downturn. Total fatalities after 1992 increased because 'daytime' absolute increases are greater than those of 'nighttime'.

No consensus explanation of what the economy actually does

No one can explain -- and demonstrate using existing crash information -- what exactly the economy does to change the yearly incidence beyond changing the amount of driving. Changes in recreational and riskier driving are often given as explanations of the economic mechanis But such explanations can only be hypotheses.

While many studies have shown that economic activity affects crash levels concurrently in a positive manner (highs associated with highs; lows, lows) there is no consensus or proof of what the economy actually does beyond affecting the amount of driving. Such a path cannot possibly explain many of the changes given, at least not with the aggregate measures of driving or exposure available. One suggestion of the economic mechanism is that it affects not so much the amount of driving as the risk distribution of that driving. However, this cannot be consistently shown, it not being the case around 1992. During this period, economic activity may be associated more with 'daytime' as shown in Table 3.

Several mechanisms

The economy, in fact, could do any number of things to affect the yearly frequency of crashes. It need not -- and probably does not -- act through one mechanism or path. That is probably why it has been so difficult heretofore to find a consistent set of crashes that change with economic activity.

The possibilities of what economic activity does are many although not without limits.

Differential effects on people and exposure. short- vs. long-range effects. changes from a manufacturing to a service economy -- there are many possibilities.

Whatever effect the economy does have. the feeling is that these effects are played out within a level of social control like safety programs and secular trends -- social. demographic. and technological in nature. Thus, the economic effect is likely distorted and attenuated. Even the question of whether it is 'economic' is open to debate and definitional considerations. For example, new job creation may occur. but it may be the social change (gender roles. loosening social control. etc.) surrounding the creation that produces the real effect on crashes. The timing of the social effects does not necessarily coincide with the economic. Some pure economic changes may be structural and persist for a long time, as those resulting from a change in gasoline prices or insurance rates. (As mentioned above, various persons will make different interpretations based on their perspectives.)

Economic growth rates differ by region
Across time. the association of motor vehicle fatalities with economic activity seems to exist. But clearly it has been shown that variables representing various types of economic activity will not always track with a fatality-involved crash series. Even if time-invariant tracking could be achieved. statistical models do not seem to be the path through which understanding of what exactly the economy does. other than possibly changing the amount of driving, will be gained.

Without question the most work on reasons for changing crash levels has been done from an economic perspective. It has long been suspected that the level of economic activity has an effect on motor vehicle crashes as well as suicides. homicides. and many other health conditions. The relationships found are not always concurrent or in the same direction. It may take a while for economic activity to have any effect. particularly with health conditions. (This lag makes empirical estimation and quantification difficult.) While health conditions may be influenced adversely during economic downturns. suicides and motor vehicle crashes are thought to be reduced.

For motor vehicle crashes. no one has been able to adequately explain what the economy actually does beyond causing more driving. Changes in recreational and riskier driving have often been mentioned as the mechanisms at work in addition to increases in the amount of driving. But changes in crash levels since 1985 to the present has cast some doubt on this hypothesis. The latest changes suggest that there are many paths through which economic activity affects crash levels. This may be the reason that no one has been able to track. correlate. or associate economic variables with total fatalities. or subsets of. and other crashes over long periods of time. Simply put. although it seems plausible. the economic influences on crashes cannot be adequately and consistently demonstrated over time.

A number of theoretical and methodological difficulties exist in discovering economic influences. Some of these difficulties are listed below. Most economic variables represent a aggregate activity and experience of the general population. To the extent that crashes may involve a more restrictive population. the economic variables are less representative of the at-risk population. For instance. unemployment of young males would seem an appropriate economic variable. particularly for crashes involving fatalities. However. if fatalities are drawn somehow more selectively from the driving of certain types of young males. the aggregate unemployment rate of young males may contain extraneous and confounding information.

Economic variables not only affect social behavior concurrently -- but also in distributed ways (leads and lags). The full effects of an increase in investment, for instance. are not felt immediately on. say. employment and even more indirectly on consumer spending. an activity that might result in more and different types of driving. Understanding these leads and lags is a specialty unto itself. Complexity exists because the leads and lags have not been stable or 'well behaved' over time. Thus. finding correlations between crashes and an economic variable. even after finding the proper lead or lag. may never result in a truly predictive explanation.

Many economic variables are only proxies for desired theoretical concepts. Measures of unemployment, for instance. do not capture the wealth of workers. or their willingness to spend. As another example. current changes in income do not necessary capture peoples expectations about the amount. and timing. of their lifetime earnings. Theoretically, these expectations are the basis of spending at anyone time. In addition. many persons have stable incomes and changes in aggregate economic activity may have little effect on their behavior. Teenagers. dependent family members. and retirees would be a prime example of such.

Methodologically. the unemployment rate is in reality constrained to move within a range. This constraint makes establishing correlation with other variables like a crash series difficult.

A more complex explanation on how economic activity might produce changes in crash levels is offered. If economic activity does act to influence yearly changes in crash levels. its effects are mediated and distorted by social control. notably highway safety programs: and by secular trends. like changes in demographics and technologies.'Economic effects' are defined broadly to include not only those measured by traditional economic indicators -- but the accompanying social changes: degree of social integration. levels of supervision. changing work roles. diversity etc. It includes as well structural change. the more constant result in of a change in gasoline prices or loss of manufacturing. The economic effects do not act with precision (variable leads and lags) -- making quantitative understanding difficult. It is acknowledged that this explanation is only a hypothesis.

Recommendations

The following recommendations for continued research into reasons for yearly fatality incidence change are made. Look for commonality with other types of unintended injuries. suicides.

indexed crime, alcohol consumption patterns, and health outcomes. Further partition fatality series using gender, and other variables as warranted. Gender is deemed important because so of the increases in per capita rates may be increased licensing among females, particularly so as cohorts more into the older age groups.

NOTES

1. The partitioning into nighttime and daytime of total fatalities is currently being used by the author to analyze highway-rail crossing crashes. As well, it is also being used for study of fatalities involving older drivers.

2. Fatalities result from natural experiments and just as controls are used in laboratory experiments. controls are needed for natural experiments. The external factors have been the most neglected when evaluating reasons for changes in the yearly incidence of fatalities.

3. A cautionary note that partitioning by purely statistical approaches. or by the way fatalities are classified for publication, does not always preserve the causal mechanism of interest. Care should be taken anytime partitioning is attempted. Errors of omission are usually preferable to those of commission. Also transforming fatality series as by normalizing to form ratio variables can interject artifactual variation.

4. Referenced on Table. There seem to be a lack of symmetry between double-digit in magnitude increases and declines. The end of World War II. 1946, there has been only one such positive increase although 1950 and 1964 came close.

REFERENCES

1. Hoxie, Paul and Skinner, David. A Statistical Analysis of Socio-Economic Influences on Tree Groups of High-Risk Fatalities. unpublished. August 1985.

2. Partyka, Susan C. Simple models of fatality trends revisited seven years later. *Accident. Analysis, and Prevention*. Vol. 23, No.5 pp. 423-430; 1991.

Sources of Exposure Data for Safety Analysis

PUBLICATION NO. FHWA-RD-97-025

NOVEMBE

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

Technical Report Documentation Page

1. Report No. FHWA-RD-97-025	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SOURCES OF EXPOSURE DATA FOR SAFETY ANALYSIS		5. Report Date November 1997 6. Performing Organization Code
7. Author(s) Campbell, K.L., Joksch, H.C., Blower, D., Kostyniuk, L.P., Pendleton, O.J., and Griffin III, L.I.		8. Performing Organization Report No. UMTRI-96-17
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, MI 48109-2150	Texas Transportation Institute The Texas A&M University System College Station, TX 77843	10. Work Unit No. (TRAIS) 3A3B 11. Contract or Grant No. DTFH61-93-C-00123
12. Sponsoring Agency Name and Address Office of Safety and Traffic Operations R&D Federal Highway Administration 6300 Georgetown Pike McLean, Virginia 22101-2296		13. Type of Report and Period Covered Task Report October 1993 - March 1996 14. Sponsoring Agency Code

15. Supplementary Notes

Contracting Officer's Technical Representatives (COTRs): Michael S. Griffith and Joe Bared, HSR-20

16. Abstract

This report describes existing and emerging exposure data sources for highway safety analysis. Existing exposure data sources reviewed include: Highway Performance Monitoring System (HPMS), Highway Safety Information System (HSIS), Long-Term Pavement Performance (LTPP) Monitoring System, Nationwide Personal Transportation Survey (NPTS), National Truck Trip Information Survey (NTTIS), Operational Exposure Data Sources, Residential Transportation Energy Consumption Survey, Truck Inventory and Use Survey (TIUS), and Weigh-in-Motion (WIM) devices. Emerging data sources are new sources or existing sources that have not been traditionally used to derive exposure estimates. Three areas were reviewed for possible emerging exposure data: Intelligent Transportation Systems (ITS), transportation planning surveys, and traffic volume data collected by the States. One-page summaries are provided for each exposure data source. A longer description covers the purpose of the collection, contents, period covered, sample design, data collection methods, sample size, data quality, data format, possible cautions in using the exposure data, and availability of the data

17. Key Words Exposure data, highway safety	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 102	22. Price

Form DOT F 1700.7 Reproduction of completed page authorized

U.S. Department
of Transportation

National Highway
Traffic Safety
Administration

DOT HS 807 677
NHTSA Technical Report

May 1991

A Collection of Recent Analyses of Vehicle Weight and Safety

Technical Report Documentation F

1. Report No. DOT HS 807 677	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

A Collection of Recent Analyses of Vehicle
Weight and Safety

5. Report Date
May 7, 1991

6. Performing Organization Code
NRD-31

7. Author(s)
Klein, T.M; Hertz, E; Borener S.

8. Performing Organization Report No.

9. Performing Organization Name and Address
Mathematical Analysis Division
National Center for Statistics and Analysis
400 7th St. S.W.
Washington, D.C. 20590

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Research and Development
National Highway Traffic Safety Administration
400 7th St. S.W.
Washington, D.C. 20590

13. Type of Report and Period Covered
NHTSA Technical Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report documents the results of an analysis of the effect of car weight on safety. The analysis encompassed a nun ber of crash modes including fatality risk in single-vehicle nonrollover crashes, serious injury and fatality risk in car-to car crashes, and serious injury risk in collisions of cars with medium/heavy trucks. This work was undertaken as part o an effort to study the long-term effects of the major reductions in passenger car weight of the 1970's and 1980's.

Data from the State of Texas for accident years 1984 through 1987 and the State of Maryland for accident years 1984 through 1988 were used. The analysis employed logistic regression methods to model the (conditional) risk of serious jury as a function of a number of accident-level and person-level covariates.

The findings of these analyses are as follows:

In car-to-car crashes, the change in injury rate associated with the reduction in vehicle fleet weight from 3,700 to 2,70 pounds has been estimated from the Texas data to be an additional 14 percent. The Maryland data produced an estimated increase in the serious driver injury rate of 4 percent for the shift from a 3,700 to a 2,700 pound average fleet weight. The impact on fatal injuries was not statistically significant, possibly due to a paucity of state data for fatally in jured drivers.

In collisions involving cars and medium/heavy trucks, the change in the serious injury rate associated with the reductic in vehicle fleet weight from 3,700 to 2,700 pounds has been estimated from the Texas data to be an increase of approximately 11 percent.

For single-vehicle nonrollover crashes, the change in fatal injury rate associated with the reduction in vehicle fleet we from 3,700 to 2,700 pounds has been estimated from the Texas data to be an increase of approximately 10 percent.

17. Key Words
car weight, injury likelihood,
logistic regression

18. Distribution Statement
Document is available to the public
through the National Technical
Information Service
Springfield, VA 22161

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 19	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Young driver accidents: a matter of immaturity or inexperience?

Ipe H. Veling

1. Introduction
2. Accidents
3. Risk perception
4. Driving behaviour
5. Countermeasures

1. Introduction

In all countries in the world the risk of being killed or seriously injured in a car accident is extremely high for young people, starting with their driving career.
Risks are two to four times higher for young novice drivers as compared to older more experienced drivers.
Economically and with respect to human well-being in general this is a very serious problem. In the Netherlands every year about 200 young drivers are killed and 1900 are seriously injured in car accidents. A substantial amount of these injuries result in permanent handicaps.

Reducing the high accident risks of young drivers has therefore the utmost priority in traffic safety policy.

To be able to take adequate countermeasures, one needs to know the causes of the high risks of young drivers.

In general two types of causes can be distinguished:

- lack of skills, because of limited driving experience and/or insufficient driver training
- risk seeking behaviour, that is often found to be a co-product of becoming mature

Depending on which kind of behaviour determines the high risks of young drivers, different countermeasures can be effective.

If skill is involved, education-like measures are indicated. Depending on which type of skill is involved, the education should be directed to:

- car handling
- risk perception

If on the other hand the high accidents risk of young drivers is mostly a matter of risk seeking behaviour, enforcement-like measures are most indicated. Examples of these measures are:

- punishing (via police enforcement)
- rewarding (via insurance's)
- influencing attitudes and values

In order to gain insight into which countermeasures are probably most effective in reducing the accident risks of young drivers, the relative importance and impact of young age and limited driving experience as causes of high accident risks and driver behaviour of young drivers will be analyzed in this paper.
At first the relative accident risk will be discussed as a function of age and driving experience. Then it will be examined to what extent skill or risk perception can explain the high risks of youngsters.
Referring to these findings it will be checked if young drivers behave themselves according to the risk they perceive. Data are presented with respect to driving speed.
Based on these findings it is finally discussed which countermeasures are most indicated and can be recommended for implementation.

The data that are used in the paper come from a series of large traffic safety surveys that carried out in the Netherlands from 1988 till 1997. In total the number of respondents in the survey about 80,000.

2. Accidents

For car drivers over the age of 24 years the number of car accidents per million kilometres have slight relation with the amount of driving experience. Starting with about 5 accidents per millio kilometres in the first year after licensing, after 4 till 6 years of driving experience the number accidents increase till 10. When people get more driving experience the number of accidents decrea again till 5 accidents per million kilometres.

For young drivers in the age of 18 till 24 a completely different picture exists.

Directly after their licensing they have over 20 accidents per million kilometres. That number gradual decreases with increasing driving experience until it reaches the number of accidents of older drivers.

With respect to novice drivers the picture shows three important findings:

- older novice drivers do not seem to be the problem
- the initial risks of young inexperienced drivers are high: this shows that safe driving possible also with hardly any driving experience
- the high initial risks rapidly decline after gaining experience: this shows that safe driving possible also for young drivers

To lower the accident risks of novice drivers one could restrict attention to young novice drivers a could attempt to let the young novice drivers start their driving career at the low risk level of old novice drivers or older more experienced drivers.

To get insight in how that can be done, one should know what makes the difference between older and younger novice drivers and what is changing in young novice drivers during their first years of driving. The variables in terms of which differences will be examined are:

- risk perception
- driving behaviour

3. Risk perception

Older and younger and more and less experienced drivers do differ systematically in the accident risks they perceive. Confronting drivers with specific behaviours in standardised traffic situations (e.g. driving 100 km/h on a rural roadway) it can be seen that during their first years of driving experience young as well as older drivers learn to estimate the probability of getting an accident higher.

This could explain the risk decline for the young novice drivers. However, in that case the same decline should also have been found for older novice drivers of which the perceived risk also increases.
This means that the effect must be moderated by a second variable. That variable proves to be the perceived severity of the accidents.

Older novice drivers start driving with rather high estimates of the severity of the accidents. Those estimates decrease during the first years of experience. On the other hand, young novice drivers start their driving career with rather low severity estimates, which gradually increase during the first years.

This explains why young and older novice drivers differ directly after getting licensed: they perceive the same probabilities, but different severity's. Younger novice drivers underestimate the severity of the accidents highly.
The same finding also explains why the increase of perceived risk decreases the accident risk of young novice drivers and leaves the accident risks of older novice drivers unaltered.

If perceived risk is defined as the product of probability and severity estimates, the picture is clear.
The amount of risk perceived (probability times severity) of older novice drivers remain constant during the first years, while the perceived risk of younger novice drivers increase during the same period

Summarising, it can be stated that

- young novice drivers have more accidents than older novice drivers because of systematic underestimation of the severity of accidents
- accident rates of young novice drivers decrease during their first years of driving as a result of the fact that they learn to estimate the probability and the severity of accidents much higher (and probably more correct)

4. Driving behaviour

The most obvious reaction to perceiving more risk would be: driving at lower speeds.
According to the data however, this does not happen. Although young novice drivers perceive mo and more risk as they gain experience, they do not drive slower. On the contrary, there is even a slig increase in driving speed in general.
This finding in combination with the fact that the actual accident risk decreases could only be explain by an enormous improvement of the driving skill of young novice drivers during their first years. T improvement must be so significant that it makes higher speeds possible with lower actual risks.

The explanation that during the first years risk tolerance levels (i.e. that they accept more risk) does n fit, because of the decline in actual accident rates. If during the years gradually more risk would acceptable, than this should have been resulted in more instead of less accidents.

The initial differences between younger and older novice drivers can be explained by the difference driving speed. Young novice drivers drive on all types of roads considerably faster than older drivers.

Summarizing, it can be stated that:

- the initial difference of driving speed of younger and older novice drivers can explain t higher accident risks of the younger drivers
- besides better risk perception also better vehicle control is learnt during the first years driving

5. Countermeasures

The foregoing analysis made clear that the high accident risk of young novice drivers is a consequen of their underestimation of the probability and the severity of accidents, resulting (amongst oth things) in unadapted high speeds. After about 5 years of driving the problem diminishes when you drivers learn:

- to estimate the severity and probability of accidents more appropriate
- to get better control of their car (with the same or higher driving speeds) in complex traff situations

Effective interventions could be:

- Rising the age at which people get licensed from 18 into e.g. 25

  The traffic safety impact depends of course on the alternate risks of people if they are not allowed to use cars; when everyone then would use the moped, the safety effect of rising the licensing age would be negative.
  However, because of all kinds of economical and political reasons, rising the licensing age by changing the law is not a realistic option. On the other hand, rising the licensing age at a voluntary basis does seem to be possible.
  In the Netherlands all students get an almost free season-ticket for rail- and bustransport. This has as an effect that the mean age at which they get licensed increases considerably.

- Improving the perception of the severity of accidents

  By experiencing and demonstrating novice drivers on driving grounds the criticality of high speeds, the mechanical forces of high speeds and consequences of accidents, drivers can be made more aware of the severity of accidents.
  This would result in lower initial accident risks.

- Improving risk perception

  As a part of the driver training and/or as a post-licensing course, the risk perception of drivers can be substantially improved and can probably shorten the learning period of young novice drivers. To what extent is not clear at this moment.
  The best results are acquired with on-the-road additional training on roads and under circumstances that are new for the driver.

- Improving car control skills in complex situations

  Young novice drivers improve in their first years of driving (by bitter experience) their driving skills to a large extent. The improvement consists mainly of more automated taskperformance
  This could be reached by lengthening the period of driver training considerably.

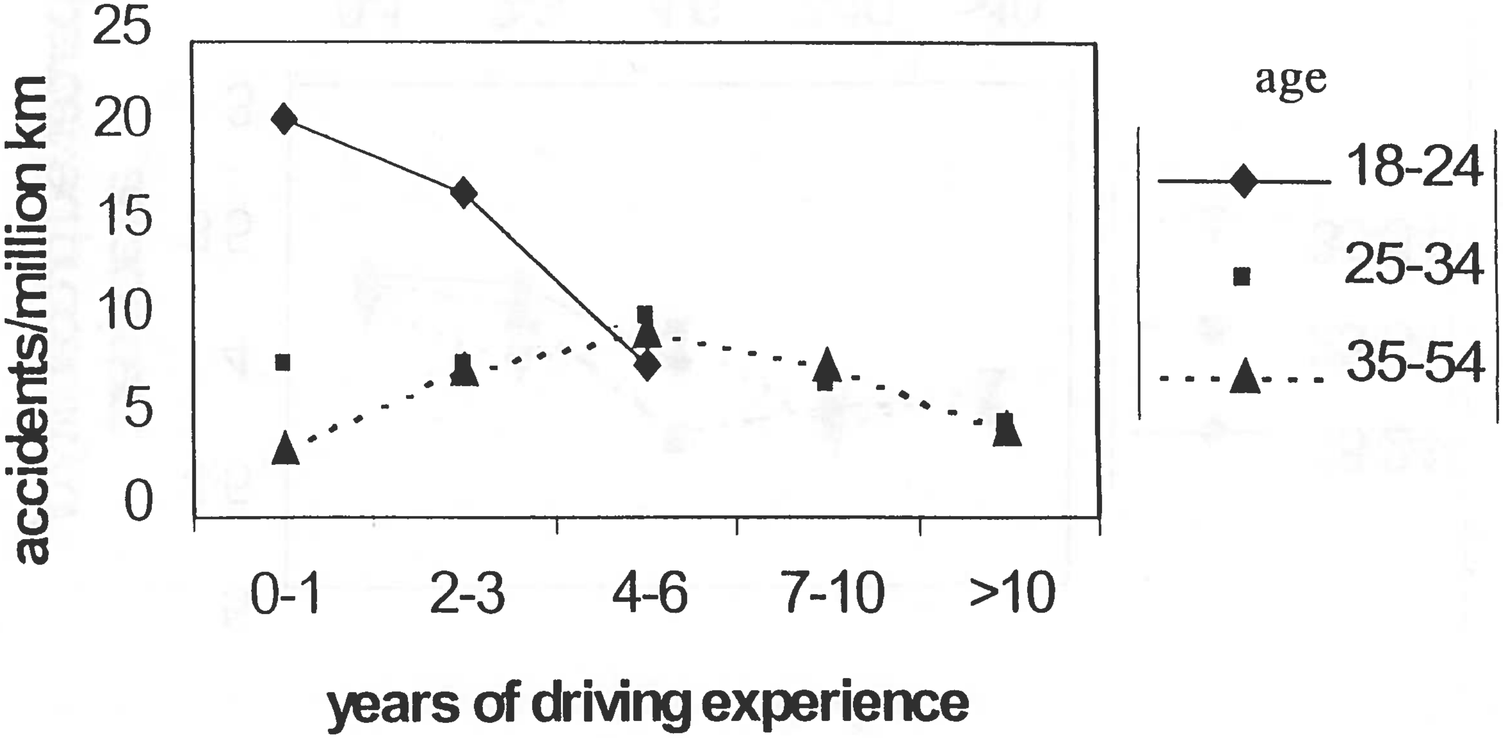
- Adding extra motives to safe driving

  As long as and as far as risk perception, automated car handling skills are not sufficient for safe driving, extra motives could be introduced.
  These extra motives could be
  - probability of being punished (point demerit system)
  - probationary licensing combined with driving restrictions (e.g. max. speed of 100 km/h)
  - forcing young novice drivers only to drive while accompanied with older experienced drivers

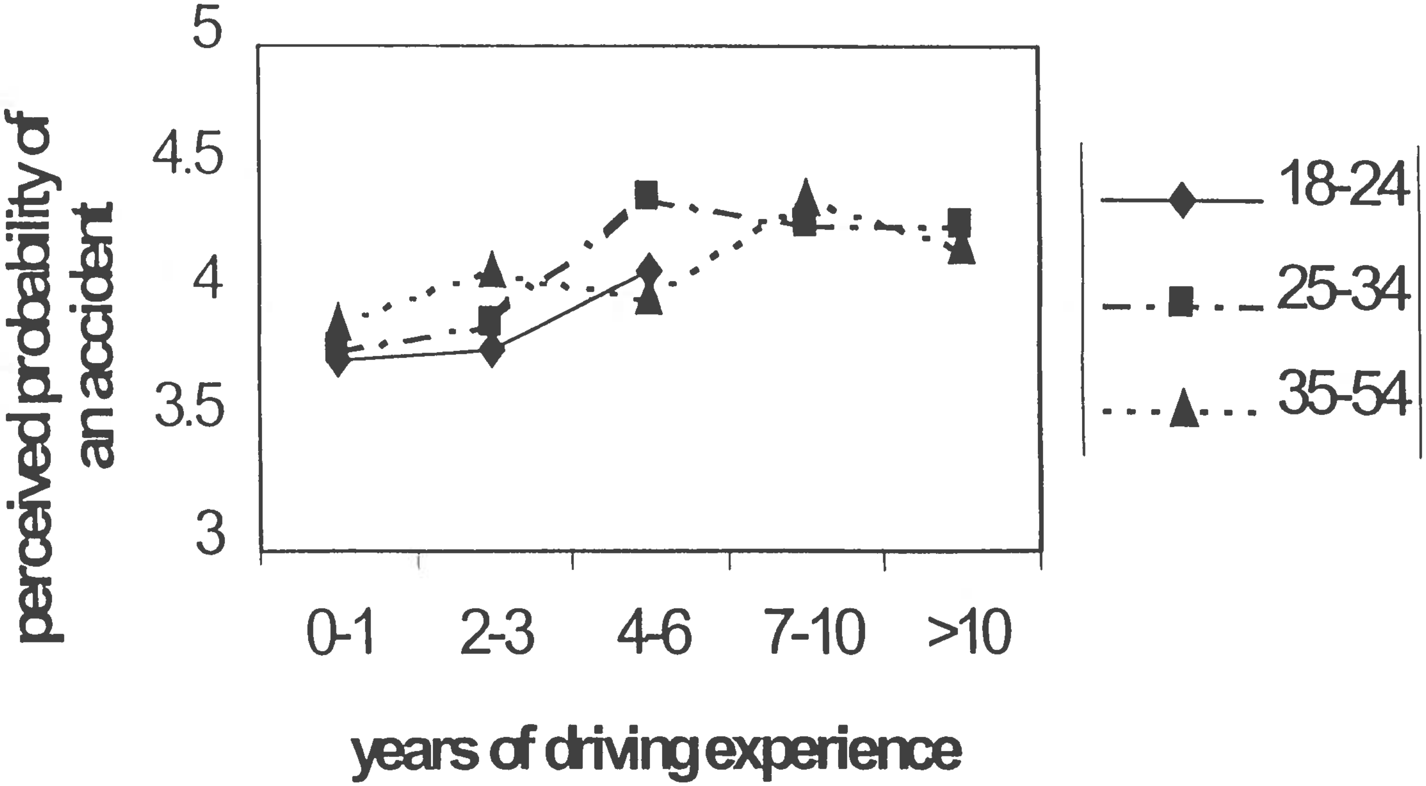
Young Driver Accidents: A Matter of Immaturity or Inexperience?

Traffic Test

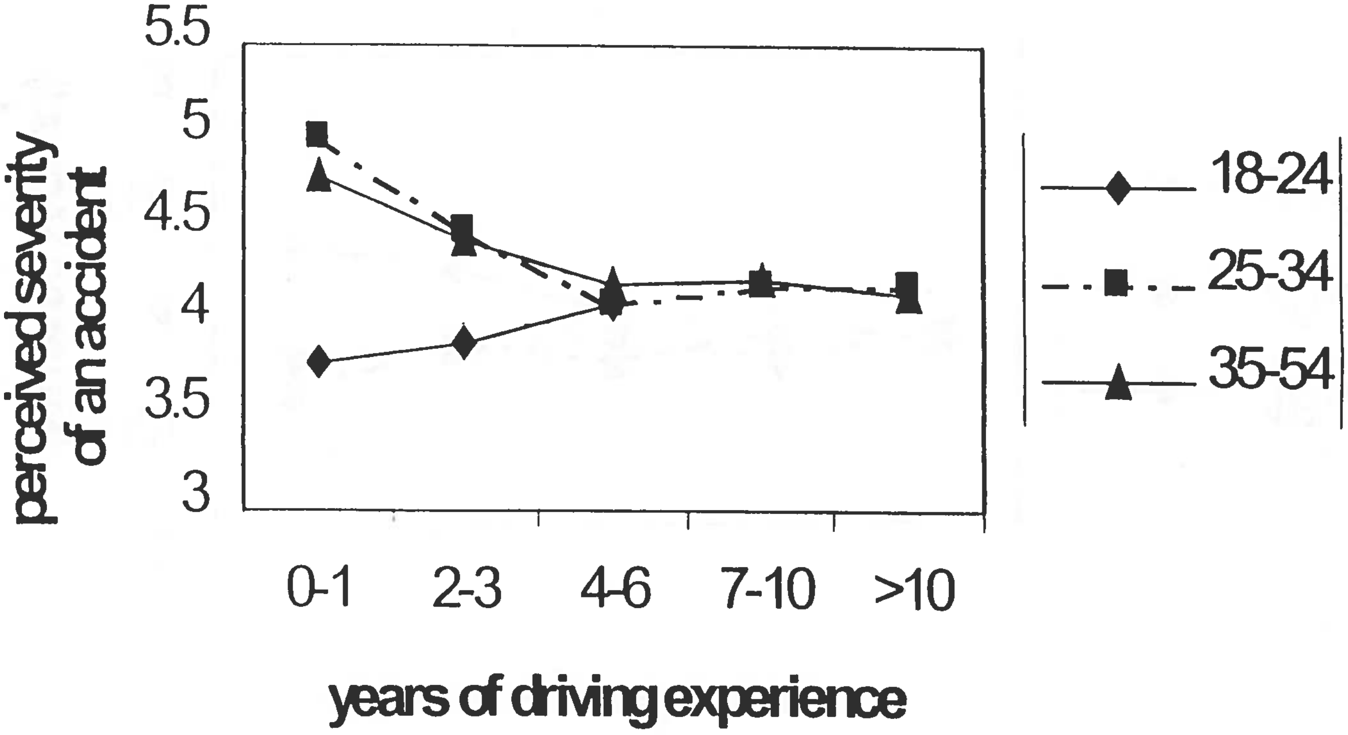
Ipe Veling



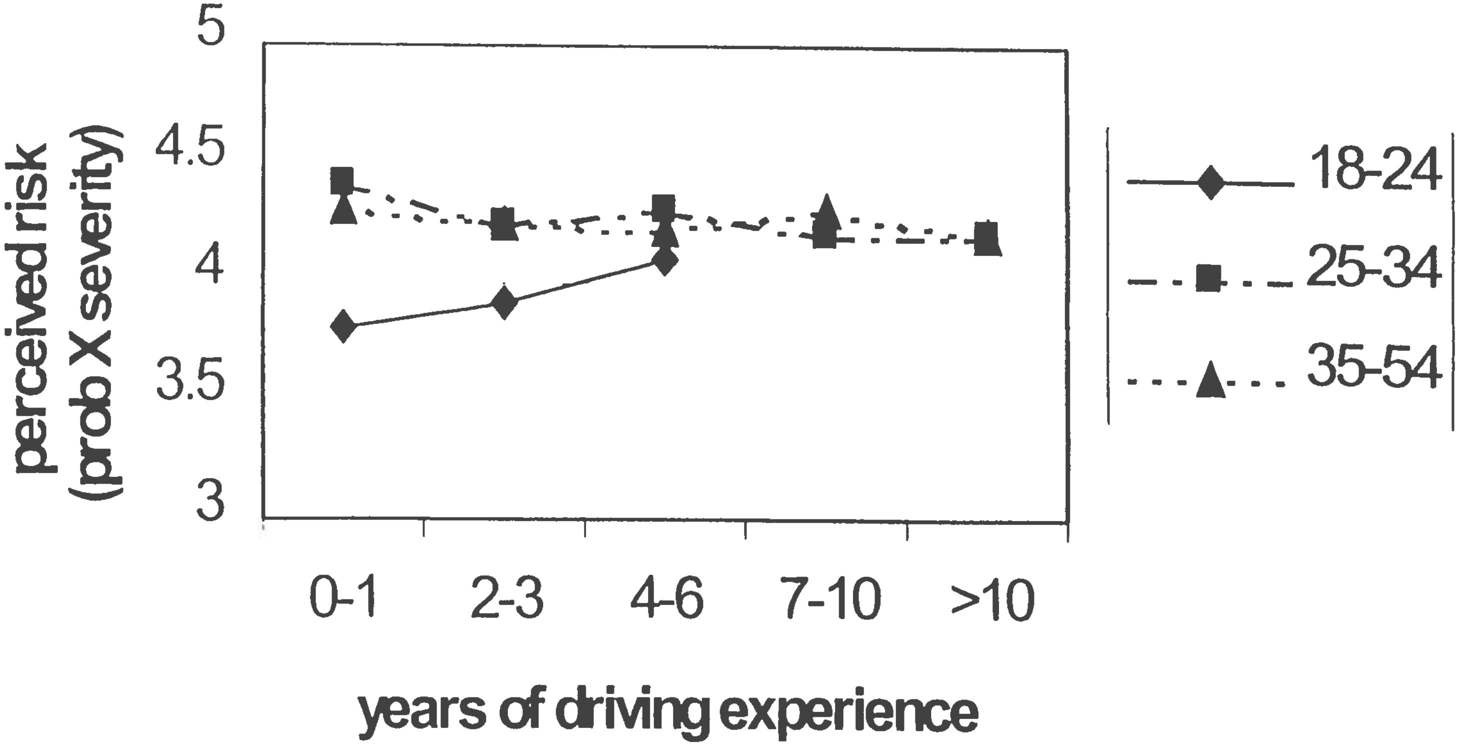
Safe driving is possible, also with hardly any driving experience
Safe driving is possible, also for young drivers



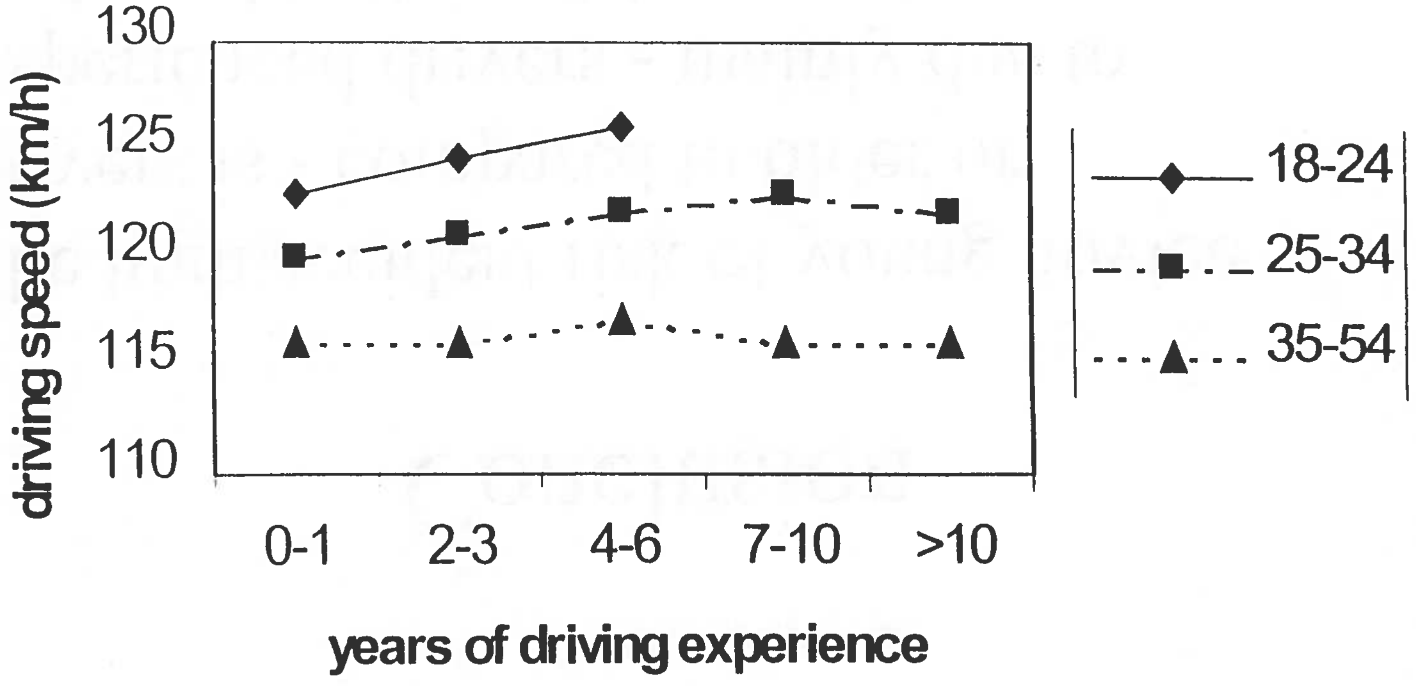
Getting more experienced means learning the riskyness of driving



Young novice drivers underestimate the severity of accidents



High accident rates of young novice drivers are caused by understimation of the severity of accidents



Besides better risk perception, also better vehicle control is learnt during the first years of driving

Conclusion

The high accident risk of young novice drivers is - compared to older or experienced drivers - mainly due to underestimation of the severity of accidents

Recommendations

- Rise the age of licensing
- Improve the perception of the severity of accidents
- Improve driving skills in driver training
- Add extra motives for safe driving

RISK AND RISK MODELS IN TRAFFIC RESEARCH

Peter Lourens
Centre for Environmental and Traffic Psychology
University of Groningen, The Netherlands

Elements of presentation at the workshop Exposure & Risk, AVV Rotterdam, April 20th 1999:

* Risk - definitions; triplets of scenario/probability/outcome; risk – dimensions
* Models - human behavior feedback; risk compensation/homeostasis
* Research - experimental; theoretical framework of unsatisfied appetency
* Research questions and wishes – exposure/driving style/accident involvement/point system/reward systems/post-license driver training

Abstract:

The concept of **risk** is a cognitive construct that people use to express cause-effect relationships of a special nature. Many definitions of this concept of risk can be found in the literature. Most of these definitions imply a triplet of elements, namely:

SCENARIOS PROBABILITIES OUTCOMES/CONSEQUENCES

First of all, the number of scenarios is in principle infinite, which means that in most cases there is a large and often important rest category. Secondly, probabilities are of uncertain and should actually not be expressed in a single number, but in a curve or even a family of curves. People are poor assessors of probability anyway. Finally, some of the possible or probable outcomes of a scenario must be unpleasant or negative for the scenario being called a risky one. But outcomes are practically always multidimensional. All these aspects make risk assessments a complicated and difficult job.

Risk perception in the domain of traffic participation is strongly influenced by some basic dimensions underlying the evaluation of risk. A list of eleven basic dimensions will be presented to explain the peculiarities of traffic risk perception.

Risk models of different kind have been presented and abundantly discussed in traffic research literature of the last 15 years with risk homeostasis theory (Wilde) as an extreme case. In later years the discussion was focussed on the phenomenon called risk compensation or human behavior feedback. Changing the traffic system by introducing a safety measure leads to some extent to behavioral adaptations by the traffic system users. The history of research findings and insights will be shortly presented with some experimental evidence that not everybody shows compensatory behavior. Whether or not compensation occurs can be theoretically understood and, thus, predicted by taking into account the notion of satisfied and unsatisfied appetency (Dussault, 1996).

Research wishes and questions will be illustrated with some results of an analysis on a Dutch database. This database contains disaggregated data on both the traffic system input variables of the driver population (characteristics of drivers, including their annual mileage) and the output variables of the driver population in terms of habitual driving behaviour (operationalized in number of fines) and accident involvement. Accidents increased as annual mileage increased. A relationship between traffic rules violations (fines) and accidents turned out to exist in all classes of annual mileage. Moreover, multivariate analysis showed that - corrected for annual mileage - male and female drivers do not differ in accident involvement; younger drivers have the highest rate of accidents and level of education is not related to accident involvement.

Peter Lourens
COV
Groningen

Exposure & Risk, 20-4-

THE CONCEPT OF RISK

SCENARIOS	PROBABILITIES	CONSEQUENCES
A	p1	c1
B	p2	c2
C		multidimensional
Rest category	pn	

	1.0	

In the ETSC-paper, it says:

$$\text{RISK} = \frac{\text{Number of accidents, casualties or fatalities}}{\text{Volume of travel}}$$

Is this ‘RISK’? Or just level of unsafety?

RISK PERCEPTION

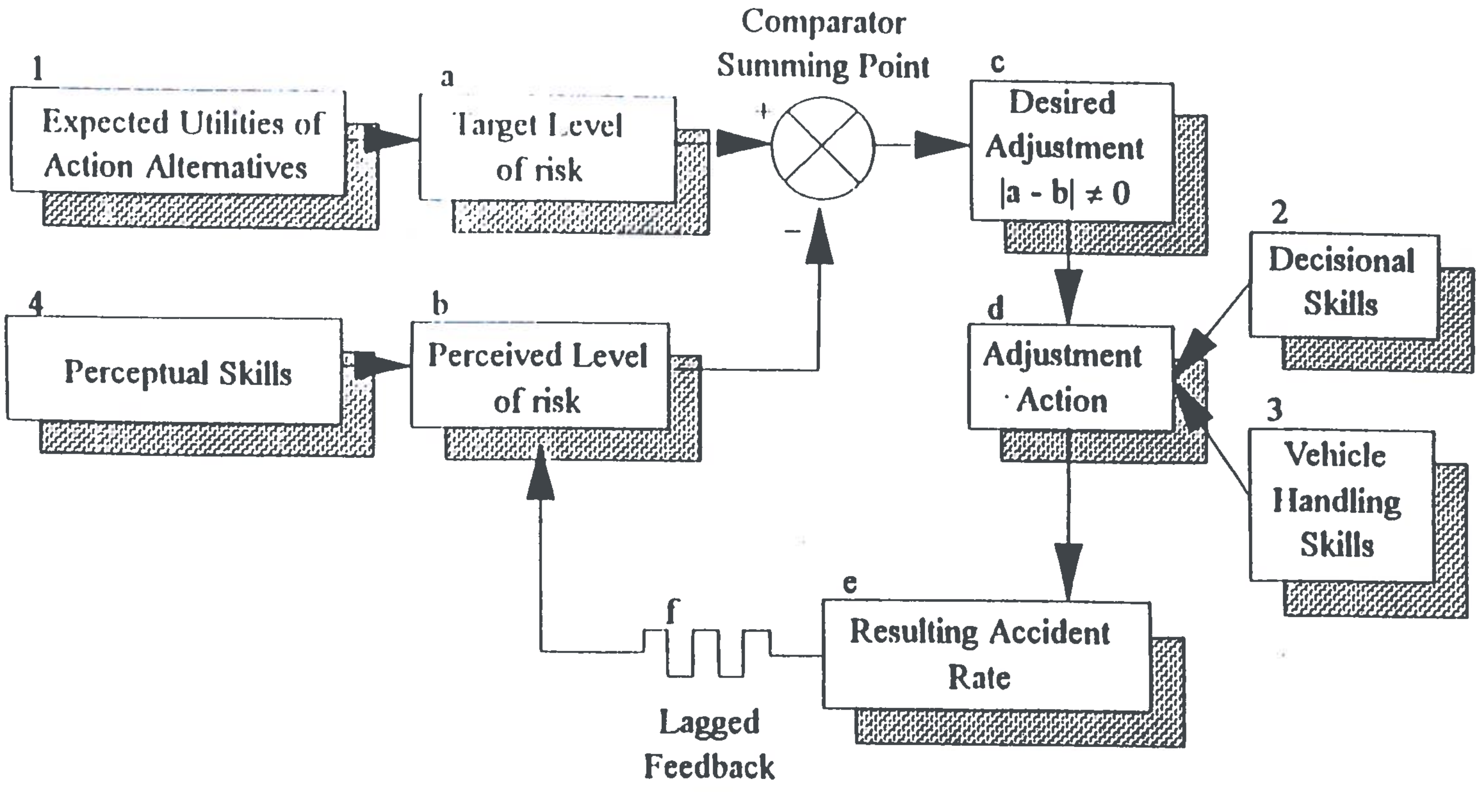
IN COMPARING DIFFERENT ACTIVITIES

THE FOLLOWING DIMENSIONS DETERMINE

RISK JUDGMENTS

1. Potential degree of harm or fatality
2. Physical extent of damage (area affected)
3. Social extent of damage (number of people involved)
4. Time distribution of damage (immediate and/or delayed effects)
5. Probability/ambiguity of undesired consequence
6. Controllability (by self or trusted expert) of consequences
7. Experience with, familiarity, imaginability of consequences
8. Voluntariness of exposure (freedom of choice)
9. Extent and clarity of expected benefits
10. Social distribution of risks and benefits
11. Harmful intentionality

Risk taking in car driving



RISK MODELS

Evans' formula: $\Delta \text{ S Act.} = (1 + f)\, \Delta \text{ S Eng.}$

'Engineering' approach: $f = 0$
'Economic' approach: $-1 < f < 0$
'RHT' approach: $f = -1$

Stetzer and Hofmann (1996):

- New approach
- Laboratory task
- Results:

'Engineering' effect	49%
'Economic' effect	47%
'RHT' effect	4%

THEORY OF UNSATISFIED APPETENCY

DUSSAULT (1996)

* TWO MOTIVATIONAL SYSTEMS

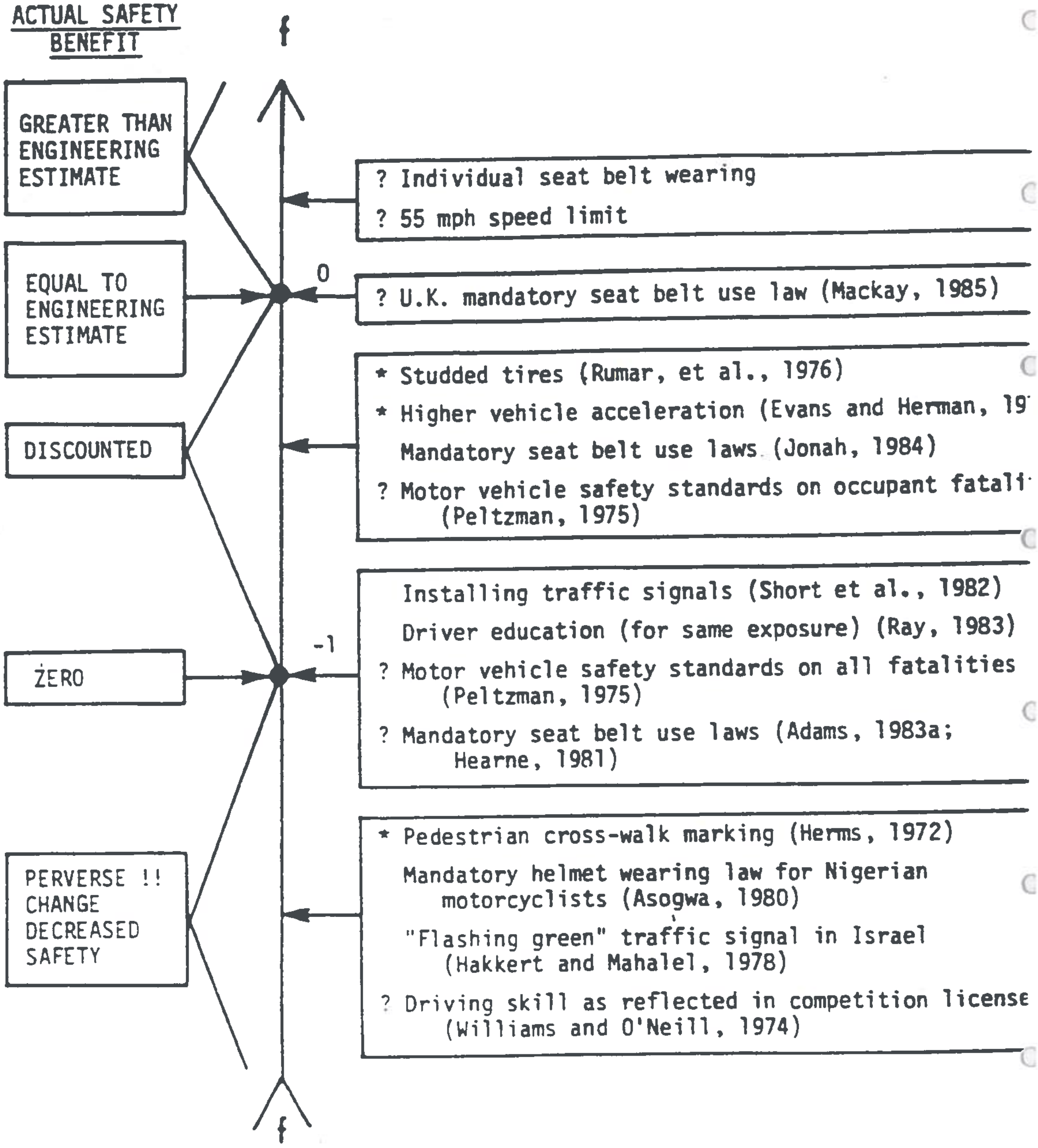
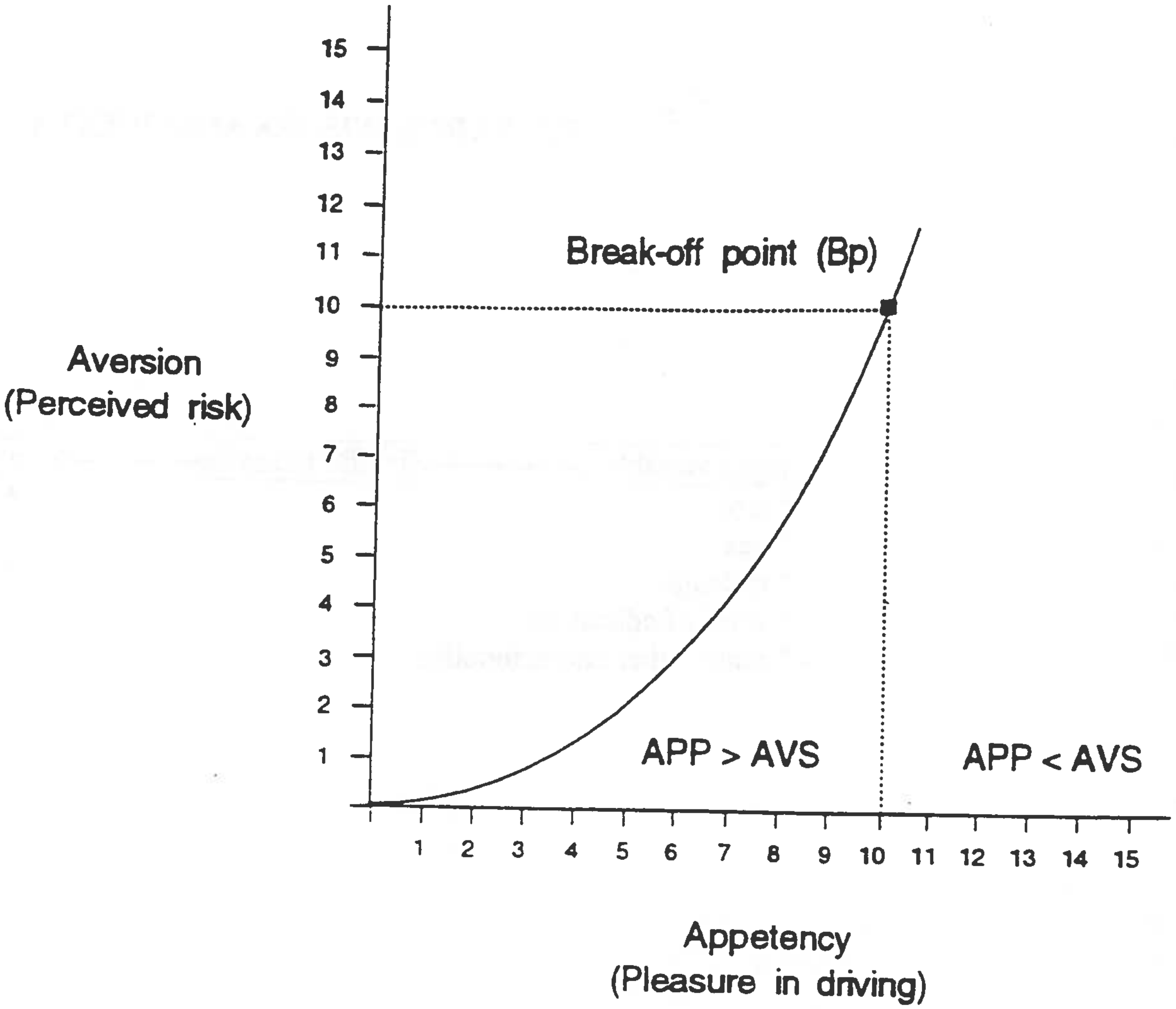


Figure 1 *Graphical representation of values of f associated with the safety measures discussed in the te absence of a reference indicates that the effect inferred in the present paper was based on a variety of in tion. The * indicates a fairly clear-cut result (e.g. based on good data and not critically dependent on qu able assumptions. The ? indicates a questionable or speculative result (e.g., weakly supported by data, dependent on questionable assumptions, data subject to alternative interpretations). Note that, in cont Figure 2, both f and safety increase as one reads from the bottom to the top of the page.*


Aversion
(Perceived risk)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Break-off point (Bp)
APP > AVS
APP < AVS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Appetency
(Pleasure in driving)

RESEARCH WISHES AND QUESTIONS

Input variables: ------------> Traffic behavior -----------> Output variables:

Input variables:
* age
* sex
* mileage
* level of education
* many other characteristics

Output variables:
* fines, yes/no
* accidents, yes/no
* type of accidents

Table 1. Number of drivers in five classes of annual milage

Class	Annual mileage	Number of drivers
1	0 - 5,000 kilometres (kms.)	10,184
2	5,001 - 15,000 kms.	13,886
3	15,001 - 25,000 kms.	6,382
4	25,001 - 50,000 kms.	3,914
5	50,001 and more kms.	989
Total		35,355

Table 2. Percentage of drivers with one or more fines and accidents per 1,000 drivers of the five classes of annual mileage

class of annual mileage	% with one or more fines	accidents per 1,000
1	8	47
2	14	68
3	23	102
4	35	134
5	40	186

Table 3. Number of accidents per 1,000 drivers with and without a fine in each of the five classes of annual mileage

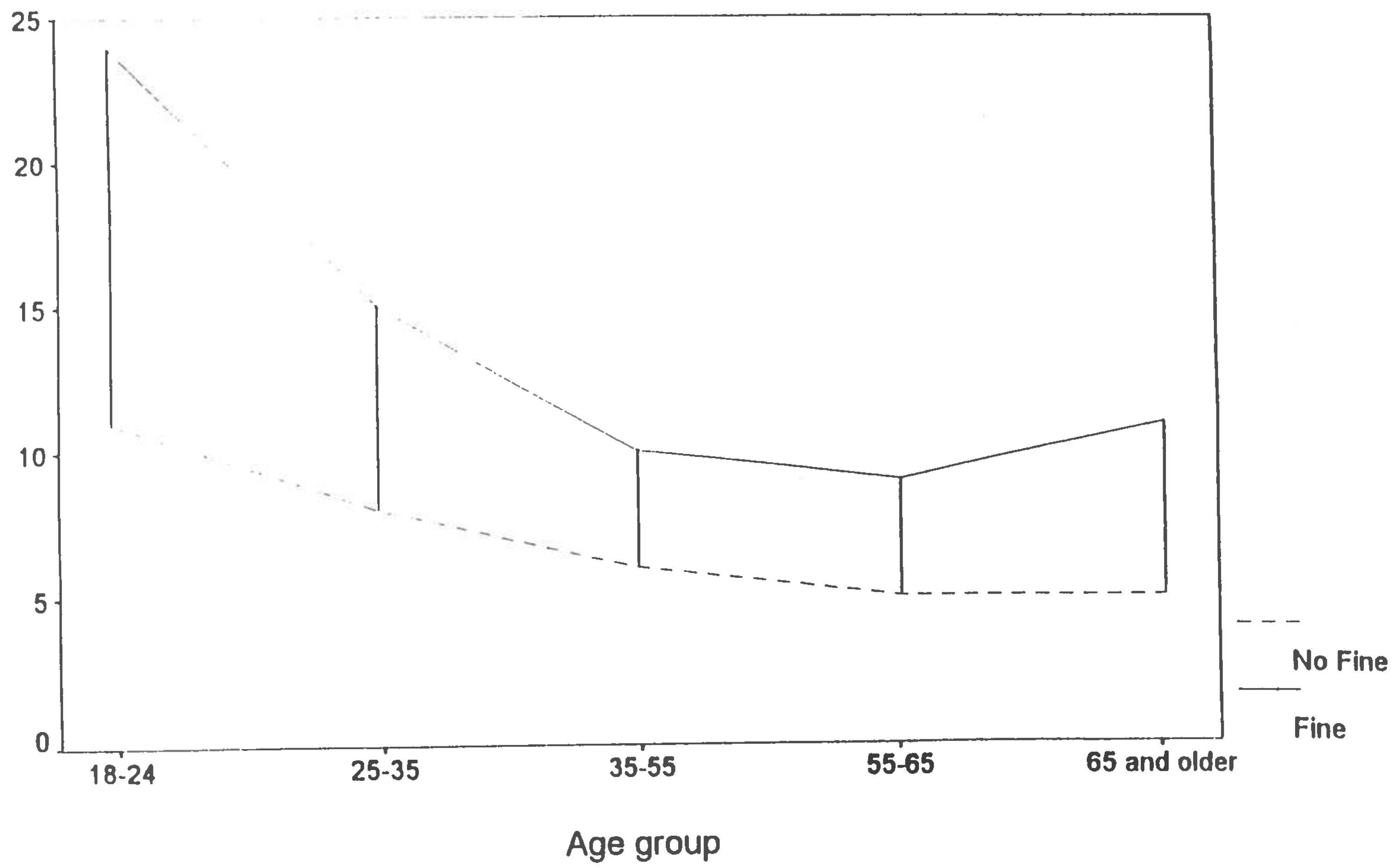
lass of annual mileage	drivers with a fine	drivers without a fine	Chi-square	p-value
1	87	43	33.47	$p < .001$
2	103	62	45.73	$p < .001$
3	130	93	16.39	$p < .001$
4	166	118	17.93	$p < .001$
5	230	158	8.06	$p < .01$

Table 4. Results of the multivariate analysis with annual mileage as a covariate

Factor	Mean Square	df	F	Signifi
Annual mileage	19.490	1	228,364	.00
Sex	.212	1	2.484	.11
Age	1.605	4	18.805	.00
Education	.157	2	1.836	
Fines	1.180	2	13.820	.00
Sex by age	.181	4	2.120	.07
Sex by education	.213	2	2.492	.08
Sex by fines	.007	2	.876	.4
Age by education	.119	8	1.399	.1
Age by fines	.251	8	2.938	.0
Educ. by fines	.160	4	1.871	.

Table 5. Number of car accidents in a period of one year per 1,000 drivers for different age groups and classes of annual mileage

ass of ann. mileage	age: 18-24 y.	age: 25-35 y.	age: 35-55 y.	age: 55-65 y.	age: 65 y. and older
1	65	51	34	28	39
2	150	78	50	42	51
3	199	113	76	75	61
4	185	136	105	82	77
5	228	212	122	100	200
Total	120	88	60	50	52


25
20
15
10
5
0
18-24
25-35
35-55
55-65
65 and older
Age group
No Fine
Fine

Wishes for research:

- Better risk research – risk perception, risk acceptance, risk compensation
- Better disaggregate database research

Wishes for policies:

- Penalty point system – for ALL drivers
- Preliminary driving license for new drivers
- Post-license driver training for drivers with a certain number of penalty points

Designing new road safety policy

by Ab van Poortvliet, TRC Rotterdam

The Directorate General for Passenger Transport is studying on new road safety transport. The Transport Research Center is supporting them in doing so. An overview of the research is given in th paper.

Towards a risk approach

As mentioned in the paper of Mrs. Donk, today's road safety policy aims at reducing the absolute number of fatalities and injuries. The goal is to reduce the number of fatalities with 50 percent regarding the reference year 1986, and the number of injuries with 40%. Today, however, it is not c how best to obtain the reductions aimed for. The insight into what measures to take on what locatio and the effects to be expected, are largely unknown. This means that policy makers have to rely on e *post* monitoring, and that it is unclear what investments have to be made to attain the goals.

Years of research and accident data have accumulated, meaning that it is possible to develop a more anticipatory approach to safety problems, which is usually referred to as 'a risk approach to road saf It has a technical dimension and a political dimension.

Technical dimension. The information currently available are accident data, i.e., fatality data (nearly 100% registration coverage), injury data (around 70% registration coverage of serious injuries), and damage data (around 20% registration coverage), traffic intensity data (mainly limited to highways), and road characteristics (almost all paved roads). Furthermore, there are numerous fragmented insig into the costs and effects of safety measures. In the risk approach we calculate risk figures by dividin the consequences of accidents (fatalities, injuries) by the traffic intensity, resulting in damage (fataliti injuries) per million vehicle kilometers.

Both risk figures and the absolute number of fatalities can then be used to set priorities by selecting those roads that are remarkably or even unacceptably dangerous. A catalogue of measures including their costs and benefits can then be used as an orientation to solve the problem (takin measures requires a detailed analysis of the problem situation, of course). This enables to divid budget available for road safety in an optimal way, or, inversely, gives insights into the budget neede to attain the safety goals set.

Political dimension. The approach sketched above has technical difficulties. I think that most of the can be overcome, however, and of more importance, it is a very technocratic approach that does not account for the way road management is organized and the politics around road safety. In the Netherlands we have four types of road managers, which are central government (which includes regional offices), roads of the province, roads of the municipality, and roads that are managed by organizations for water management.

An application of the risk approach can have consequences the way budgets are divided amo the four types of organizations, and within each type. This can be done within central government, b requires much commitment from all parties involved (including those that will receive less budgets). Decision making on this issue is top politics, which is little addressed in the research. Instead, we ha chosen for a bottom-up approach, and try to find what possibilities and barriers are present for the application of a risk approach at the regional level.

In a pilot project, we test how all four types of road managers can work with a simple prototype of the risk approach, and whether they would commit themselves to the results when roac safety measures are based on a comprehensive safety oversight of all roads in a region. In a second project, we try to formalize the tested approach, and in a third stage we support the policy departme in writing a Memorandum on Road Safety. In the meantime, we try to enlarge insight and support b giving workshops within government, and for a wider audience in a later stage. Representation of th results, for example in a road safety atlas, will be instrumental to achieve this goal.

Overview of the Presentation

- Introduction
- Objectives
- The Technical Dimension
- The Political Dimension
- ‘Risk Communication’
- Future Research
- Questions and Discussion

Objectives

1. To control the number of fatalities and injuries to an 'acceptable level', i.e., to realize road safety policy goals.

2. To allocate resources in an 'optimal way', i.e., to enhance cost-effectiveness, while acknowledging fairness and long-term effects.

3. To make the costs and benefits of road safety measures visible to our organizations, Parliament, and society.

Introduction

Q: A risk approach!
A: What risk approach?

Other transport industries:

Analyzing accident scenarios by means of tools such as fault- and event tree analysis

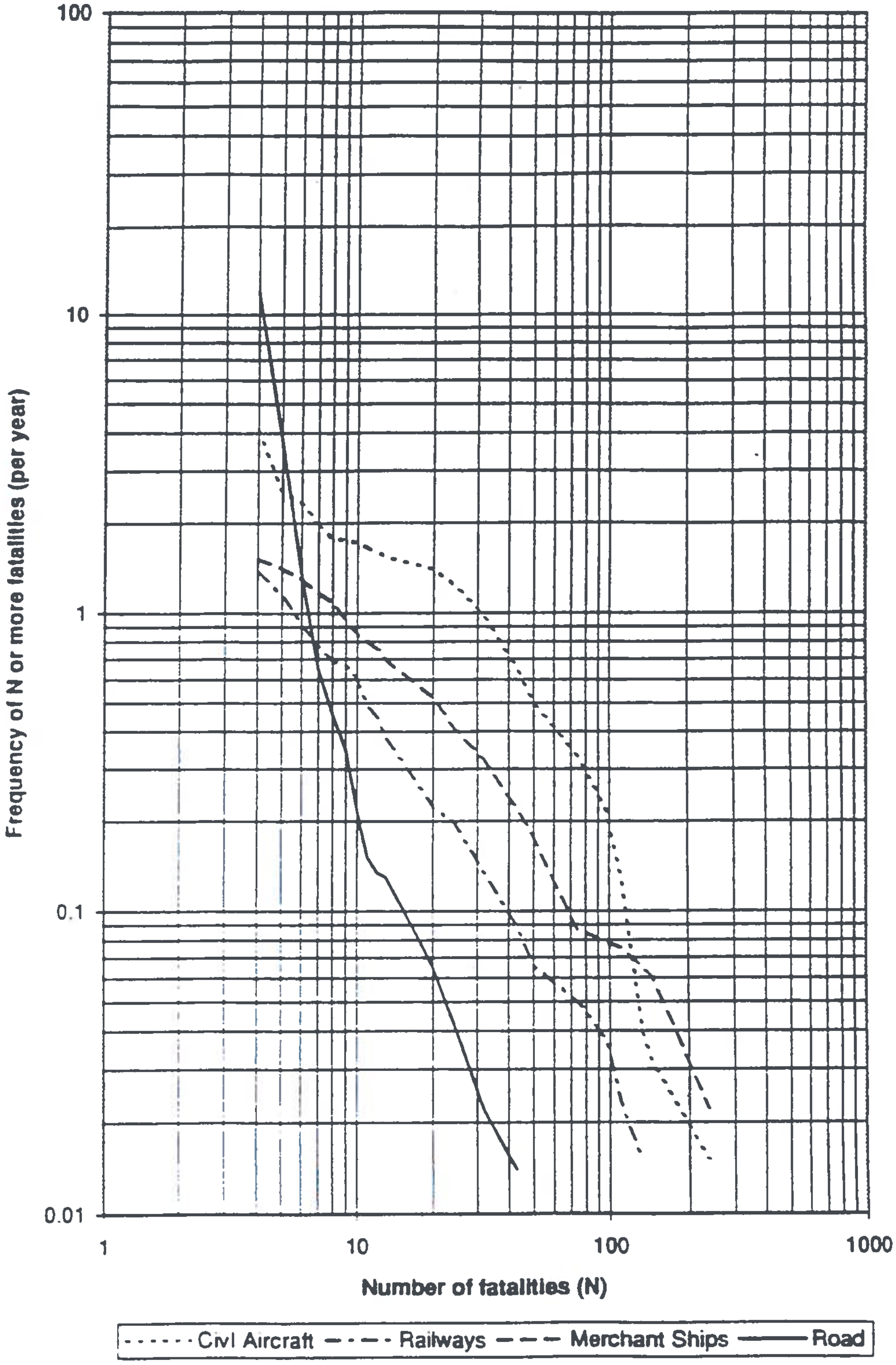
Prediction based on models, supported with historic accident data

Road transport:

'Infinite' number of accident scenarios, numerous accidents, much empirical data

Prediction based on historic accident data, from which models may be derived

Figure 7.2 : FN Curves for UK Transport



C6185\excel\fncurve njc Chart 1

Passenger Transport Safety; A Comparison Across the Modes

Safety performance in European passenger transport 1989 - 1993

	Fatalities (per year)	Casualties (per year)	Pax km (bn, per year)	Fatality rate (per bn pax km)	Fatality rate (per bn pax hours)
Air	153	225	383	0.40	177
Sea	77	155	18	4.40	253
Rail	195	1,176	281	0.69	33
Road	50,676	1,813,631	3,603	14.06	521

(Source: Transport Committee, *Cross Channel Safety*, HMSO, London, 1995)

Risk Approach: The Technical Dimension

road sections *type (t) *length (l) *# accidents ($n_{fat, inj, mat\ dam}$) *traffic intensity (i)	local risk = n/i for every road section	comparison local risk with avarage risk for road type for every road section → ranking 1: black roads (abs.#) → ranking 2: red roads (rel. #) → ranking 3: red roads' (rel. #/av.)
total # fatalaties and injuries in the region in 1986	policy goals (SVV II) directly applied	regional road safety targets

Proposed solution:

1. reduce risk for roads with extremely high risk figures (top of ranking 2 and 3) to guarantee a minimum of fairness towards individual residents.
2. calculate expected fatalities, and reduce the number of fatalities most cost-effectively

Risk Approach: The Technical Dimension (II)

1. Identify risky road sections and crossings (data manipulation as indicated on previous slide)
2. Select the most dangerous road sections and crossings (apply safety norms)
3. Use a generic list of solutions that might be appropriate (project 'measurement catalogue')
4. Analyze the most hazardous sections in-detail to find the cause(s) of bad safety performance; find specific solutions
5. Compare generic and specific solutions, discuss the similarities and differences
6. Formulate an argument which solution to implement, including expected costs and benefits
7. Compare the costs and benefits of all solutions, and try to optimize on safety gain.

Step 4 requires the use of more detailed methods and techniques, one of them will be studied in the pilot project as well. Caution: it may limit to treatment of 'black spots'.

Of particular interest with regard to step 4 is the study of accident scenarios as it is performed by TRC/SWOV.

Risk Approach: The Political Dimension

Numerous organizations are involved in road safety management → multiple values, interests, goals, and rules These should be accounted for when designing a new approach to road safety.

Re-designing politics cannot be done within TRC; therefor our strategy is a bottom-up approach:

- start with a basic technical approach
- test it in a real-life setting, while being sensitive to technical shortcoming and organizational and political barriers
- learn: make adjustments, and, when necessary, advise tc change targets
- formalize methods and support in policy-making

A pilot project in the region Limburg is crucial in studying t possibilities for de-central application of the technical tool. The objective is to realize integral planning to enhance cos efficiency of risk reduction for the region *as a whole*. Such planning should *interactively* be done by the officials the regional organizations involved

Risk Communication

Two good reasons to communicate on road safety:

- Numerous organizations are involved, and need to be informed to obtain their cooperation
- Road safety is a public utility, meaning that residents have a right on information. Furthermore, the public (organized, but also unorganized) has much indirect influence

Most of the initiative for risk communication is at the Directorate General for Passenger Transport. A direct GIS-presentation of hazardous locations on internet 'risk atlas', however, may well stimulate the discussion and end in risk reduction.

Future Research

Integration of existing knowledge into the risk approach (centrally available knowledge, but also tacit knowledge in the region). This includes target group policy.

Refinement of accident scenarios, estimations of their contributions, and the cost and effects of their solutions

How to establish norms, and how to keep them up-to-date
How to monitor compliance? How to evaluate the approac

Some remarks on the concept of risk

by Sten Bexelius, AVV, Rotterdam, 25 March 1999.

A note prepared for the Workshop Exposure and Risk on April 20th 1999.

Accident rates in for instance air travel have gone down dramatically during the last 60 years. Does it mean that the risk has gone down? After all the number of people killed in airplane crashes (world wide) is higher than 60 years ago.
If the accident rates (fatalities per billion passenger miles) had not gone down, than the enormous expansion of air traffic never would have occurred. The accident rate (or rather its reciprocal) should be looked upon as a performance index. Improved safety performance is a necessary condition for the expansion of certain economic activities.

I am obviously criticizing the way some people use the notion of risk. A high total risk is not acceptable just because an accident rate is below a certain value. An accident rate can sometimes be used as an indicator for the risk level, but not always.

A human life does not consist of miles. It can be measured in years (or for instance hours, although that sometimes is less practical). In general risk levels should be related to the time people are exposed. Think for instance of the children playing in a certain residential area. The fact that increasing car traffic probably lower their accident rate measured in accidents per vehicle mile is complete misleading since their risk level measured in accidents per hours played outdoor probably is increased by the same growth of traffic.

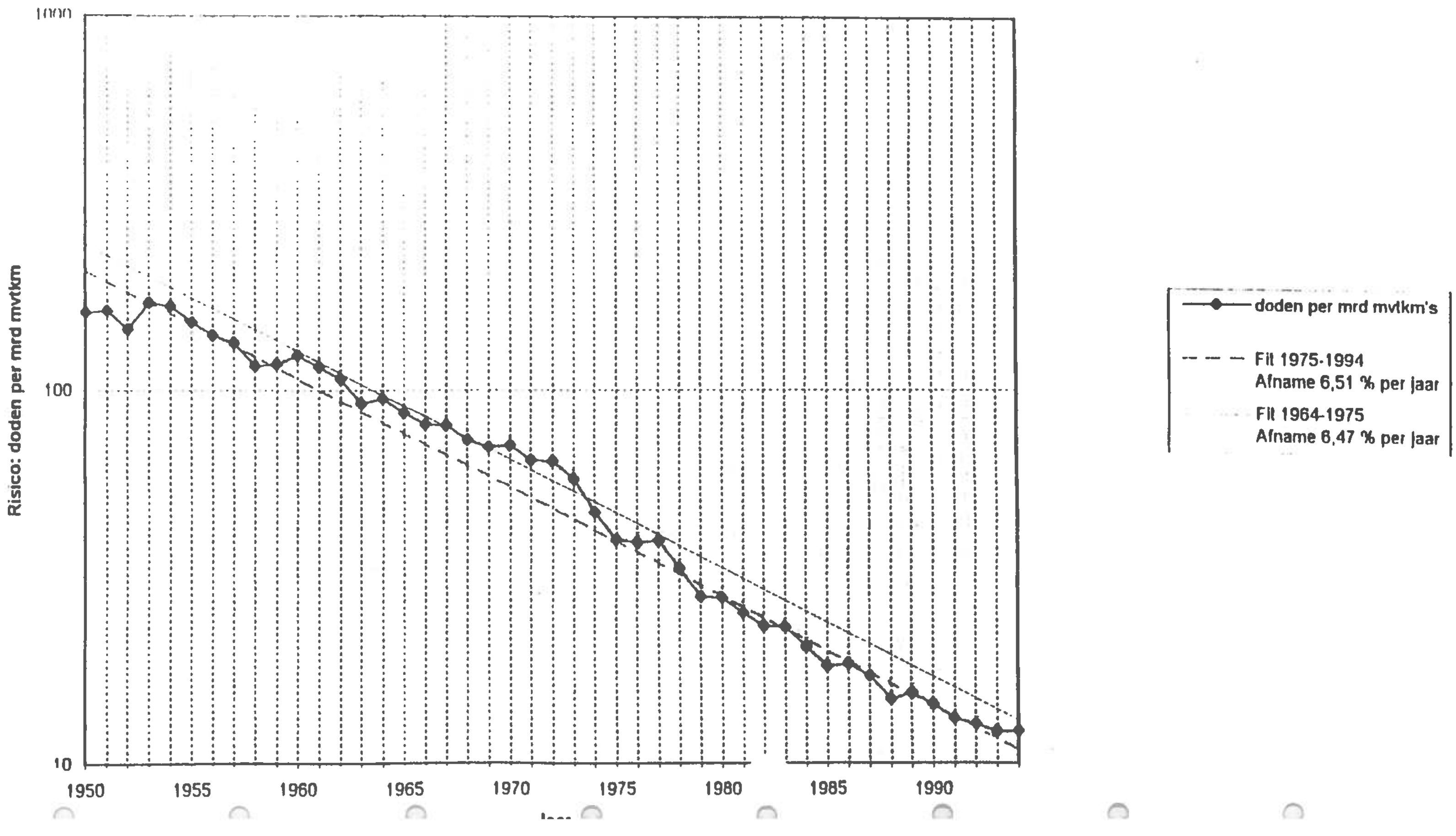
Also if we look at the political goals, they are set in terms of total number of victims. They contain no link to the number of miles driven.

So accidents rates should be looked as performance indices. They are of great value when you want to compare different lay-outs, make forecasts of number of accidents etc. However they are of limited value when you discuss personal risks.

To use the concept of risk we need data in a suitable form. This forms a large bottleneck for the moment. Most accident statistics are not organized in such a way that they easily can be used to calculate risk levels. Furthermore data of exposure form a problem. Most exposure data are based on surveys using rather small samples. The third problem is the mismatch between definitions used in those surveys and in the accident statistics.

The introduction of the concept of risk will lead to different conclusions as far as practical work is concerned. For the short term the most urgent one is that the provision of data has to be (re)organized.

Risicoontwikkeling 1950-1994



Road safety in The Netherlands

injury rates on different road types (1986)

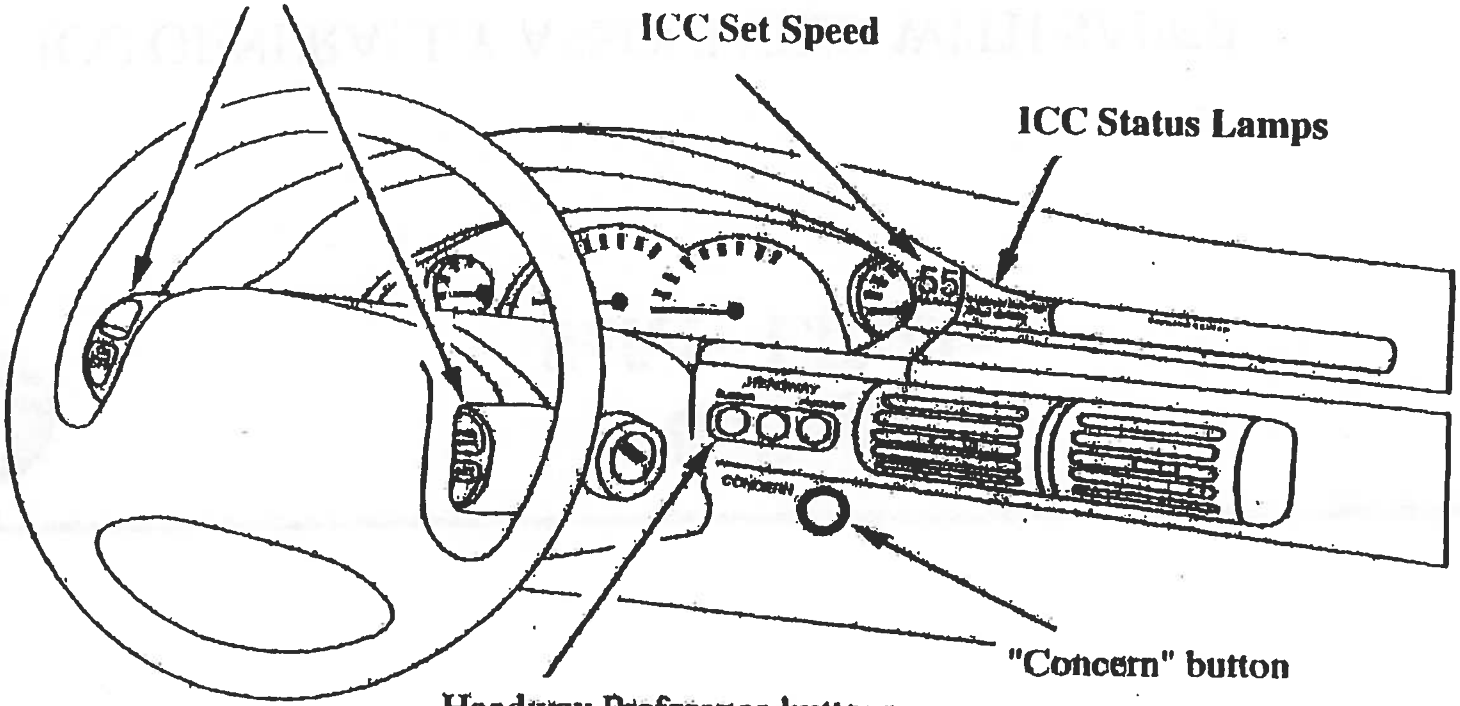
road type	speed limit	mixed traffic	intersecting/oncoming traffic	injury rates per 10^6 km
residential areas	30	yes	yes	0.20
urban street	50	yes	yes	0.75
urban artery	50/70	yes/no	yes	1.33
rural road	80	yes/no	yes	0.64
express road	80	no	yes	0.30
motor road	100	no	yes/no	0.11
motorway	100/120	no	no	0.07

Safety Evaluation of the Intelligent Cruise Control (ICC) System

Sponsored by
Office of Vehicle Safety Research
National Highway Traffic Safety Administration

DTS-73 Division Meeting
April 6, 1999

ICC Driver Interface - Schematic



Chrysler's
cruise control switches

ICC Set Speed

ICC Status Lamps

"Concern" button

Headway Preference buttons

Findings
Safety Effects

- ICC GENERALLY ASSOCIATED WITH SAFER DRIVING vs. MANUAL
- IF WIDELY DEPLOYED, PROJECTED TO RESULT IN NET SAFETY BENEFITS
- SOME SAFETY CONCERNS, BUT NOT A GENERAL PROBLEM FOR ICC