Injuries: a continuous challenge for public health

The analyses in this thesis were performed within the framework of the "Injury and Traumatology Scenario Study" and the "Injury and Traumatology Monitoring Study". Both projects were initiated by the Steering Committee on Future Health Scenarios. They were financed by the Ministry of Public Health, Welfare and Sports.

Financial support for the printing of this thesis was obtained from the Department of Public Health, Erasmus University Rotterdam.

Ed van Beeck
Injuries: a continuous challenge for public health
Thesis Erasmus University Rotterdam - With summary in Dutch

ISBN 90-72245-87-3
Keywords: Injuries; trends; societal burden; determinants; forecasting; monitoring
Date of issue: May, 1998

Cover and lay-out: HP Design, Zoetermeer
Printing: Printpartners Ipskamp, Enschede

Injuries: a continuous challenge for public health

Acute lichamelijke letsels:
een blijvende uitdaging voor de
volksgezondheid

PROEFSCHRIFT

Ter verkrijging van de graad van doctor
aan de Erasmus Universiteit Rotterdam
op gezag van de Rector Magnificus
Prof.dr P.W.C. Akkermans, M.A.
en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op
woensdag 10 juni 1998 om 11.45 uur

door

Eduard Ferdinand van Beeck

geboren te 's Gravenhage

PROMOTIECOMMISSIE

Promotor: Prof.dr J.P. Mackenbach

Overige leden: Prof.dr R.J.A. Goris
Prof.dr A. Hofman
Prof.dr R.M. Lapré

Contents

CHAPTERS 2, 3 AND 4 ARE BASED ON THE FOLLOWING PAPERS AND MANUSCRIPTS:

2.1 van Beeck EF, Looman CWN, Mackenbach JP. The rise and fall of accident mortality in the Netherlands: the role of dynamics in the incidence and case fatality of injuries (submitted).

2.2 van Beeck EF, van Roijen L, Mackenbach JP. Medical costs and economic production losses due to injuries in the Netherlands. J Trauma 1997;42:1116-1122.[1]

3.1 van Beeck EF, Mackenbach JP, Looman CWN, Kunst AE. Determinants of traffic accident mortality in the Netherlands: a geographical analysis. Int J Epidemiol 1991;20:698-796.[2]

3.2 van Beeck EF, Borsboom GJJ, Mackenbach JP. Economic development and traffic accident mortality in the industrialized world, 1962-1990 (submitted).

4.1 van Beeck EF. The use of the Delphi method in forecasting accidents in the year 2000. In: Adler M, Ziglio E (eds). Gazing into the oracle: the Delphi method and its application to social policy and public health. London: Jessica Kingsley Publishers, 1996, p. 193-212.[3]

4.2 van Beeck EF, Mackenbach JP, van Oortmarssen GJ, Barendregt JJM, Habbema JDF, van der Maas PJ. Scenarios for the future development of accident mortality in the Netherlands. Health Policy 1989;11:1-17.[4]

4.3 van Beeck EF, Mackenbach JP. Future health scenarios as a tool in the surveillance of unintentional injuries. Health Policy 1997;40:13-28.[4]

Reproduced with the permission of:
- *Williams and Wilkins*[1]
- *Oxford University Press*[2]
- *Jessica Kingsley Publishers*[3]
- *Elsevier Science Ireland Ltd.*[4]

1 Introduction

1.1

Injuries:
a dynamic public health problem

This thesis deals with injuries, a public health problem often neglected by health policy makers and the medical profession. It will focus on trends in the societal burden of this important "disease".

In fact, injuries reflect one of the most persistent public health problems of all times. Almost half a century ago, John Gordon, one of the founding fathers of injury epidemiology, reported that death rates fom injuries had remained virtually unchanged between 1900 and 1946 and had shifted from the sixth to the third most important cause of death in the USA[1]. More recent analyses from several industrial countries have shown only minor changes in the overall injury mortality rates over the entire past century, especially in comparison to the spectacular decreases in mortality due to infectious diseases.[2-4] The current injury mortality rates of many industrialized countries more or less existed already at the beginning of this century. They are probably very much the same as those prevailing at the beginning of "modernization" in the nineteenth century, as can be derived from historical data from England and Wales.[5-8] Moreover, injuries being an even more important cause of death in premodern times seems plausible.

Although overall injury mortality data in a long term perspective give the appearance of a persistent and static problem area, in fact we are dealing with a very dynamic field. The high level of injury mortality in industrialized countries at the beginning of this century was due to other major external causes than the high level of today. The field is characterized by the continuous introduction of new hazards to societies and by the exposure of new generations to longer existing risks. This leads to newly emerging subproblems or the return of problems which had seemingly been conquered. Beneath the surface of apparently stable overall injury mortality data, dynamic trends with respect to specific subproblems can be found.

The unchanged injury mortality rate in the USA during the first half of this century as reported by John Gordon, for example, was the result of an increasing mortality due to motor vehicle traffic accidents which was compensated by declining accident mortality figures outside the traffic system (e.g. due to drowning).

Because of their dynamic nature injuries are not unimportant in relation to changing patterns of mortality and disease in populations. Over the past two centuries a transition took place in most industrialized countries from a cause of death pattern dominated by infectious diseases with very high mortality to a pattern dominated by chronic diseases and injuries with lower mortality.[9-11] In most developing countries, this transition is still under way.[12] This development is referred to in the literature as the "epidemiologic transition". Many researchers have tried to establish the extent to which various underlying determinants, including preventive measures and improvements of medical care, have contributed to the observed changes in mortality and disease patterns[3]. So far, however, most of this research has focused on chronic conditions and infectious diseases [e.g.13-17] and only little attention has been paid to injuries and their consequences.

This thesis explores long-term developments in the frequency of injuries and their underlying factors and can thus shed some light on their role in the epidemiologic transition.

Special attention is paid to the dynamics of separate subclasses of injuries, for it must be recognized that injuries can be caused by a variety of widely different events (see figure 1.1.1). It has become customary to make a first distinction between "unintentional" and "intentional" injuries respectively.[2]

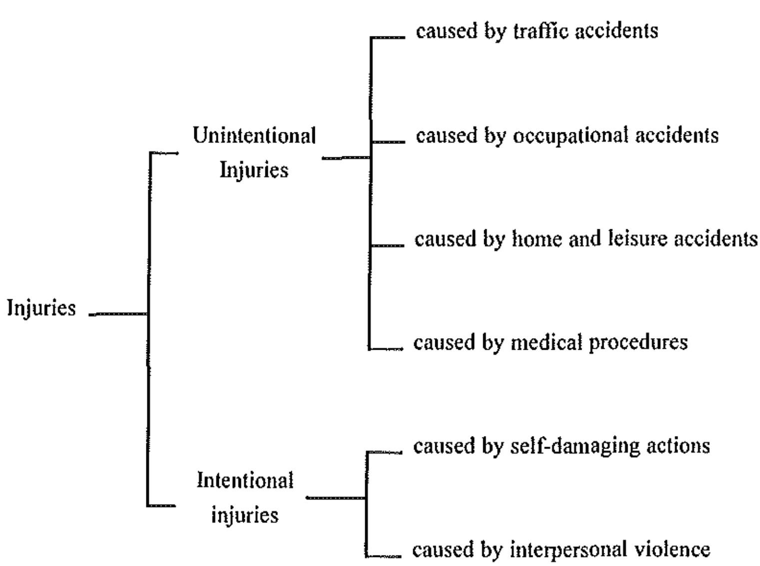
Unintentional injuries are those sustained by the victims of an accident. They are caused by sudden events which were not intended to happen. They are synonymous to "accidental injuries".

Intentional injuries are either self-inflicted (suicide and attempted suicide) or the result of interpersonal violence (homicide and assault). Both unintentional and intentional injuries are the result of a wide range of specific external causes.[18-19]

This thesis mainly focuses on unintentional injuries as caused by three major types of accidents: traffic accidents, occupational accidents and home and leisure accidents. An accident is defined as "an unexpected and unintended event caused by external forces, resulting in acute physical injury".[20] Traffic accidents are those involving at least one moving vehicle. Occupational accidents are those occurring during paid employment or industrial activities. Home and leisure accidents are all other unintentional events, with the exception of those resulting from a medical procedure. Some of these accidents take place in the home situation, for example in the course of housekeeping or Do-It-Yourself-activities. Others occur elsewhere, such as sports accidents, accidents on the street without the involvement of a moving vehicle, and accidents at school.

Figure 1.1.1

A classification of injuries by external cause



1.2

Quantitative methods to support injury prevention and control

The continuous introduction of new hazards to society and the exposure of new generations, time and again, to longer existing risks, make the field of injuries one of the most challenging to public health policy. Changes in disease and mortality patterns can take place quite rapidly because the exposures in this area have acute health effects. This calls for accurate public health surveillance systems as a basis for the continuous development and evaluation of prevention and control strategies.

Public health surveillance has been defined as "the ongoing systematic collection, analysis and interpretation of health data essential to the planning, implementation and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know".[21]

This thesis presents a number of quantitative analyses that were performed within the framework of a public health surveillance system in the Netherlands. This system started in 1985 and was initiated by the Steering Committee on Future Health Scenarios, a body advising the Dutch government on long-term health planning.[22] The thesis focuses on the societal burden of injuries in the Netherlands, dealing with developments in this area over a period of 50 years.

The following three main types of activity were undertaken within the scope of the public health surveillance system:

- assessment of the frequency and societal burden of injuries;
- research into determinants of injury mortality;
- forecasting and monitoring of injuries.

Each type of activity will be separately introduced in the next sections of this paragraph, which will also briefly explain the various quantitative methods that were used.

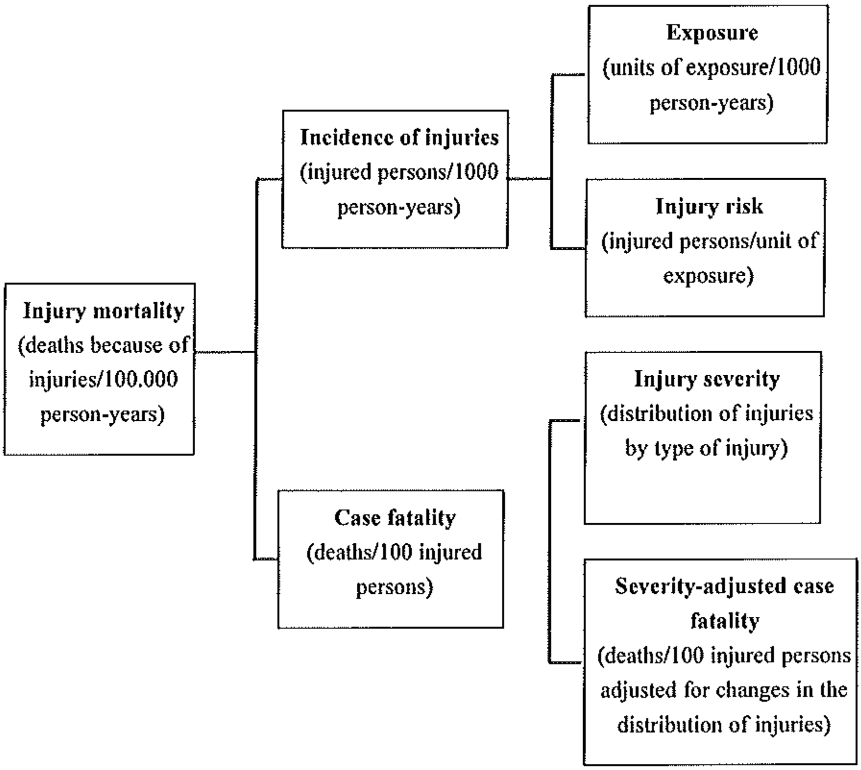
1.2.1 ASSESSMENT OF THE FREQUENCY AND SOCIETAL BURDEN OF INJURIES

An important tool in studying the frequency of injuries is the performance of a trend analysis. This not only shows the current size of the problem, but also sheds light on changes in the frequency of injuries and their consequences. It clearly illustrates shifts in the relative contributions of separate subclasses and offers insight into the factors behind these observations.

We analyzed injury mortality trends in the Netherlands since 1950. This analysis used the conceptual model presented in figure 1.2.1.

Figure 1.2.1

A framework for the analysis of injury mortality



According to this model (changes in) rates of mortality (the number of deaths per 100.000 person-years) are the result of (changes in) the rates of the incidence of injuries (the number of injured people per 1000 person-years) and the case fatality (the number of deaths per 100 injured persons). The incidence of injuries is the result of the exposure (e.g. the number of passenger car kilometres per 1000 person-years) and the injury risk (the number of injured persons per unit of exposure). The case fatality is the result of the injury severity (the distribution of injuries by type of injury) and the severity-adjusted case fatality (the number of deaths per 100 injured persons adjusted for changes in the distribution of injuries). The exposure, injury risk, injury severity and severity-adjusted case fatality are influenced by demographic, economic, socio-cultural and technological factors (all "autonomous" from the point of view of health policy makers), as well as by policy measures aimed at the prevention of injuries or the improvement of medical care for injury victims. This conceptual model allowed us to perform a systematic analysis of developments in the epidemiology of injuries. It helped to explain historical trends over the past fifty years.

The aforementioned trend analysis used traditional indicators from public health surveillance systems (mortality, incidence and case fatality).

Within the field of injury prevention and control it has recently been recognized that information on these traditional indicators should be supplied with data on the economic costs of injuries. This information is expected to have great value for setting public health priorities.[23]

Producing reliable estimates of the costs of diseases and injuries, however, is known to be rather difficult[24]. When performing a cost-of-injury study, there are several cost elements which can be included and several methods of cost estimation which are available.[25]

Within the framework of our public health surveillance system, a detailed assessment of the health care costs and economic production losses due to injuries in the Netherlands was made. To estimate economic production losses we used the recently developed friction cost method,[26-27] the first time this method had been applied in a comprehensive cost-of-injury study. The aim of the study was to provide information on the current societal burden of injuries in the Netherlands.

1.2.2 RESEARCH INTO DETERMINANTS OF INJURY MORTALITY

Within the framework of our public health surveillance system we performed two studies in which the focus was on determinants of injury mortality. A matrix developed by William Haddon jr.[28] yielded a basic framework of thought for studying determinants of injury mortality. This "Haddon-matrix" assumes that injuries are the result of factors related to a host (a potential victim or perpetrator), an agent (an object carrying an amount of potentially damaging energy) or the environment. These factors can all come into play during different phases known as the pre-event phase (circumstances preceding the accident), the event phase (circumstances during the accident) and post-event phase (circumstances in the aftermath of the accident).

This thesis is focused on injuries at the population level. A potential determinant at this level is the population exposure to injury risks. The frequency of injuries highly depends on factors such as the traffic mobility rate, the labour force participation rate and the sports participation rate. These factors are not included in the Haddon-matrix.

In order to identify the main determinants of injury mortality at the population level we used the conceptual model presented in figure 1.2.1. This model is an elaboration of the Haddon-matrix and may help to establish the contribution of several underlying components to variation in injury mortality. These components are related to the pre-event phase (exposure and injury risk), event phase (injury severity) and post-event phase (severity-adjusted case fatality).

We used this model to perform an ecological analysis of regional differences in traffic accident mortality within the Netherlands and a study of traffic accident mortality within the industrialized world between 1962 and 1990. We specifically studied traffic accidents as they are a major cause of death and disability with dynamic trends in both industrialized and developing countries.[29] Both studies aim to establish the role played by exposure in relation to the frequency of injuries, and focus on economic background factors as a determinant of injury mortality and its underlying components. The national economy is known to be an important background factor in relation to the health of individuals and populations.[30] The general evidence shows that economic growth has a tendency to improve the health of populations. Growing prosperity, however, also fosters the large scale introduction and growth of new hazards to society.

1.2.3 FORECASTING AND MONITORING OF INJURIES

Quantitative methods for forecasting and monitoring of injuries are a potentially powerful tool for policy makers in the field of injury prevention and control. In the previous paragraph injuries were identified as a heterogeneous public health problem of a continuous and dynamic nature. Policy makers need surveillance instruments to increase their anticipatory capacity. They urgently require tools which make it possible to foresee possible newly emerging and/or recurring subproblems in the field of injuries. Moreover, they need "early warning systems" to detect undesired trends as early as possible without raising too many false alarms.

The international experience in the development and application of tools for forecasting and monitoring of injuries is still limited. And in 1985, when we started our public health surveillance system, no comprehensive projections in this field had been performed at all. We therefore developed a new forecasting method which could subsequently be used as a tool in the surveillance of unintentional injuries in the Netherlands. We developed a quantitative approach for calculating the future burden of injuries under a set of alternative external conditions. This approach was based on the scenario methodology.[31] The quantitative effects of scenarios were computed with the help of a public health model developed by our department.[32] This was a formal and detailed elaboration of the conceptual model of figure 1.2.1. We estimated the future burden of injuries, in terms of mortality and disability in the population, based on varying developments in exposure, injury risk, injury severity and severity-adjusted case fatality.

Possible future developments in the separate components of figure 1.2.1. were estimated with the help of a Delphi study[33] which produced quantitative information usable as input for our public health model. The quantitative results of our future health scenarios for the period 1985-2000 were reported to policy makers in 1988 and subsequently used as a framework for continuous monitoring of unintentional injuries in the Netherlands. Because we started our surveillance system in 1985, and could follow epidemiologic developments for more than ten years afterwards, we were able to evaluate the new method. By comparing the projections with actual observations we could asses the validity of the forecasts. In addition, we tried to establish whether the availability of those forecasts facilitated the early identification of undesired trends, and/or contributed to health policy in the Netherlands.

1.3

Aims and structure of this thesis

This thesis reports and discusses the results of a number of studies into injuries in the Netherlands, which were performed within the framework of a public health surveillance system initiated in 1985. These studies aimed to answer the following main questions:

1. Which trends can be observed in the frequency of injuries in the Netherlands since 1950, how can they be explained, and what is the current societal burden of injuries?

2. What are the determinants of injury mortality at the population level, and of traffic accident mortality in particular?

3. What is the value of expert based quantitative future health scenarios for forecasting and monitoring of injuries?

The structure of this thesis is closely related to the above questions. *Chapter 2* reports and discusses studies into the epidemiology and economic burden of injuries. *Chapter 3* deals with our research into determinants of traffic accident mortality. In *chapter 4* the development, implementation and evaluation of future health scenarios as a new tool in forecasting and monitoring of injuries is presented. *Chapter 5* is devoted to a general discussion. In this chapter several methodological issues are discussed in relation to a summary of the main findings. In addition, it positions our findings within the framework of the epidemiologic transition theory. Finally, challenges for the future are dealt with: in injury surveillance, in injury research, and in injury prevention and trauma care.

1.3

In reading this thesis it should be noted that the sequence of the various studies presented in different chapters does not reflect the chronological order in which they were performed.

We started our surveillance activities with the development of forecasting methods. A surveillance period of more than ten years followed. This gave us the opportunity to assess the value of the forecasting methods that were initially developed (see chapter 4). We were moreover able to perform additional studies into the epidemiology and economic burden of injuries (see chapter 2) and the determinants of traffic accident mortality (see chapter 3).

REFERENCES

1. Gordon JE. The epidemiology of accidents. Am J Public Health 1949;39:504-515.
2. Baker SP, O'Neill B, Ginsburg MJ, Li G. The Injury Fact Book; second edition. New York: Oxford University Press; 1992.
3. Mackenbach JP. De veren van icarus; over de achtergronden van twee eeuwen epidemiologische transities in Nederland.(The feathers of Icarus; about the backgrounds of two centuries of epidemiologic transitions in the Netherlands, in Dutch). Utrecht: Bunge;1992.
4. Caselli G. National differences in the health transition in Europe. Bloomington: Indiana University; 1993.
5. Greenwood M, Martin WJ, Russel WT. Deaths by violence, 1837-1937. J R Stat Soc 1941;104:146-171.
6. Logan WPD. Mortality in England and Wales from 1848 to 1947; a survey of the changing causes of death during the past hundred years. Pop Studies 1950;4:132-178.
7. Forbes TR. Coroners' inquisitions from London parishes of the Duchy of Lancaster : the Strand, Clapham, Enfield, and Edmonton, 1831-1883. J Hist All Sciences 1988;43:191-203.
8. Stocks P. Fifty years of progress as shown by vital statistics. Br Med J 1950;1:54-57.
9. Omran AR. A century of epidemiologic transition in the United States. Prev Med 1977;6:3-51.
10. Omran AR. Epidemiologic transition in the United States: The health factor in population change. Pop Bull 1980; 32: whole issue.
11. Omran AR. The epidemiologic transition theory. A preliminary update. J Trop Pediatr 1983;29:305-316.
12. Mackenbach JP. The epidemiologic transition theory. J Epidemiol Community Health 1994:48:329-332.
13. Powles J. Changes in disease patterns and related social trends. Soc Sci Med 1992;35(4): 377-387.
14. Barker DJP. Rise and fall of Western diseases. Nature 1989;338:371-372
15. Beaglehole R. International trends in coronary heart disease mortality, morbidity, and risk factors. Epidem Rev 1990;12:1-15.
16. Wolleswinkel-van den Bosch JH, Looman CWN, van Poppel FWA, Mackenbach JP. Cause-specific mortality trends in the Netherlands, 1875-1992: a formal analysis of the epidemiological transition. Int J Epid 1997;26:772-781.
17. Wolleswinkel-van den Bosch, Van Poppel FWA, Tabeau E, Mackenbach JP. Mortality decline in the Netherlands in the period 1850-1992: a turning point analysis. Soc Sci Med 1998 (in press).
18. World Health Organization (WHO). International Statistical Classification of Diseases and Related Health Problems, Tenth Revision. Geneva: WHO; 1992.
19. Nordic Medico-Statistical Committee (NOMESCO). NOMESCO Classification of External Causes of Injuries. Copenhagen: NOMESCO; 1996.

References

20. Lapré RM, Mackenbach JP (eds). Accidents in the year 2000; accident and traumatology scenarios 1985-2000. Dordrecht: Kluwer; 1989.
21. Thacker SB, Berkelman RL. Public health surveillance in the United States. Epidem Rev 1988;10:164-190.
22. Brouwer JJ, Schreuder RF (eds). Scenarios and other methods to support long-term health planning. Utrecht: Uitgeverij Jan van Arkel; 1986.
23. Rogmans WHJ, Mulder S (eds). Priority setting in accident prevention. Amsterdam: European Consumer Safety Association; 1995.
24. Drummond MF. Cost-of-illness studies: a major headache. PharmacoEconomics 1992;2:1-4.
25. van Beeck EF. Methods to assess the costs of injuries. In: Rogmans WHJ, Mulder S (eds). Measuring the severity and costs of accidental injuries. Amsterdam: European Consumer Safety Association; 1998.
26. Koopmanschap MA, van Ineveld BM. Towards a new approach for estimating indirect costs of diseases. Soc Sci Med 1992;34:1005-1010.
27. Koopmanschap MA, Rutten FFH, van Ineveld BM et al. The friction cost method for measuring indirect costs of disease. Journal of Health Economics 1995;14:171-189.
28. Haddon W Jr. A logical framework for categorizing highway safety phenomena and activity. J Trauma 1972;12:197-207.
29. Söderlund N, Zwi AB. Traffic-related mortality in industrialized and less developed countries. Bull WHO 1995;73:175-182.
30. Brenner MH. Mortality and the national economy: a review and the experience of England and Wales 1936-1976. Lancet 1979;ii:568-573.
31. Schnaars SP. How to develop and use scenarios. Futures 1986;10:122-142.
32. Mackenbach JP, van Oortmarssen GJ, van Beeck EF et al. Projections of the epidemiology of accidents; a computer model for calculating the future incidence of accidents and their consequences. In: Lapré, RM, Mackenbach JP (eds). Accidents in the year 2000; accident and traumatology scenarios 1985-2000. Dordrecht: Kluwer; 1989.
33. Adler M, Ziglio E (eds). Gazing into the Oracle: the Delphi Method and its application to social policy and public health. London: Jessica Kingsley Publishers; 1996.

2 The frequency and societal burden of injuries in the Netherlands

2.1 *The rise and fall of accident mortality in the Netherlands : the role of dynamics in the incidence and case fatality of injuries*

2.2 *Medical costs and economic production losses due to injuries in the Netherlands*

2.1

ABSTRACT

Objective: To detect and explain changing trends in the mortality, incidence and case fatality of unintentional injuries in the Netherlands.

Method: With the help of national registration data we analyzed trends in traffic injuries, occupational injuries and home and leisure injuries. We established the contribution of developments in the incidence and case fatality to mortality trends since 1950. We studied the influence of trends in exposure and injury risk on trends in the incidence of injuries, and we related case fatality trends to developments in injury severity.

Results: Accident mortality in the Netherlands is characterized by rapid changes. Between 1950 and 1970 it rose because of an increasing incidence of injuries. This was followed by a sharp decline in mortality based on a decreasing incidence combined with a rapidly falling case fatality. Since the second half of the 1980s the decline in accident mortality has levelled off as the incidence of several injury subclasses has once again risen. The observed trends are based on several background factors, including economic fluctuations (influencing exposure), preventive measures (reducing the injury risk and injury severity) and improvements of trauma care (lowering the severity-adjusted case fatality).

Conclusions: Growing or new exposures tend to increase the injury incidence and mortality. This can be compensated by measures reducing the injury risk, injury severity or severity-adjusted case fatality. Since the second half of the 1980s this compensation has fallen short in the Netherlands. This demonstrates the necessity of new policy measures in spite of the impressive reductions in public health damage already reached.

2.1

The rise and fall of accident mortality in the Netherlands: the role of dynamics in the incidence and case fatality of injuries

2.1.1 INTRODUCTION

Unintentional injuries represent a continuous challenge for public health. As in other industrialized countries,[1] they cause an extensive amount of public health damage in the Netherlands. Annually, one fifth of the Dutch population seeks medical treatment as a result of an unintentional injury.[2] This high rate of health care utilization means that we are dealing with an important source of medical costs. And unintentional injuries are an important source of temporary and permanent disabilities in the population too. They constitute, for example, one of the main three causes of economic production losses resulting from health damage in Dutch society, outnumbered only by psychiatric disorders and locomotory diseases.[3] Moreover, injuries represent a cause of death which may not be ignored, as they account for 2.5% of mortality in the whole population. This figure is much higher, however, where children and adolescents are concerned, in whom about one third of all deaths is the result of an unintentional injury.[4]

The current scope of this public health problem calls for action from policy makers. A possible tool to support priority setting in this area is trend analysis.[5] A trend analysis aims to detect changes in disease frequencies and their underlying determinants. It reveals which problems are on the rise and which are decreasing and elucidates the factors behind these observations. In this way, trend analysis may potentially suggest hypotheses for etiologic research, next to triggering control activities.[6]

This article reports the results of an analysis of trends in mortality from unintentional injuries in the Netherlands since 1950 and its underlying developments.

Trends in accident mortality (the number of deaths from unintentional injuries per 100.000 person-years) are the result of trends in the incidence of injuries (the number of injured people per 1000 person-years) and the case fatality (the number of deaths per 100 injured persons) respectively.

Developments in the incidence of injuries are based on trends in the exposure (the number of units of exposure per 1000 person-years, e.g. passenger kilometres) or trends in the injury risk (the number of injured persons per unit of exposure). To give an example: the number of injured motor cyclists in the population (i.e. the incidence) depends on the number of kilometres travelled by motor cycle (i.e. the exposure) and the chance to get injured per kilometre on a motor cycle (i.e. the injury risk).

Developments in the case fatality are the result of changes in the injury severity (the distribution of injuries by type of injury) or trends in the severity-adjusted case fatality of injury victims (the number of deaths per 100 injured persons adjusted for changes in the distribution of injuries). To give an example: the number of deaths per 100 injured motor cyclists (i.e. the case fatality) can drop as a result of a declining proportion of life-threatening injuries among the victims (e.g. 10% severe head injuries instead of 20%, leading to a reduction of the mean injury severity of injured motor cyclists). The case fatality of motor cycling injuries, however, can also be reduced at a higher rate than to be expected from changes in injury severity alone. If so, a reduction of the severity-adjusted case fatality can be observed. This is a potential measure to establish the effect of improvements of trauma care. It will be explained in more detail in the section on data and methods.

Developments in exposure, injury risk, injury severity and severity-adjusted case fatality are all influenced by two types of determinants. The first type includes various factors not directly influenced by public health policy, such as demographic, economic, socio-cultural and technological trends. The other type, on the contrary, refers to preventive measures or strategies aimed at the improvement of trauma care.

A systematic analysis of trends in the incidence and case fatality of injuries and their underlying parameters can provide insight into the major determinants of trends in accident mortality over a long period of time. We performed this type of analysis on a number of subclasses. As a first step we established the extent to which developments in the incidence and the case fatality affected mortality trends between 1950 and 1995. Secondly, we studied the influence of trends in exposure and injury risk on trends in the incidence of injuries, and we related case fatality trends to developments in injury severity. This article reports the results of these analyses.

The possible influence of various background factors, including preventive measures and improvements of trauma care, will be addressed in the discussion section.

2.1.2 DATA AND METHODS

Classification

Unintentional injuries are the result of traffic accidents, occupational accidents or home and leisure accidents. This distinction into three main categories is not used in information systems based on the International Classification of Diseases, such as the registries of causes of death and hospital admissions in the Netherlands. These registries only allow a distinction between traffic accidents and nontraffic accidents (including both occupational and home and leisure accidents). There are other sources, however, from which it may be derived that occupational accidents only account for a minor fraction of deaths (2%) and hospital admissions (4%) among those resulting from nontraffic accidents in the Netherlands.[4] Hence the data on deaths and hospital admissions due to nontraffic accidents can be used to estimate the figures on home and leisure accidents.

Accident mortality

Data on *accident mortality* were acquired from several sources. First, we used cause-of-death figures from the Dutch Central Bureau of Statistics (CBS).[7] These data were used to calculate trends in accident mortality and a number of major subclasses (traffic accidents, nontraffic accidents, accidental fall, accidental poisoning and accidental drowning) between 1950 and 1995. We calculated crude mortality rates and mortality rates adjusted for changes in the composition of the population between 1950 and 1995. We computed the adjusted mortality rates with the help of direct standardization. The Dutch population of 1972 was used as the standard population. The population numbers of five-year age classes (0-4, 5-9, ...) of this standard population were multiplied with the specific mortality rates of these age classes in each separate year between 1950 and 1995. This provided numbers of deaths to be expected without changes in the size and structure of the Dutch population. The adjusted mortality rate was calculated as the expected number of deaths divided by the size of the total population in 1972.

Data from the national registries on traffic accidents (VOR: Road Traffic Accident Registry)[8] and occupational accidents (BOR: Occupational Accident Registry)[9] were used to calculate accident mortality rates according to mode of transport (passenger car occupant, motor cyclist, moped rider, cyclist, pedestrian) and branch of industry (manufacturing, construction, service sector) respectively.

Incidence and case fatality of injuries

For both traffic accidents and separate subclasses of nontraffic accidents (with the exception of accidental fall), we found quite similar trends in the crude and standardized mortality rates. We therefore only calculated the crude rates of the incidence and case fatality of injuries.

We drew on several sources for data on the *incidence of injuries*. The number of traffic injuries is registered by the police in the aforementioned Road Traffic Accident Registry. As in other countries[10,11] a sizable number of the relevant cases fails to be registered.[12,13] The level of underreporting, however, is probably rather stable. During our study period no major changes in registration criteria and procedures were seen. We were thus able to perform a trend analysis. We used data on the incidence of traffic injuries by mode of transport between 1950 and 1995.

The incidence of occupational injuries by branch of industry is registered in the Occupational Accident Registry which also suffers from underreporting.[14] This registry includes injuries leading to sickness absenteeism which is highly sensitive to social security arrangements. Between 1950 and 1995 major changes were implemented in the Dutch system of social security, most notably at the end of the 1960s and at the beginning of the 1990s. For this reason, trends in the field of occupational injuries will be presented for the period 1970-1991 only, when the registration level was likely to have been stable.

Data on the incidence of home and leisure injuries in the population at large are lacking. In order to gain insight into the incidence of home and leisure injuries and its subclasses we used data from the National Medical Registry (LMR),[15] which provides detailed information on the number of hospital admissions in the Netherlands. We used data from the period 1972-1995. In 1972, about 60% of all hospitalized patients were registered, whereas in 1995 a coverage rate of almost 100% had been reached. All available data were extrapolated into national rates, assuming that the participating hospitals were representative for the whole country.

This procedure was not applied to earlier data as the participation rates of hospitals were too low. The numbers of hospital admissions due to nontraffic accidents were used as estimates of the (clinical) incidence of home and leisure injuries after exclusion of all injuries resulting from a medical procedure.

Case fatality figures were calculated by combining the published data on accident mortality and on the incidence of injuries. We calculated case fatality figures according to the mode of transport by dividing traffic deaths by injured persons in the following subclasses: passenger car occupants, motor cyclists, moped riders, cyclists, and pedestrians. We calculated case fatality figures according to the branch of industry by dividing occupational injury deaths by injured persons in the following subclasses: manufacturing, construction, and the service sector.

Exposure and injury risk

Exposure data were available for both traffic accidents and occupational accidents. Exposure figures by mode of transport were obtained from publications of the Central Bureau of Statistics on traffic mobility and vehicle ownership. As a primary measure of exposure we used the number of passenger kilometres by mode of transport in the population. Data on this indicator were extracted from annual mobility surveys of the Central Bureau of Statistics.[16] This source provided us with data on the annual numbers of passenger kilometres travelled per 1000 persons-years in the period 1960-1995. It provided us with all necessary data on travelling by passenger car, motor cycle, moped, or as a pedestrian. A substantial part of the figures on cycling, however, was derived from specific surveys of the Foundation on Road Safety Research.[17]

Exposure data on occupational accidents by branch of industry were obtained from publications on the Occupational Accident Registry.[9] As an indicator of exposure we used the numbers of man-years at labour in the population in manufacturing, construction, and the service sector.

Figures on the *injury risks* were calculated by combining the available data on the incidence of injuries and on exposure. We calculated injury risks according to the mode of transport by dividing the numbers of injured persons by the numbers of kilometres travelled in the following subclasses: passenger car occupants, motor cyclists, moped riders, cyclists and pedestrians. We calculated injury risks according to the branch of industry by dividing the numbers of injured persons by the numbers of man-years at labour in the following subclasses: manufacturing, construction, and the service sector.

Injury severity and severity-adjusted case fatality

Developments in the *injury severity* and the severity-adjusted case fatality were specifically studied for traffic injury victims. We used data on the distribution of injuries by type of injury in order to distinguish a number of broad classes with different severity levels. These data were acquired from the National Medical Registry (LMR).[15] With the help of this data source, we were able to distinguish the following types of injury: intracranial injuries; internal injuries of organs in the chest, pelvis or abdominal region; fractures of the lower extremity; fractures of the upper extremity; fractures of skull, neck or chest; open wounds and contusions; luxations and distortions; burns; intoxications; other injuries. The severity of these separate types of injury is highly variable, in the sense that some are accompanied by high risks of death (e.g. intracranial injuries), while the case fatality is about 0% in others (e.g. luxations and distortions).

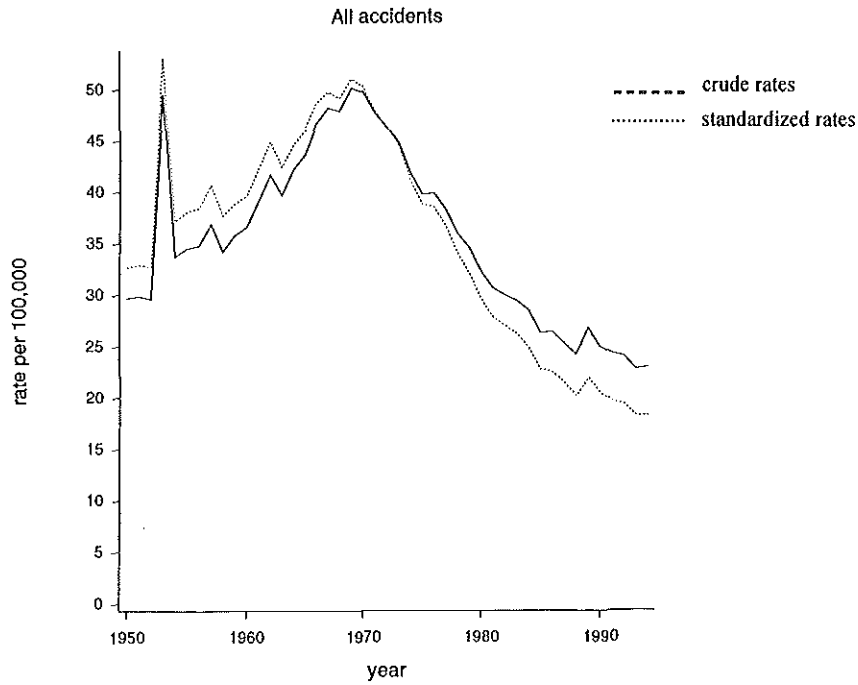
The National Medical Registry includes data on the numbers of injured persons admitted to hospital (i.e. the clinical incidence) and on the numbers of deaths inside the hospital. With the help of these data we could calculate the crude case fatality rates of hospitalized traffic victims from 1972 until 1995. This was done for separate years by dividing the numbers of traffic deaths inside the hospital by the numbers of hospitalized traffic injury victims. This offers a case fatality measure that excludes victims dying at the site of the hospital or before arrival at the hospital.

We also calculated the *severity-adjusted case fatality rates* of hospitalized traffic injury victims from 1972 until 1995. This was done in a procedure of indirect adjustment. For 1995, we computed injury-specific case fatality rates, distinguishing the aforementioned types of injury (intracranial injuries etc.). These were subsequently used as standard rates. For separate years (1972, 75, 80, 85, 88, 95), the numbers of traffic injury victims, according to the type of injury, were multiplied with the injury-specific standard rates of 1995. This provided numbers of deaths to be expected without changes in the injury-specific case fatality rates. By dividing observed numbers of deaths by the expected numbers of deaths a severity-adjusted case fatality rate could be calculated.

We had to rely on this procedure of indirect adjustment, because only for one year (1995), injury-specific case fatality rates were available. This procedure offers valuable information. By comparing crude rates and severity-adjusted case fatality rates an impression is gained of the contribution of changes in injury severity to a reduction of traffic deaths inside the hospital. A small difference means that other factors than injury severity have been important.

Figure 2.1.1

Accident mortality and its major subclasses in the Netherlands, 1950-1995 (crude rates and standardized rates per 100.000 person-years)



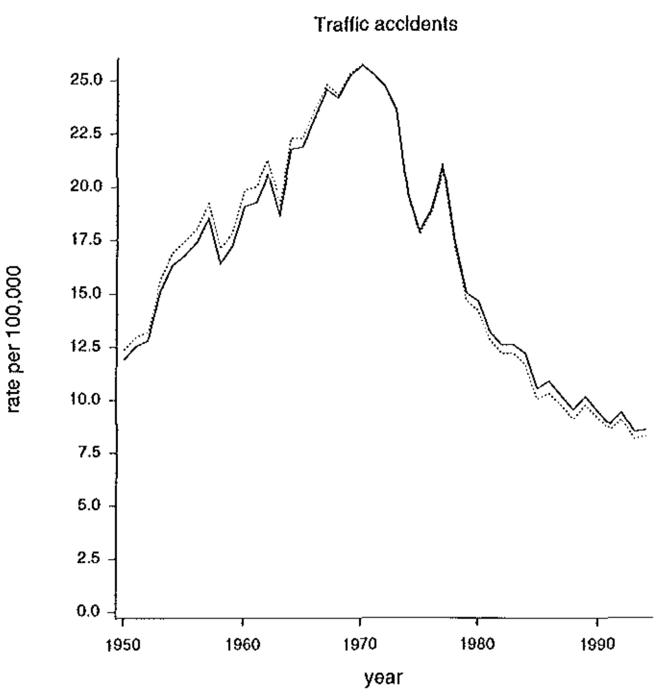
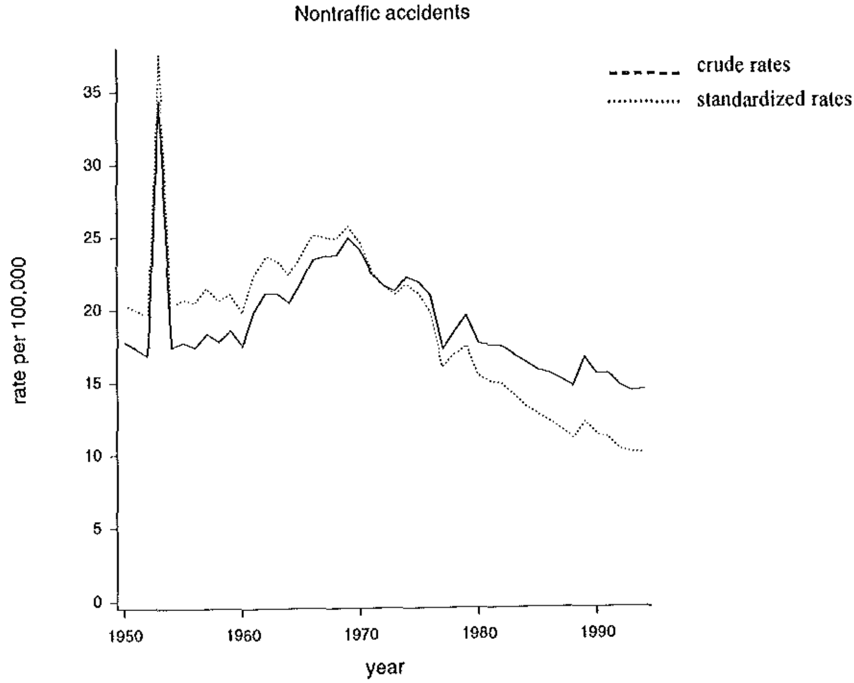


Figure 2.1.1 - Continued

Accident mortality and its major subclasses in the Netherlands, 1950-1995 (crude rates and standardized rates per 100.000 person-years)



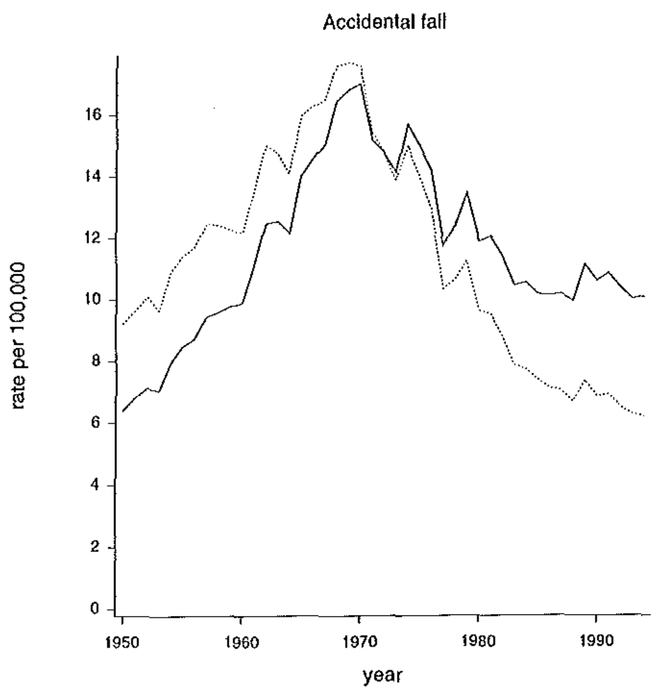
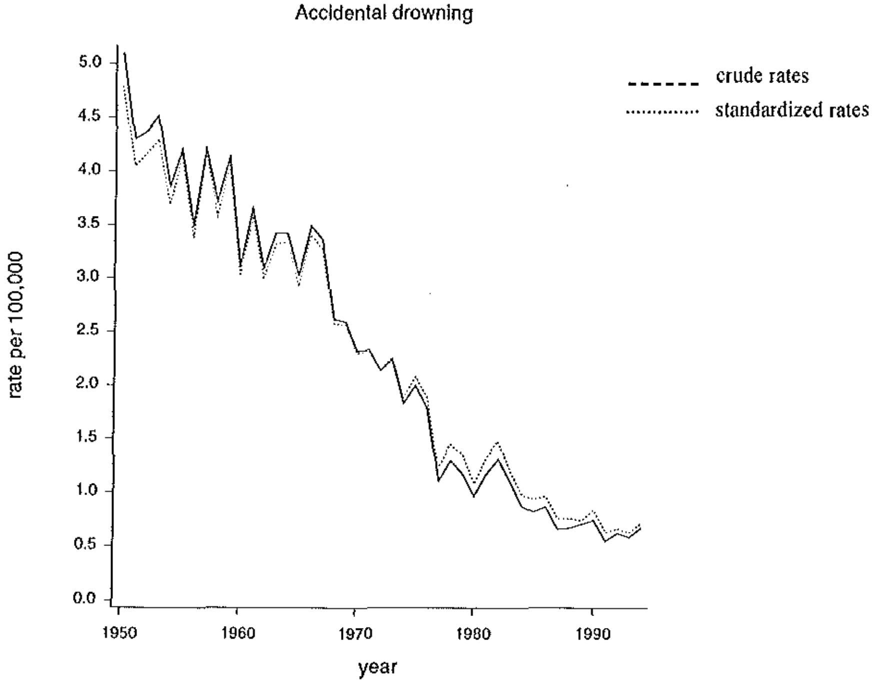
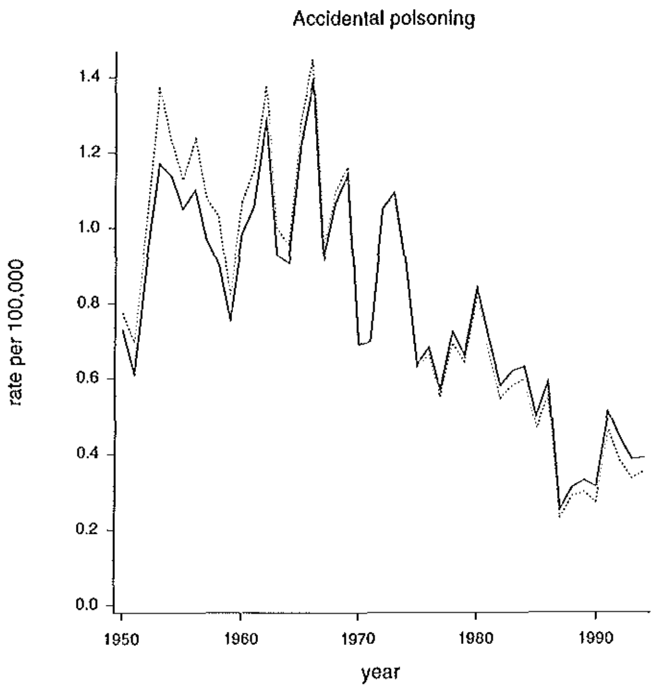


Figure 2.1.1 - Continued

Accident mortality and its major subclasses in the Netherlands, 1950-1995 (crude rates and standardized rates per 100.000 person-years)





2.1.3 RESULTS

Trends in accident mortality

Figure 2.1.1 shows that the development of accident mortality in the Netherlands since 1950 is characterized by rapid changes. Accident mortality (all categories combined) increased sharply during the period 1950-1970, and subsequently embarked upon a rapid decline that only recently has levelled off. The peak in the figure for the year 1953 reflects a major flood disaster. The rate of mortality as a result of traffic accidents follows a similar pattern. This more or less applies to deaths as a consequence of nontraffic accidents as well (i.e. an estimate of mortality due to home and leisure accidents) although they showed a less spectacular increase up to 1970.

The development of the mortality rate is illustrated separately for three subclasses of nontraffic accidents. Mortality due to accidental fall has been developing quite similar to traffic accident mortality. Accidental drowning as a cause of death has declined since 1950. Accidental poisoning claims few fatalities and therefore shows an erratic pattern in the mortality statistics, but nevertheless seems to have declined as a cause of death since the end of the 1960s until at least the end of the 1980s.

The figure shows that in all specific subclasses the crude and standardized rates are quite similar, with the exception of accidental fall.

Trends in the incidence and case fatality of injuries

The rise and fall of accident mortality in the Netherlands is the result of trends in the incidence and case fatality of injuries and of interactions between these parameters.

Figure 2.1.2 shows that in the area of traffic injuries three different periods can be identified. Between 1950 and 1970 there was a sharp increase in traffic accident mortality (all modes of transport combined) based on a rising incidence of injuries (figure 2.1.2A). In the period 1970-1985 there was a spectacular mortality decline because of rapidly falling figures for both the incidence and case fatality of injuries. In the period 1985-1995 mortality has been further decreased, but at a much slower rate than in the previous period. In this most recent period the observed decrease in traffic accident mortality has been due to a further decline in the case fatality, whereas the incidence of traffic injuries has more or less remained at the level of 1985.

Figure 2.1.2

The mortality, incidence and case fatality of traffic injuries in the Netherlands, by mode of transport, 1950-1995

A. All traffic injuries

B. Passenger car occupants

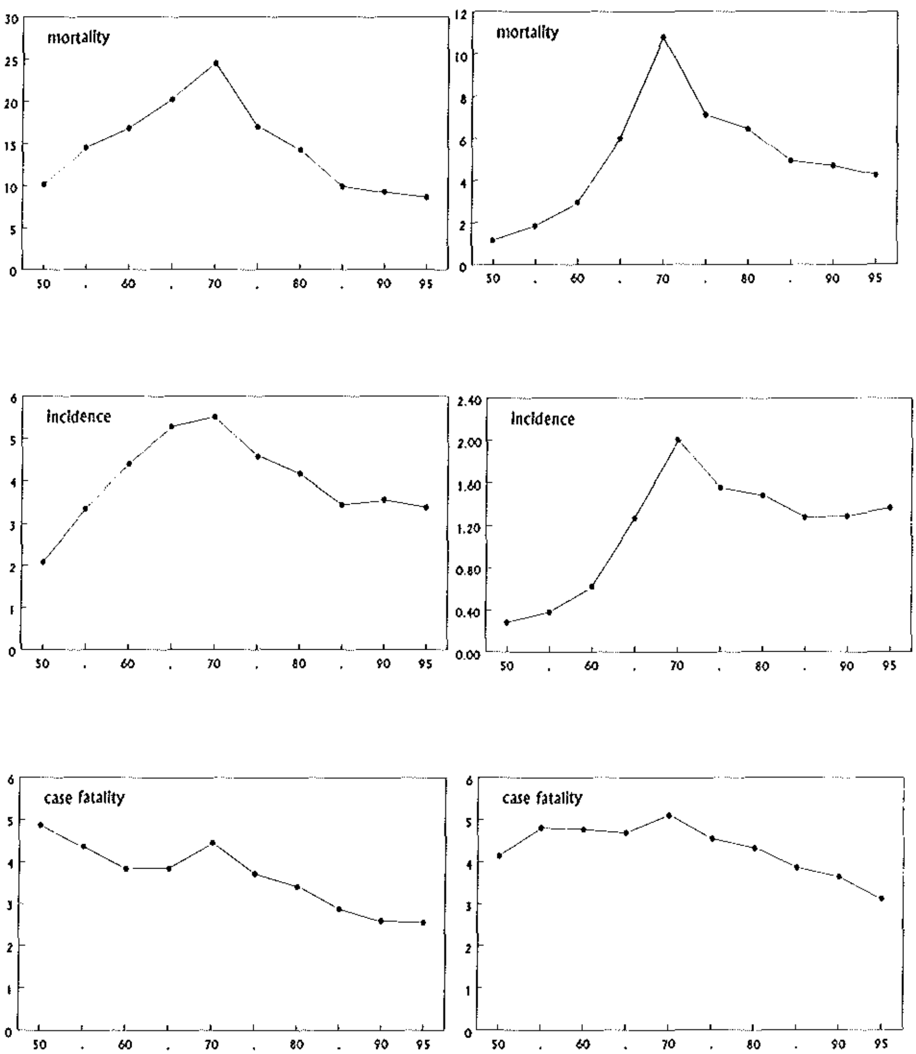


Figure 2.1.2 - Continued

The mortality, incidence and case fatality of traffic injuries in the Netherlands, by mode of transport, 1950-1995

C. Motor cyclists

D. Moped riders

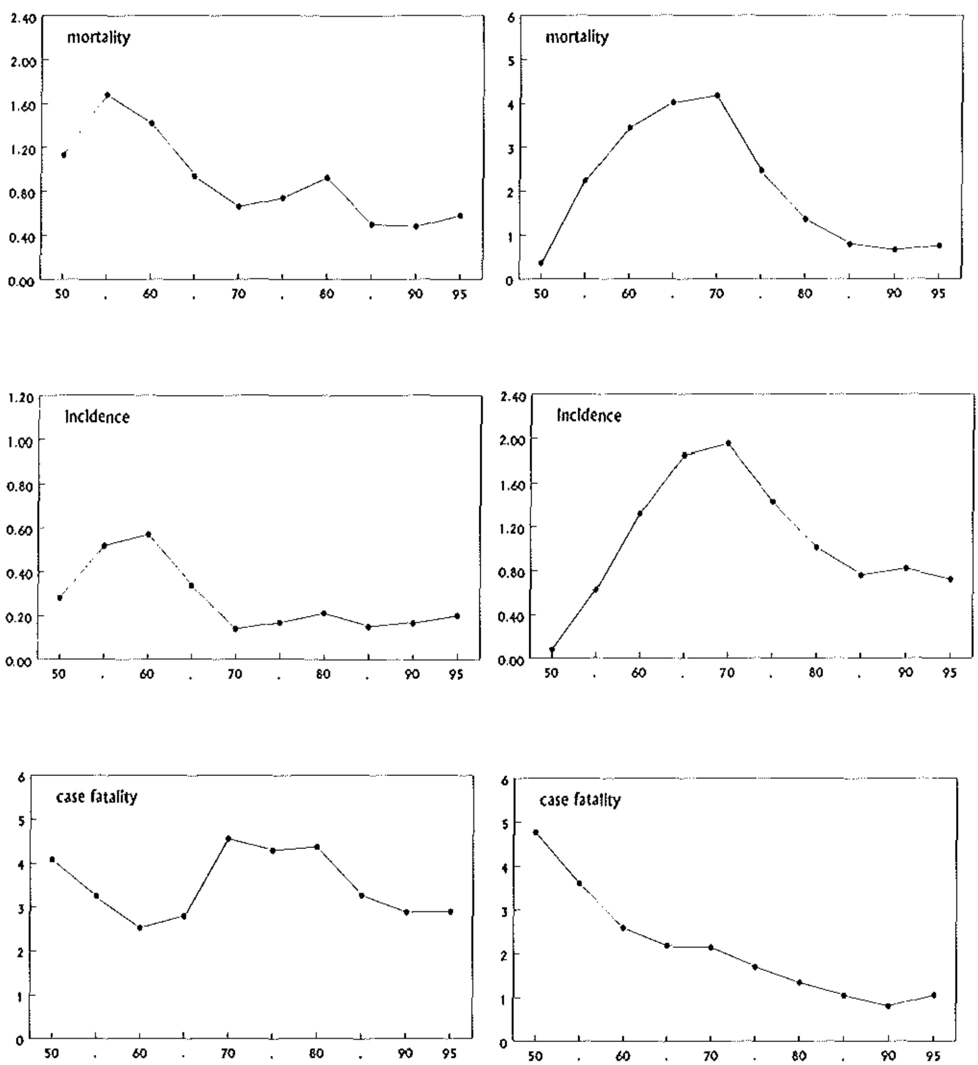


Figure 2.1.2 - Continued

The mortality, incidence and case fatality of traffic injuries in the Netherlands, by mode of transport, 1950-1995

E. Cyclists

F. Pedestrians

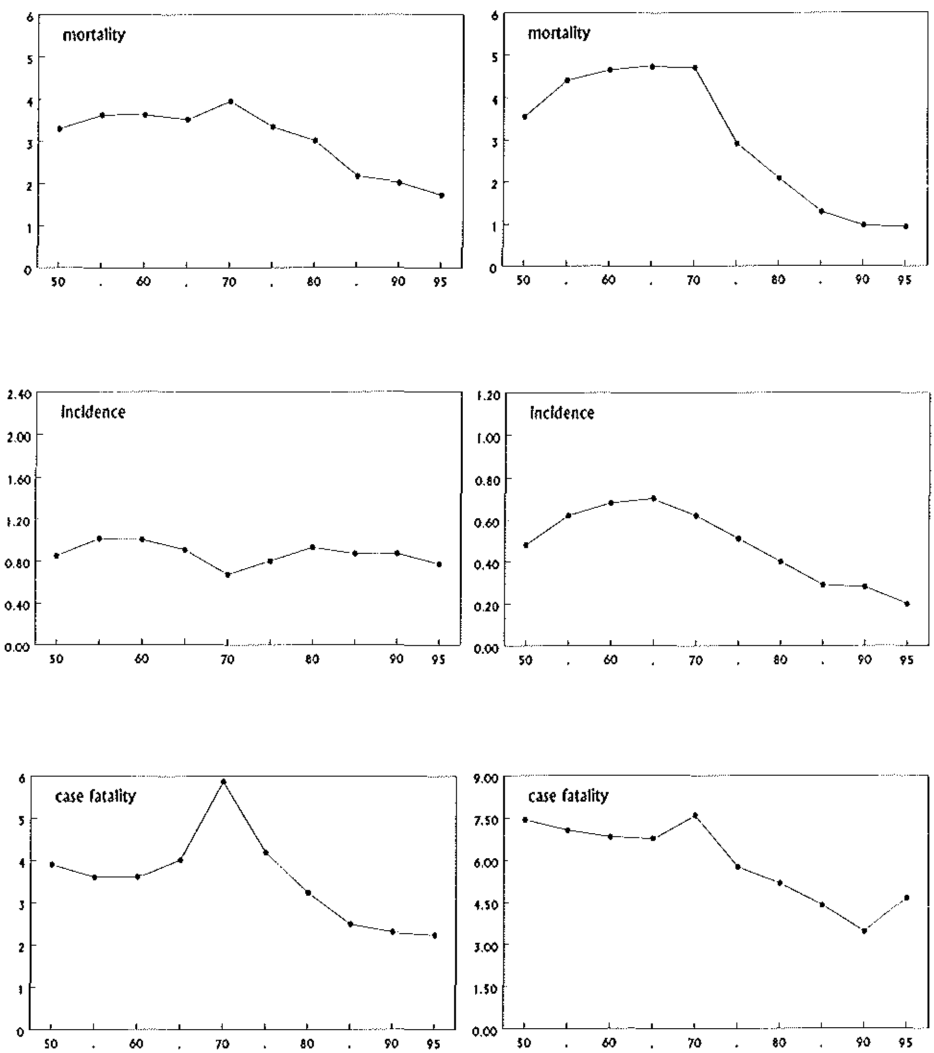


Figure 2.1.2 also sheds light on specific developments for separate modes of transport. The aforementioned distinction into three periods can be clearly observed for passenger car occupants (figure 2.1.2B). In the Netherlands, this subclass accounts for about 50% of all traffic deaths. The developments are quite similar to traffic accident mortality as a whole. It is striking to note that the incidence of injuries of passenger car occupants has even risen since 1985. In the case of passenger car occupants, the further decline in mortality since 1985 is wholly attributable to decreases in case fatality. Dynamic changes can also be observed in the other modes of transport (figure 2.1.2C-F). As with passenger car occupants, mortality trends between 1950 and 1970 are mainly based on changes in the incidence of injuries, whereas since 1970 the influence of developments in case fatality has become another major factor.

Trends in the incidence and case fatality of occupational injuries were studied for the period 1970-1991. Figure 2.1.3 shows a spectacular fall in occupational accident mortality in the Netherlands between 1970 and 1985 based on the combined effect of a falling incidence and declining case fatality in all branches of industry. After 1985 a relatively minor further decline in mortality is found. As with traffic injuries this is completely based on a further decline of the case fatality. Recently, the incidence of occupational injuries (with the exception of injuries due to manufacturing) would appear to be on the rise.

As already mentioned, trends in the incidence and case fatality of home and leisure injuries cannot be studied directly because figures from the population at large are lacking. However, figures on hospital admissions due to nontraffic accidents since the beginning of the 1970s are available for study (see figure 2.1.4). These figures can be compared to the trends in nontraffic accident mortality already presented (see figure 2.1.1). Such a comparison yields a broad impression of the mechanisms underlying mortality trends in this area.

Figure 2.1.4 shows that the incidence of hospital admissions due to home and leisure injuries has been fluctuating since the early 1970s. Interestingly the trends have developed in opposite directions for two major subclasses. The decreasing incidence of accidental poisonings would seem to contribute to the mortality decline of this subclass (see figure 2.1.1). The clinical incidence of accidental fall, on the contrary, has risen. This means that the declining mortality due to accidental fall (see figure 2.1.1) can probably not be explained by a decreasing incidence of injuries. It points to a declining case fatality as the major underlying parameter.

Figure 2.1.3

The mortality, incidence and case fatality of occupational injuries in the Netherlands, by branch of industry, 1970-1991

A. All occupational injuries

B. Manufacturing

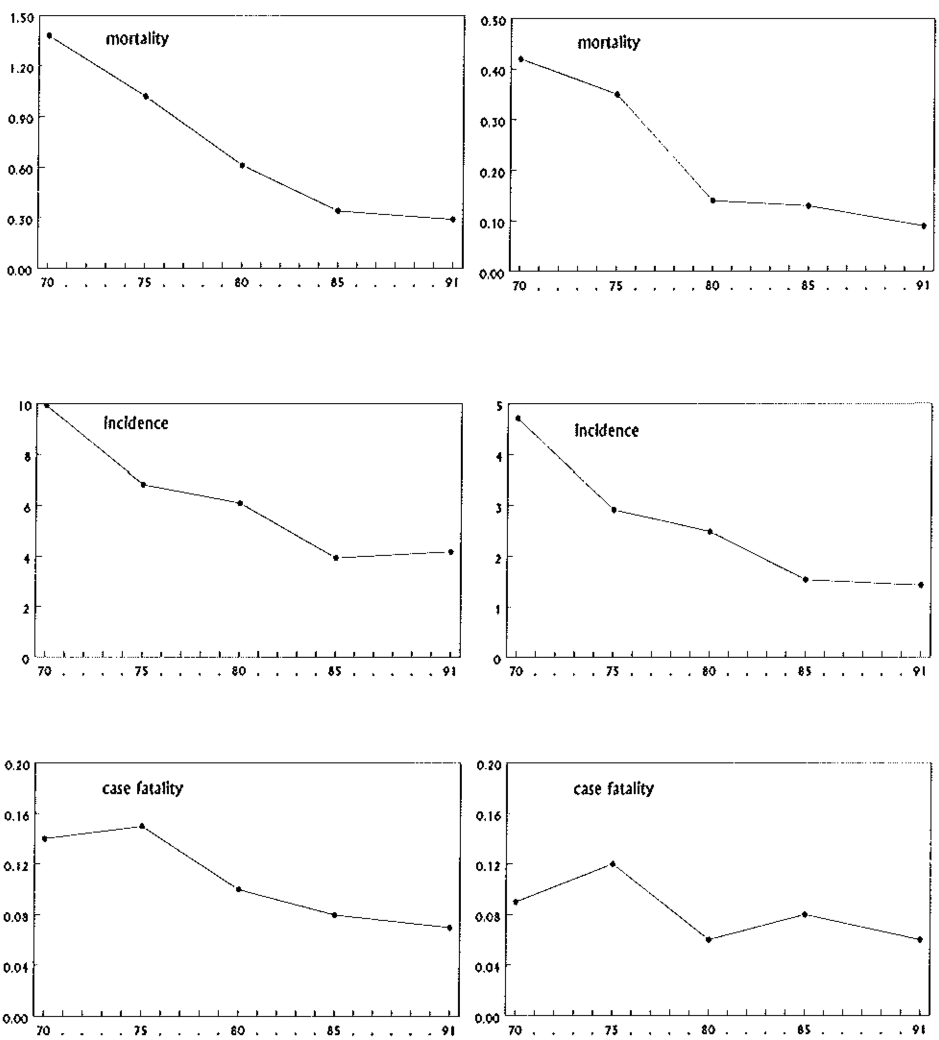


Figure 2.1.3 - Continued

The mortality, incidence and case fatality of occupational injuries in the Netherlands, by branch of industry, 1970-1991

C. Contruction | D. Service sector

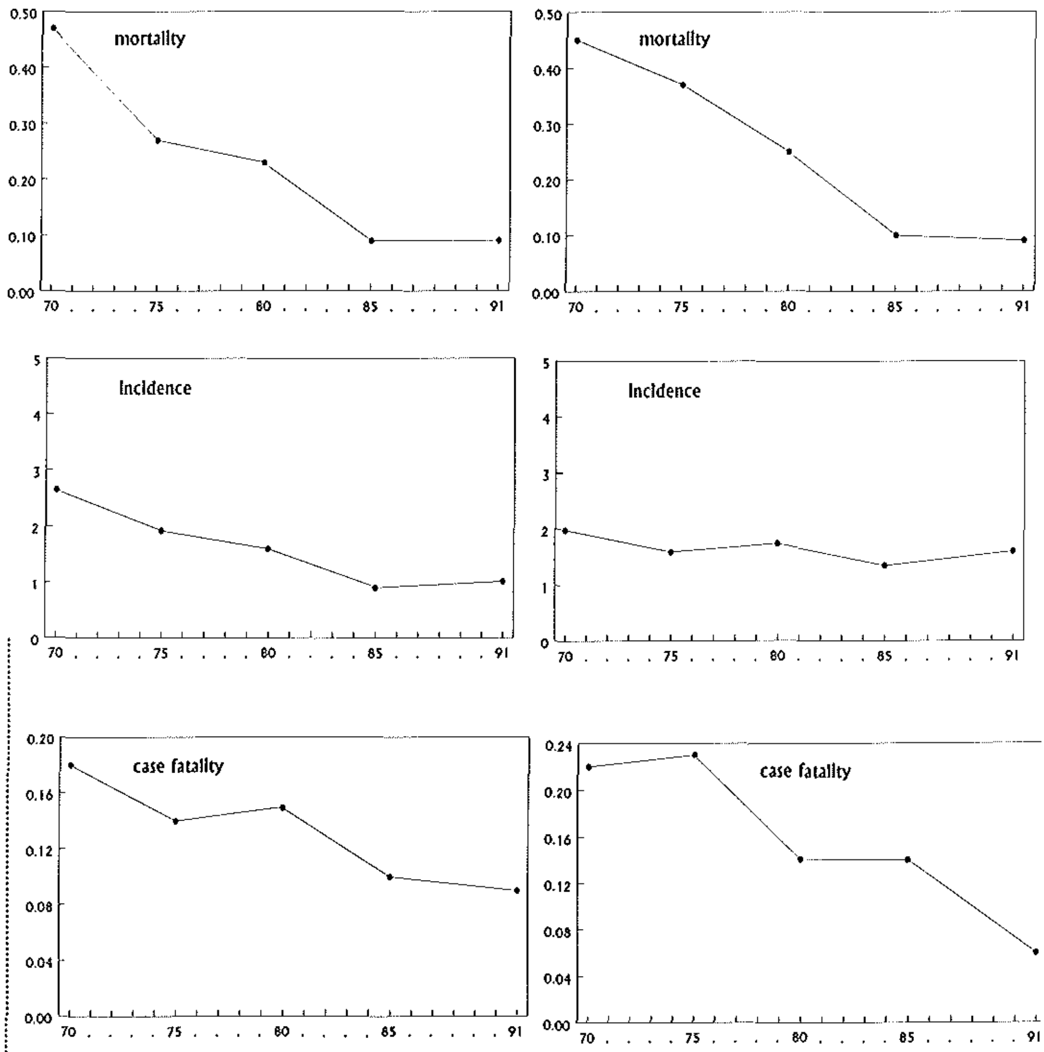
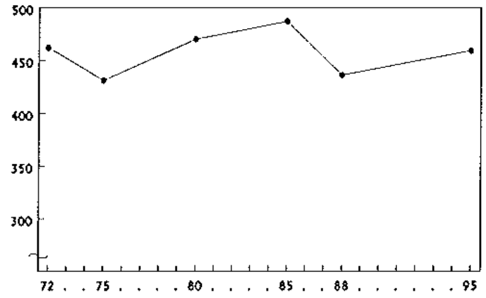


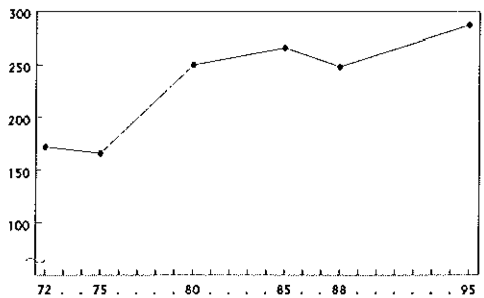
Figure 2.1.4

The clinical incidence of home and leisure injuries in the Netherlands, 1972-1995 (hospital admissions per 100.000 person-years)

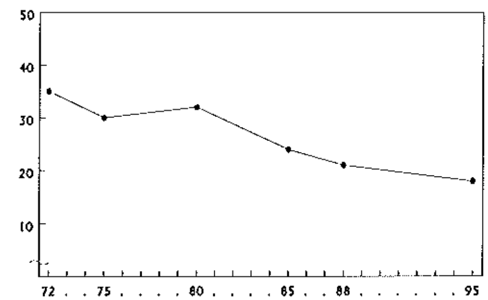
A. All home and leisure injuries



B. Accidental fall



C. Accidental poisoning



Trends in exposure and injury risk

The backgrounds of the observed trends in the incidence of traffic injuries are made visible in table 2.1.1. A rising exposure (see table 2.1.1a) is a major factor behind the growing incidence of injuries to passenger car occupants between 1960 and 1970, when the number of kilometres travelled by passenger car increased enormously (a rise by 141% between 1960 and 1965, followed by a rise by 78% between 1965 and 1970). Table 2.1.1a demonstrates that the steep rise in the use of passenger cars in the Netherlands levelled off in the 1970s. This is one of the factors behind the observed reversal in the incidence of injuries to passenger car occupants around 1970 (see figure 2.1.2).

Table 2.1.1

Developments in exposure and injury risk of traffic injuries by mode of transport, the Netherlands, 1960-1995 (percentual changes per five-year period)

a. Exposure (passenger kilometres/1000 person-years)

	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95
- Passenger car occupants	+141%	+78%	+13%	+9%	+3%	+12%	+5%
- Motor cyclists	-25%	-56%	+25%	+40%	-14%	+17%	+28%
- Moped riders	+2%	-23%	-34%	-26%	-40%	-17%	-20%
- Cyclists	-11%	-29%	-28%	0%	+17%	+6%	-1%
- Pedestrians	n.a.	n.a.	n.a.	n.a.	n.a.	-3%	+6%
- All modes of transport, combined	+28%	+25%	+13%	+12%	+2%	+12%	+5%

b. Injury risk (injured persons/passenger kilometre)

	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95
- Passenger car occupants	-14%	-13%	-30%	-13%	-15%	-13%	0%
- Motor cyclists	-21%	-1%	-10%	-12%	-18%	-7%	-2%
- Moped riders	+37%	+38%	+9%	-4%	+19%	+35%	+13%
- Cyclists	-4%	+6%	+67%	+15%	-19%	-6%	-11%
- Pedestrians	n.a.	n.a.	n.a.	n.a.	n.a.	+1%	-35%
- All modes of transport, combined	-6%	-16%	-27%	-19%	-19%	-9%	-9%

n.a. = not available

A second factor behind this reversal is the rapidly declining injury risk of passenger car occupants (see table 2.1.1b). This decline was especially sharp between 1970 and 1975 (this period saw a 30% decline in injury risk, whereas in other periods a constant decrease of 10-15% was met). This decline, however, has stopped recently. This would appear to be a reason behind the newly rising numbers of injuries among passenger car occupants in the most recent period. Another factor is the slight acceleration of exposure growth since 1985 (see table 2.1.1a).

Table 2.1.1 further shows a number of dynamic trends in exposure and injury risk among the other modes of transport. The use of the motor cycle, for example, has highly fluctuated throughout time. In the most recent period, there has been a growing popularity of the motor cycle (see table 2.1.1a), which is reflected in increasing incidence and mortality figures (see figure 2.1.2).

Table 2.1.2

Developments in exposure and injury risk of occupational injuries by branch of industry, the Netherlands, 1970-1990 (percentual changes per five-year period)

a. Exposure (man-years at labour/1000 person-years)

	1970-75	1975-80	1980-85	1985-90
- Manufacturing	-14%	-12%	-14%	+6%
- Construction	-17%	0%	-30%	+19%
- Service sector	+3%	0%	+4%	+27%
- All occupations, combined	-7%	0%	-9%	+18%

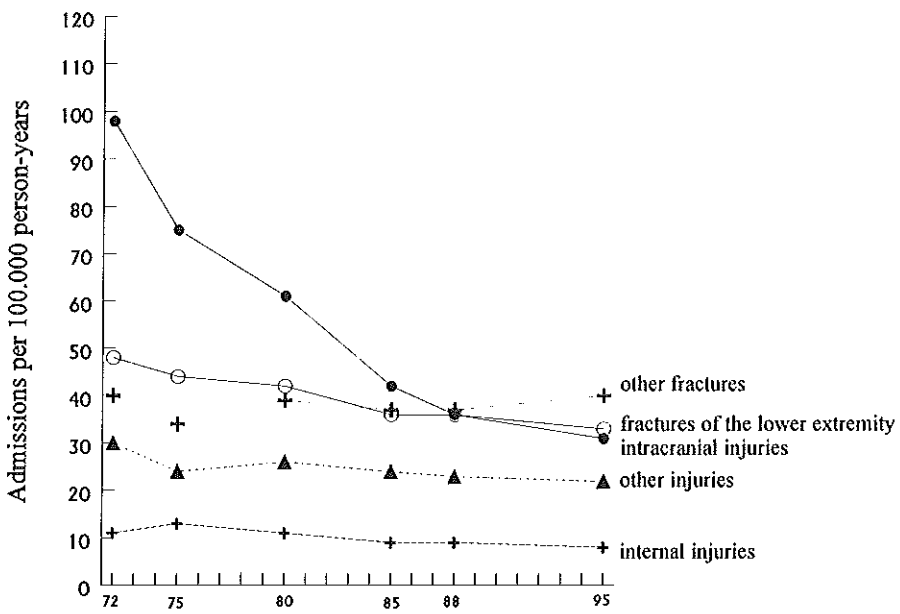
b. Injury risk (injured persons/man-year at labour)

	1970-75	1975-80	1980-85	1985-90
- Manufacturing	-28%	-3%	-30%	-12%
- Construction	-13%	-17%	-21%	-2%
- Service sector	-25%	+8%	-23%	-10%
- All occupations, combined	-24%	-34%	-28%	-11%

Background developments behind trends in the incidence of occupational injuries are made visible in table 2.1.2. This table shows that in the period 1970-1985 the number of man-years at labour declined in all branches of industry, with the exception of the service sector (see table 2.1.2a). The injury risks declined as well (see table 2.1.2b). This combination has led to a declining incidence of occupational injuries between 1970 and 1985. Since 1985 trends in both exposure and injury risk have changed. The labour force has increased in all branches of industry (see table 2.1.2a), whereas the declines in injury risk have levelled off (see table 2.1.2b). This explains why the incidence of occupational injuries has risen in the most recent period under review.

Figure 2.1.5

The clinical incidence of traffic injuries in the Netherlands, by type of injury, 1972-1995 (hospital admissions per 100.000 person-years)

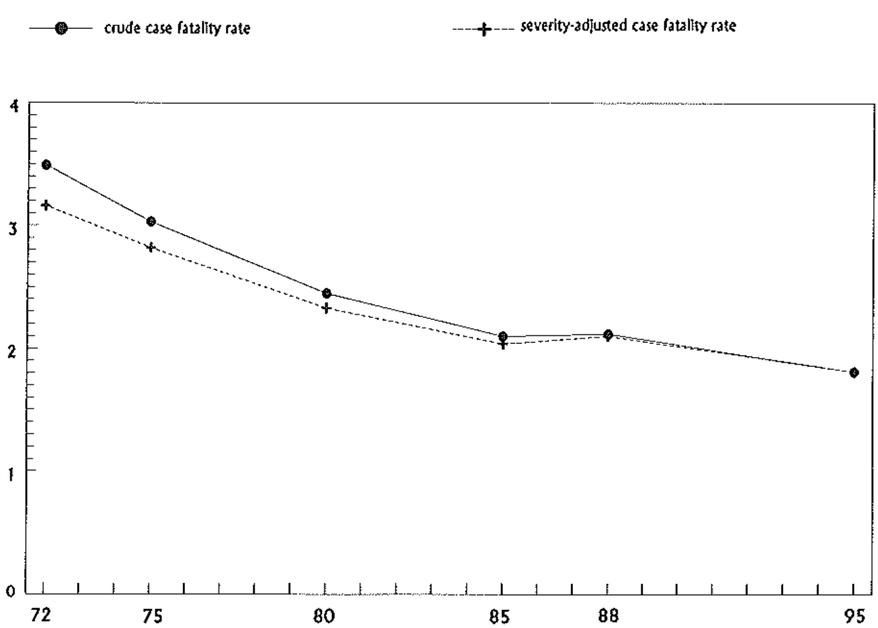


Trends in injury severity and severity-adjusted case fatality

The case fatality of traffic injuries has declined significantly since 1970 (see figure 2.1.2). Using direct standardization we then checked whether this could be explained by changes in the age and sex of the traffic victims. We found that after adjusting for age and sex the decline in case fatality was even slightly greater. This means that the observed decline in the case fatality was caused by other factors. We studied the possible contribution of changes in injury severity by examining trends in hospital admissions resulting from traffic accidents according to type of injury (see figure 2.1.5). Figure 2.1.5 reveals that the number of patients suffering intracranial injuries dropped very rapidly compared with the falling rates for other types of injury, especially during the period between 1972 and 1985. Thus the share of intracranial injuries declined from 43 % in 1972 to 23 % in 1995. This is an important observation, as intracranial injuries account for more than half of all traffic deaths.

Figure 2.1.6

The case fatality of hospitalized traffic injuries in the Netherlands, 1972-1995 (crude rates and severity-adjusted rates per 1000 injured persons)



Apart from changes in the distribution of injuries by type of injury, trends in the severity-adjusted case fatality could be important (see figure 2.1.6). Figure 2.1.6 shows that the case fatality of hospitalized traffic victims rapidly declined between 1972 and 1995. There is a small difference between the crude rates and the figures adjusted for changes in the distribution of injuries. Of the decline in case fatality of hospitalized traffic victims only some 20% can be explained by changes in the breakdown according to type of injury.

2.1.4 DISCUSSION

Using injury surveillance data, we established the impact of dynamics in the incidence and case fatality of injuries on changes in the accident mortality trends. Accident mortality in the Netherlands increased between 1950 and 1970, to be followed by a sharp decline that has only recently levelled off. The figures for both traffic accidents and nontraffic accidents (occupational and home and leisure accidents) reflect the rapid changes in the incidence and case fatality of injuries. These can be related to possible underlying factors. First of all, however, the influence of possible registration artefacts must be ruled out. There are several reasons for assuming that registration error has not substantially influenced the results of our study. Similar trends were found in several independent data sources. Figures were taken from periods during which no major changes in registration criteria or procedures were implemented.

And the observed developments in the incidence of injuries are plausible in the light of exposure developments. As registration error is probably not responsible for the observed trends in the incidence and case fatality of injuries, other determinants must have influenced the exposure, the injury risk, the injury severity and/or the severity-adjusted case fatality of injury victims.

It was shown that developments in exposure (passenger kilometres travelled, man-years at labour) have greatly influenced trends in the incidence of traffic and occupational injuries. As a rule, increasing or new exposures lead to growing numbers of injuries and deaths in the population. The rate of economic growth may well be a major underlying determinant in relation to exposure developments. Traffic mobility increased enormously during the years of rapid economic growth (1950-1970), then levelled off when the national economy plunged into successive recessions (1970-1985) and curved upward again during the recent spell of economic recovery (1985-1995).

Economic growth has also been important in relation to occupational accidents. The number of man-years at labour declined between 1970 and 1985, to be followed by a recent upswing as a result of the said economic fluctuations. The national economy is known to be a determinant of injuries at the population level.[18] In addition, however, other autonomous factors have influenced exposure developments. These probably include demographic trends, socio-cultural trends and technological trends.[19]

Autonomous factors have probably also played an important role in relation to the injury risks (injured persons per unit of exposure). We found rapidly decreasing injury risks (for both traffic and occupational accidents) between 1970 and 1985. It should be noted, however, that many injury risks had already been on the wane before 1970. As in other industrialized countries the constantly declining injury risks in traffic could be based on adaptation mechanisms, including an increasing familiarity with motorized traffic.[20] The decreasing injury risks at work may have been influenced by autonomous factors too, including the fact that the percentage of young (less than 25 years) and older workers (above 55 years) fell between 1970 and 1985; these are the age groups with by far the highest injury risks. Similar developments are reported in other countries.[21,22] Equally, technological progress will have helped to reduce the amount of high-risk employment. A final factor is the shift seen throughout the entire industrialized world towards employment in the service sector, which boasts a lower injury risk than does employment in agriculture, manufacturing and construction.

Apart from autonomous factors, preventive measures have certainly helped to reduce the injury risks, in particular in the area of traffic injuries. Those measures were, in the first instance, of an infrastructural nature leading to reduced injury risks at an early stage. These infrastructural improvements can be seen as a policy component of the adaptation mechanisms referred to above. Secondly, a range of specific measures came into effect in the period 1970-1975, which was shown to have had a much steeper reduction in injury risks than any other time. The most important preventive measures in this period were:

- the lowering of the speed limit on roads outside built-up areas (6 Februari 1974);
- the drink/driving act, prohibiting the driving of a vehicle by those with a blood alcohol level of over 0.05 per mill (1 November 1974);

- the introduction of compulsory crash helmets for moped riders (1 Februari 1975);
- the introduction of the compulsory use of seat belts (1 June 1975), preceded by the requirement that new cars be fitted with seat belts (1 Januari 1971).

Changes in injury severity have been important in relation to the declining case fatality of traffic injuries. In this context a spectacular decrease in the number and share of intracranial injuries among hospitalized patients was found. This has meant that the incidence of one of the most severe types of injury has been reduced. Some of the preventive measures that were mentioned have played a major role in this development. The compulsory crash helmet for moped riders aims to reduce the incidence of intracranial injuries, whereas seat belt use also leads to a sharper reduction of intracranial injuries than of other types of injury.[23]

Apart from changes in the injury severity a decreasing severity-adjusted case fatality is another important factor. Between 1972 and 1995 the crude case fatality rate of hospitalized traffic victims declined substantially. About 20% of this decrease could be explained by changes in the injury severity. In interpreting this finding, however, one has to consider the following. Many preventive measures (and crash helmets in particular) result in a more than proportionate reduction of the most severe injuries. Their implementation might have led to a decreased incidence of hospitalized (intracranial) injuries combined with a reduction of the mean severity score[24,25] of those injuries. Our data were not detailed enough to allow an adjustment for changes in the mean severity scores of the victims. Therefore, the effects of changes in injury severity on the case fatality of hospitalized traffic injuries are probably greater than shown by our calculations.

Nevertheless factors other than changes in injury severity are likely to have contributed to the declining case fatality rates as well. The case fatality not only declined for traffic injuries (all modes of transport), but for occupational (all branches of industry) and home and leisure injuries (accidental fall) as well. This may well partly be ascribable to improvements in medical care since 1970, such as:
- the improved treatment of severely injured patients by the introduction of intensive care;
- the improved diagnosis and treatment of intracranial injuries by the introduction of the CT-scan;
- the increasing proportion of operated injury victims;
- the more rapid post-operative mobilisation of injury victims.

Some evidence on the role of medical care in relation to the case fatality of injuries in the Netherlands has already been reported in the literature. It was found that a significantly lower percentage of preventable fatalities is evident in hospitals offering more advanced trauma care.[26] And in an analysis of regional mortality differences in the Netherlands a significant negative association was found between the presence of hospitals in the region offering advanced care and the case fatality of traffic injuries.[27] Moreover, it was found that medical care plays an important role in relation to the declining case fatality of injuries due to accidental fall. This holds in particular for hip fractures. The clinical case fatality for this type of injury, which accounts for the majority of deaths from accidental falls, has declined sharply since 1970. The most impressive reductions were achieved in the age groups in which the percentage of patients operated on was considerably increased.[28]

In conclusion, our study has shown that the dynamic trends in accident mortality in the Netherlands since 1950 are based on several background factors. Autonomous factors, such as economic fluctuations and their influence on exposures, are probably of considerable importance. In addition, some indication was gained of the influence of both preventive measures (reducing the injury risk or the mean level of injury severity) and improvements in trauma care (reducing the severity-adjusted case fatality).

Our study has further shown that favourable trends in accident mortality can be accompanied by unfavourable trends in the incidence of injuries. Mortality trends should therefore not be monitored without using data on the incidence of injuries, as unfavourable public health developments could be misssed.

Our study has finally shown that after a rapid increase (1950-1970) and an even more spectacular fall (1970-1985), we have now entered a third phase in the post-world war II development of accident mortality: recent trends, in particular in the incidence of injuries, are unfavourable. This points to the necessity of new measures aimed at reducing the incidence and severity of injuries. It seems that, certainly if substantial reductions in the injury risks and severity levels are no longer achievable, the control of exposure should be considered. Increasing or new kinds of exposure tend to increase the incidence of injuries, leading to an untolerable amount of health damage.

REFERENCES

1. Baker SP, O'Neill B, Ginsburg MJ, Li G. The Injury Fact Book; second edition. New York: Oxford University Press; 1992.
2. Mulder S, Bloemhoff A, Harris S, van Kampen LTB, Schoots W. Injuries in the Netherlands. Eur J Public Hlth 1998 (in press).
3. van Beeck EF, van Roijen L, Mackenbach JP. Medical costs and economic production losses due to injuries in the Netherlands. J Trauma 1997;42(6):1116-1122.
4. Den Hertog P, Toet H, Mulder S. Kerncijfers letsel door ogevallen en geweld. (Unintentional and intentional injuries, in Dutch). Amsterdam: Consumer Safety Institute; 1997.
5. van Beeck EF. Trend monitoring as an instrument for priority setting. In: Rogmans WHJ, Mulder S (eds). Priority setting in accident prevention, p. 37-45. Amsterdam: European Consumer Safety Association; 1995.
6. Thacker SB, Berkelman RL. Public health surveillance in the United States. Epidemiologic Reviews 1988;10:164-190.
7. CBS. Overledenen naar doodsoorzaak, leeftjd en geslacht, serie A1, 1950-1995. (Mortality by cause of death, age and sex, series A1, 1950-1995, in Dutch). Voorburg: CBS; several years.
8. CBS/VOR. Statistiek van de verkeersongevallen op de openbare weg, 1950-1995. (Statistics on traffic accidents on public roads, in Dutch). The Hague: SDU-publishers; several years.
9. CBS/BOR. Statistiek der bedrijfsongevallen, 1970-1991. (Statistics of occupational accidents, in Dutch). The Hague: SDU-publishers; several years.
10. Hutchinson TP. Road Accident Statistics. Adelaide: Rumsby Scientific Publishing; 1987.
11. Shinar D, Treat JR, MacDonald ST. The validity of police recorded accident data. Accid Anal Prev 1983;15:175-191.
12. Harris S. Verkeersgewonden geteld en gemeten. (Enumeration and measurement of road traffic accident victims, in Dutch). Leidschendam: SWOV; 1989.
13. van Beeck EF, Mackenbach JP. Accidents Monitoring Report 1992: developments since 1985. Rijswijk: Steering Committee on Future Health Scenarios; 1992.
14. Andriessen SA. Nog altijd geen representatieve registratie arbeidsongevallen (Still no representative reporting of occupational accidents, in Dutch). Arbeidsomstandigheden 1988;64:751-754.
15. CBS/SIG. Diagnosestatistiek ziekenhuizen, 1972-1995. (Hospital diagnosis statistics, in Dutch). The Hague/Utrecht: LMR; several years.
16. CBS. De mobiliteit van de Nederlandse bevolking, 1960-1995. (The mobility of the Dutch population, in Dutch). The Hague: SDU-publishers; several years.
17. Welleman AG, Blokpoel A. De ontwikkeling van de verkeersveiligheid van fietsers in relatie tot het gebruik van de fiets. (The development of traffic safety for cyclists in relation to the use of the bicycle, in Dutch). Leidschendam: SWOV; 1984.
18. Söderland N, Zwi AB. Traffic-related mortality in industrialized and less developed countries. Bull WHO 1995;73(2):175-182.

19. Lapré RM, Mackenbach JP (eds). Accidents in the year 2000. Accident and Traumatology Scenarios 1985-2000. Dordrecht: Kluwer; 1989.
20. Koornstra, M. The evolution of road safety and mobility. IATSS Research 1992; 16(2): 129-148.
21. Saari J. Long-term development of occupational accidents in Finland. Scand Work Environm Hlth 1982;8:85-93.
22. Office of Technology Assessment. Preventing illness and injury in the workplace. Washington: U.S. Government Printing Office; 1985.
23. Passies G. Verkeersgewonden in Groningen 1970-1979. (Traffic injuries in Groningen 1970-1979, in Dutch). Groningen: University Hospital; 1983.
24. Champion H, Sacco W, Hunt T. Trauma severity scoring to predict mortality. Wld J Surg 1983;7:4-11.
25. Civil IH, Schwab CW. The abbreviated injury scale 1985 revisited on a condensed chart for clinical use. J Trauma 1988;28:87-90.
26. Draaisma JMTh, de Haan AFJ, Goris RJA. Preventable trauma deaths in the Netherlands: a prospective multicenter study. J Trauma 1989;29:1552-1557.
27. van Beeck EF, Mackenbach JP, Kunst AE, Looman CWN. Determinants of traffic accident mortality in the Netherlands: a geographical analysis. Int J Epid 1991;20:698-706.
28. Hoogendoorn D. Heupfracturen, operatieve behandeling en klinische sterfte. (Hip fractures, operative treatment and clinical case fatality, in Dutch). Ned T Geneesk 1987;131:326-329.

2.2

ABSTRACT

Background: In order to support injury control we assessed the direct medical costs and indirect costs of injuries in the Netherlands, making use of recent advances in health economics.

Methods: We estimated the direct medical costs with the help of available data on health care utilization as a consequence of injuries. In our calculations of indirect costs we used two alternative approaches. We used the traditional Human Capital Approach, which estimates the potential economic production losses caused by diseases or injuries. In addition, we applied the Friction Cost Method which has recently been developed as an attempt to measure the actual economic production losses to society.

Results: Injuries are an important source of medical costs and economic production losses. Almost two-thirds of the medical costs are the result of accidents among females (mainly domestic accidents of elderly women). On the contrary and independent of the method used, more than 80% of the indirect costs are the result of injuries of males (mainly caused by a high frequency of traffic injuries, occupational injuries and sports injuries among young males). The application of the Friction Cost Method enforces the importance of injuries as a source of production losses in comparison to other diseases, showing that they belong to the three main causes of indirect costs to society.

Conclusions: Estimates of the medical costs and both the potential and actual economic production losses to society clearly demonstrate that injuries should be a major concern for health policy makers and the medical profession.

2.2

Medical costs and economic production losses due to injuries in the Netherlands

2.2.1 INTRODUCTION

Injuries are a public health problem which is often underestimated by policy makers and the medical profession. In the Netherlands, as in many other industrialized countries, current health policy focuses on the prevention and treatment of chronic conditions, which are considered to be the major public health challenges of today.[1]

Several indicators, however, show that injuries should not be neglected as a public health problem of major concern. Injuries, in fact, are a big challenge in both industrialized and developing countries. It has been shown that the percentage share of injuries as a cause of death ranges from 6% in the established market economies of the world to almost 12% in China.[2] And maybe even more important are recent estimates of the burden of disability in populations. These estimates show that in the highly industrialized regions almost 10% of the number of years lived with a disability are the consequence of injuries, where this proportion even reaches 15% in developing countries.[3]

There is substantial evidence that many injuries and their consequences, such as premature death and disability, are potentially avoidable by preventive measures or adequate trauma care.[4] This fact only increases the challenge for public health policy.

In setting public health priorities, therefore, injuries should be taken into account. One of the possible tools for purposes of priority setting is the assessment of societal costs of diseases and injuries.

Cost assessment gives an impression of the diagnostic groups which in an economic perspective put a high burden on society. This is important policy information in addition to available data on morbidity and mortality in the population.

The production of reliable estimates of the costs of diseases and injuries, however, is rather difficult. From the area of health economics several methods have been emerging.[5-7]

This area of science has taught us that "cost-of-illness"-estimates have to be interpreted with care. The results of specific studies are highly dependent on the elements that are taken into account and on the methods that have been used.[8,9] A major issue in the design of a cost-of-illness-study is whether or not restrict the scope of the study to the *direct costs* (costs of health care and other expenses) or to extend this to include the *indirect costs* (costs of production losses to society).

In the area of injury control attention has hitherto mainly focused on the calculation of direct medical costs,[10-13] although some studies have also included estimates of the indirect costs.[14,15]

There is an ongoing debate among health economists about the appropriate methodology for estimating the magnitude of the indirect costs.[9] The indirect costs represent the economic impact of injuries beyond the health care sector, resulting from absence from work, disability and death. They on average represent over 50% of the total disease costs or total costs saved by health care interventions.[16] This means that novel information on these costs due to economic production losses could be very important to policy makers in the area of injury control.

Within the framework of surveillance activities undertaken to support health policy, we have assessed the direct medical costs and indirect costs of injuries in the Netherlands, making use of recent advances in health economics.[17]

The Netherlands is a small industrialized country in Western Europe. Demographic information at the time of our cost assessment shows a population size of almost 15 million persons.

One quarter of the Dutch population is younger than 20 years, while 13% may be classified as elderly (65 years and over). As in other industrialized countries, the proportion of young people is shrinking, while the share of elderly people is rising.

The Netherlands has a rather high population density, with more than 400 persons per square kilometre of land area. It has an economically active population of about 4 million males and 2 million females. As in other industrialized countries, almost two-thirds of the work force is active in the service sector. At the time of our cost assessment, the unemployment rate was 11% of the labour force in spite of a high mean level of education attainment among persons aged 20-64 years.

Our study addressed the following questions:

- What are the direct and indirect costs of injuries in the Netherlands, and how do they compare to the costs of other major diseases?

- What are the direct and indirect costs of specific subcategories of injuries in the Netherlands, and how do they compare to each other?

2.2.2 DATA AND METHODS

Our study on injury costs used a further refinement of the classification of a comprehensive cost-of-illness-study which divided the total Dutch health care budget among 48 diagnostic groups.[18] The diagnostic groups of this comprehensive study were derived from the ninth revision of the International Classification of Diseases and included the following injury categories: "traffic accidents", "non-traffic accidents" (including all accidental injuries outside the traffic system with the exception of complications of medical treatments) and "other injuries" (including medical complications, self-inflicted injuries and assault).

For the purpose of our study we further subdivided both categories of accidental injuries. Traffic accidents were specified according to the mode of transport of the injury victim: passenger car occupant, cyclist, moped rider, pedestrian, other modes of transport.

The heterogeneous category of "non-traffic accidents" was broken down into the following three subclasses: occupational accidents, domestic accidents and sports accidents.

The category of "other injuries" was not further subdivided because of a lack of adequate data enabling costs to be allocated to specific subcategories. Data on the complete category of "other injuries" will nevertheless be presented in order to give a comprehensive picture of injury costs in the Netherlands.

Direct costs

The direct costs as estimated in our study are restricted to the costs of injuries which are incurred within the health care sector. In this way an impression is gained of the proportion of the Dutch health care budget needed for the medical care of injuries and specified subcategories.

Additional direct costs, such as property damage, are not included.

Adequate data are hardly available and previous studies in the Netherlands, which included these costs, have therefore produced highly variable results.[19]

For the estimation of direct medical costs the so-called "Top Down approach" has been used.[18] This method divides the total costs of each health care sector (hospital care, nursing home care, general practitioner care, physiotherapy, domestic help, aids and appliances, ambulance transport and other medical care) according to diagnosis, age and sex. The total costs of each sector in health care are annually published by the Dutch government.[20] These total costs can be subdivided by diagnosis, age and sex with the help of health care registration data[21], and information derived from population surveys on medical consumption as a consequence of injuries.[22]

Health care registration data allowed us to subdivide the costs of hospital care, nursing home care and domestic help by diagnosis, age and sex. Population survey data made it possible to subdivide the costs of general practitioners, physiotherapy and aids and appliances by diagnosis, age and sex.

Adequate data on injuries were lacking for one important health care sector (namely that of ambulance transport), preventing us from making a subdivision according to diagnosis, age and sex. Therefore the costs of ambulance transport are not included in this study.

The "Top Down approach" in principle fits the purposes of our study. A direct comparison of the health care costs of injuries with the health care costs of other diseases can be made. The validity of the method, as in other approaches of cost assessment, depends highly on the quality of the available data. In our study hospital registration data (1988) and population survey data (1987) provided detailed information at the end of the eighties.

Table 2.2.1 provides a summary of the data which were used to divide the total costs of injuries in different health care sectors by injury category, age and sex. This table also gives an impression of the data underlying the calculations of indirect costs, which will be explained in the next section.

Table 2.2.1 shows that for all relevant parameters in our cost calculations data were available on the situation in 1987 or 1988 (with the exception of the value of household production losses where data from 1990 had to be applied).

The data were derived from statistics that were published by several national institutions between 1988 and 1992. An important part of the information came from the Central Bureau of Statistics (CBS) which annually publishes the results from national registries and population surveys from different areas, including health care.

Amongst them are data from the National Medical Registry (LMR) which annually collects very detailed information from the hospital sector. Another part of the information came from the Consumer Safety Institute (SCV) which is a national centre on injury surveillance in the Netherlands.

Most data for the calculations of indirect costs, could also be derived from the Central Bureau of Statistics (CBS). Data on long-term work disability, however, were gained from the Mutual Medical Service (GMD).

At the time of our study this organization was responsible for all medical and administrative procedures applying to patients not returning to their jobs as a consequence of a disease or an injury.

Data on household production losses were obtained from the Dutch Department of Social Affairs and Employment, which has a specific Technical Service on Earnings (LTD).

Table 2.2.1

Overview of data used for estimates of direct medical costs and indirect costs in the Netherlands.

Cost element	Data	Source
Direct medical costs		
- Hospital care	National Registry 1988	CBS / LMR 1990
- Nursing home care	National Registry 1988	CBS / LMR 1990
- Domestic help	National Registry 1988	CBS / LMR 1990
- General practitioners	Population Survey 1987	SCV 1988
- Physiotherapy	Population Survey 1987	SCV 1988
- Aids and appliances	Population Survey 1987	SCV 1988
- Ambulance transport	Not available	
Indirect costs		
- Absence paid labour	National Registry 1987	CBS 1988a
- Absence non-paid labour	Population Survey 1987/1988	CBS 1992
- Long-term work disability	National Registry 1988	GMD 1988
- Mortality	National Registry 1988	CBS 1989
- Value production loss due to fatal injuries	Lifetime earnings per person by age and sex in 1988	
- Value market production loss due to non-fatal injuries	Average earning per worker by age and sex in 1988	CBS 1988b
- Value household production loss due to non-fatal injuries	Average earning of corresponding occupations by age and sex in 1990	LTD 1992

Indirect costs

Indirect costs refer to the lost production capacity of individuals as a consequence of diseases and injuries. It may include the lost output of employed persons, the lost non-market production and the future or potential loss of production. Indirect costs do *not* include a valuation of life or non-fatal injury.[23] They do *not* refer to "human costs" such as the expression in monetary terms of losses of life expectancy or physical and mental sufferings of the victims and their relatives. Estimates of indirect costs solely describe the production losses for society from an economic perspective.

In our study, the indirect costs of injuries have been estimated with the help of two alternative approaches. First of all, we used the "Human Capital Approach". This method has a long tradition, and was previously applied in studies into the costs of injuries.[14,15] This approach estimates losses of economic production as a consequence of disease or injury at a specific age, by taking into consideration the total potential productive value of employed persons from that age until the age of retirement. Moreover, the potential non-market productive value from that age until the mean age of death is taken into account. The Human Capital Approach ignores the fact that, within production processes, in the end everybody can be replaced. During short-term absenteeism, work may be taken over by other employees or may be postponed. During long-term absences, work can be taken over by unemployed persons or by a reallocation of employees over jobs.

In an attempt to estimate the "actual" production losses to society instead of the "potential" production losses measured by the Human Capital Approach, health economists have recently developed the Friction Cost Method.[17] Our study uses this method next to the Human Capital Approach to produce estimates of the indirect costs of injuries.

The Friction Cost Method is based on the fact that a worker who becomes the victim of premature death or disability will be replaced in the economic process after a so-called "friction period". The length of this period and the resulting indirect costs depend on the situation on the labour market. The Friction Cost Method confines production losses to this friction period (2,5 months in the Netherlands in 1988), which is usually much shorter than the period from premature death or disability up to the age of retirement or the mean age of death.

In both the Human Capital Approach and the Friction Cost Method the following sources of production losses have been taken into account: premature death, short-term absenteeism, and long-term work disability (which in the Netherlands is defined as work disability after the decision is made that the patient cannot return to his job; in only a small minority of cases this decision is made within the friction period). To calculate indirect costs we used national registration data on mortality,[24] long-term work disability[25] and short term absenteeism.[26]

We valued the production loss of paid labour by using the gross average earnings per worker, broken down by age and sex and taking into account the proportion of full-time and part-time labour in the population.[27] In calculating the non-market productive value we used the market alternative approach, assuming the value of household production to be equal to the costs of hiring personnel to do the housework.[28] The average number of days of household production lost per person due to diseases or injuries was derived from a Time Use Survey in the Dutch population.[29] Future earnings per person, based on average earnings and labour force participation rates by age and sex plus imputed household values were discounted at 5% per year.

We calculated the direct medical costs and the indirect costs of injuries and other diseases in millions of Dutch guilders. These were subsequently translated into millions of U.S. Dollars based on the exchange rate between the two currencies of 1988 as provided by the Organization of Economic Cooperation and Development (OECD).

2.2.3 RESULTS

Direct medical costs

Table 2.2.2 shows the direct medical costs of injuries in comparison to other diseases within various sectors of health care. The total direct medical costs of injuries amount to 952 million U.S. Dollars a year, or almost 5% of the complete health care budget in the Netherlands.

The direct medical costs of injuries are equal to those of cancer and about half of the costs of cardiovascular diseases. As in other diseases, medical costs are mainly incurred within the hospital sector. Other important sources of direct medical costs of injuries are nursing home care and physiotherapy.

Table 2.2.2

Direct medical costs of injuries in comparison to other diseases by health care sector (The Netherlands 1988; amounts in millions of U.S. Dollars; percentage shares between parentheses)

	All diseases	Injuries	Cardiovascular diseases	Cancer	Locomotor diseases	Psychiatric diseases
All medical costs	20.075 (1.00)	952 (0.05)	1.746 (0.09)	915 (0.05)	1.397 (0.07)	4.413 (0.22)
General practitioners	906 (1.00)	40 (0.04)	77 (0.08)	17 (0.02)	55 (0.06)	28 (0.03)
Physiotherapy	530 (1.00)	63 (0.11)	4 (0.01)	1 (0.00)	376 (0.71)	11 (0.02)
Hospital care	7.033 (1.00)	641 (0.09)	825 (0.12)	795 (0.11)	685 (0.10)	322 (0.05)
Mental health care	3.046 (1.00)	- -	- -	- -	- -	3.046 (1.00)
Nursing home care	1.974 (1.00)	86 (0.04)	427 (0.22)	46 (0.02)	183 (0.09)	767 (0.39)
Other medical costs	6.586 (1.00)	122 (0.02)	413 (0.06)	56 (0.01)	98 (0.02)	239 (0.04)

Table 2.2.3 offers an impression of the direct medical costs for specific subcategories of injuries for males and females respectively. Injuries to females, mainly caused by domestic accidents, are responsible for almost two-thirds of the direct medical costs. Domestic accidents take the largest bite by far, causing more than 500 million U.S. Dollars out of the total medical costs of injuries. Injuries to cyclists form another striking subcategory and in the Netherlands cause more than twice the costs of injuries to passenger car occupants (in both males and females).

Sports injuries appear to be an important subcategory too, with medical costs which are much higher than, for example, the costs of occupational injuries or injuries to passenger car occupants.

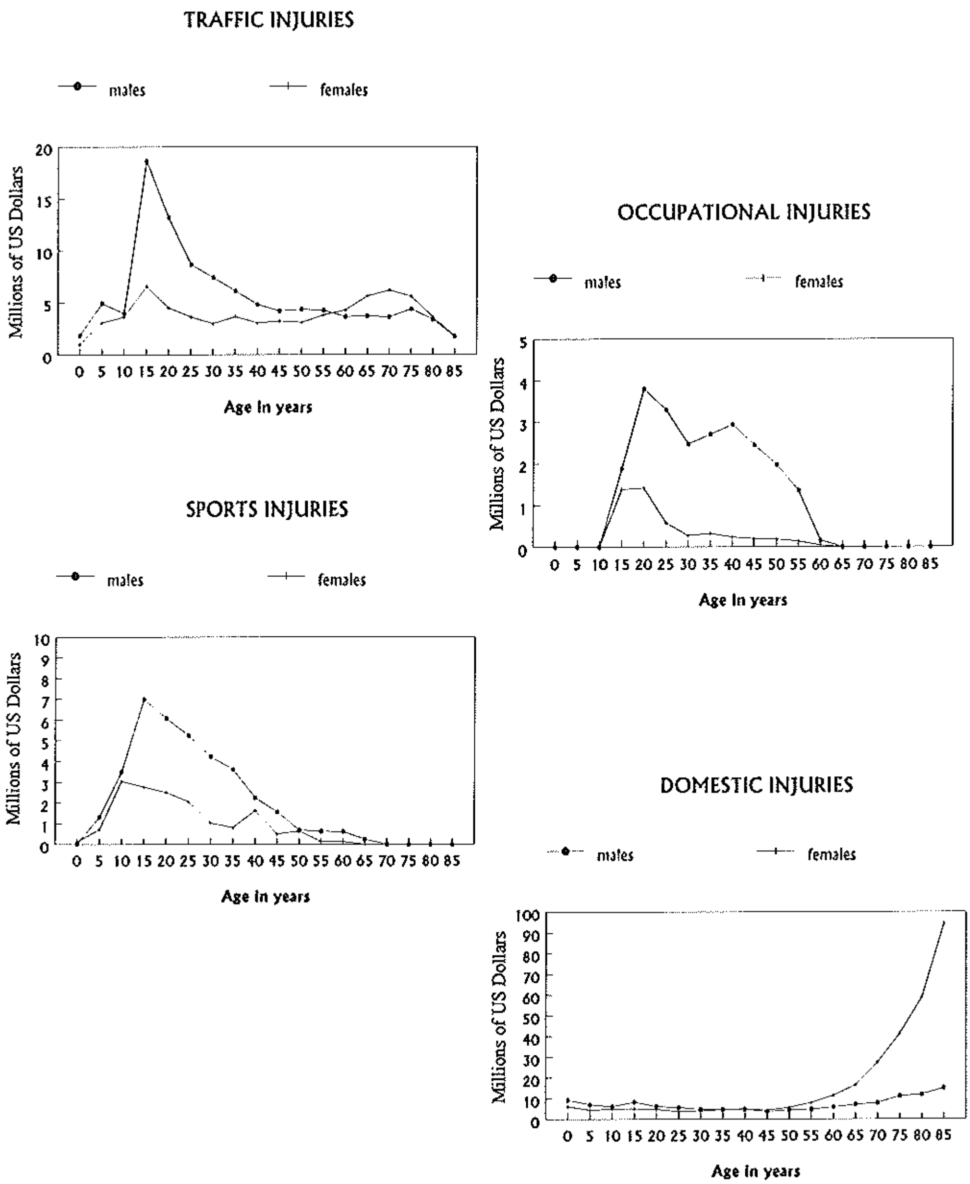
Table 2.2.3

Direct medical costs by injury category and gender (The Netherlands 1988; amounts in millions of U.S.Dollars).

	Males	Females	Both sexes
Traffic accidents (total)	106	76	182
- Passenger car occupants	17	12	29
- Cyclists	34	29	63
- Moped riders	17	5	22
- Pedestrians	13	13	26
- Other traffic	25	17	42
Non-traffic accidents (total)	199	387	586
- Occupational injuries	24	5	29
- Sports injuries	38	16	54
- Domestic injuries	137	366	503
Other injuries (total) (Intentional injuries/medical complications)	75	109	184
Total medical costs of injuries	380	572	952

Figure 2.2.1

Direct medical costs of traffic injuries, occupational injuries, sports injuries and domestic injuries by age and sex (The Netherlands 1988; amounts in millions of U.S.Dollars).



From figure 2.2.1 it can be observed at what ages the direct medical costs of injuries and its main subcategories are generated. Among males, the highest medical costs of injuries are incurred in early adulthood (15-25 years of age). This is based on the combined effect of the high costs of traffic injuries (figure 2.2.1a), occupational injuries (figure 2.2.1b) and sports injuries (figure 2.2.1c) at this age. By contrast, among women, the importance of accidents among the elderly becomes immediately clear. The high level of direct medical costs of injuries in females is based to a large extent on the very high costs of domestic accidents suffered by elderly women (figure 2.2.1d).

Indirect costs

The indirect costs of injuries have been calculated according to both the Human Capital Approach (HC) and the Friction Cost Method (FC). Table 2.2.4 shows the indirect costs of injuries in comparison to other diseases computed according to both methods. Injuries appear to be the source of 8% of the total indirect costs of diseases in the Netherlands. For males this percentage share reaches 9-10%, whereas in women it is somewhat lower (5%). Regardless of the method used, injuries rank third behind locomotor diseases and psychiatric disorders. Most strikingly, injuries have a higher proportion in the total indirect costs of diseases than cardiovascular diseases and cancer. This difference becomes even more clear when the Friction Cost Method is applied.

Table 2.2.4

Indirect costs of injuries by gender according to the Human Capital Approach (HC) and Friction Cost Method (FC) (The Netherlands 1988; percentage shares of total indirect costs).

	Injuries	Cardiovascular diseases	Cancer	Locomotor diseases	Psychiatric diseases
Human Capital Approach (HC)					
- Both sexes	0.08	0.08	0.04	0.27	0.23
- Males	0.10	0.09	0.04	0.29	0.21
- Females	0.05	0.03	0.04	0.23	0.30
Friction Cost Method (FC)					
- Both sexes	0.08	0.02	0.01	0.17	0.10
- Males	0.09	0.02	0.01	0.20	0.10
- Females	0.05	0.01	0.01	0.11	0.11

Table 2.2.5 provides information on the indirect costs of specific subcategories of injuries in males and females respectively. Contrary to the findings for the direct medical costs, it would appear that the indirect costs are mainly generated by males. The potential production losses calculated by the Human Capital Approach of males (2851 million) and females (442 million) add up to 3293 million U.S. Dollars. The actual production losses calculated by the Friction Cost Method are lower for both males (579 million) and females (123 million), adding up to 702 million U.S. Dollars.

Table 2.2.5

Indirect costs of injuries by source of economic production loss and gender according to the Human Capital Approach (HC) and Friction Cost Method (FC) (The Netherlands 1988; amounts in millions of U.S. Dollars).

	Human Capital Approach (HC)		Friction Cost Method (FC)	
	Males	Females	Males	Females
Short-term absenteeism	876	185	566	121
- Traffic accidents	157	53	85	30
- Occupational accidents	359	27	240	19
- Sports accidents	162	32	113	23
- Domestic accidents	136	54	93	37
- Other injuries	53	19	35	12
Long-term work disability[1]	1.169	179	2	0
Mortality	825	78	11	2
- Traffic accidents	337	28	4	1
- Non-traffic accidents[2]	114	5	2	0
- Other injuries	374	45	5	1
Total indirect costs of injuries	2.851	442	579	123

1) No information available for any specification by injury category.

2) No information available for a breakdown into occupational accidents, sports accidents and domestic accidents.

According to both methods, over 80% of the indirect costs are the consequence of injuries in males. This may be explained as follows. First of all, in the age category between 20 and 60 years the incidence of injuries of males is much higher than of females. Secondly, the labour force participation rate in the Netherlands is much higher for males than for females. For many injured women production losses are restricted to work in the household, which is valued rather low in comparison to most jobs in the market sector.

The relative proportion of the specific subcategories of injuries in the indirect costs is highly dependent on the method used. In the Human Capital Approach, traffic accidents are a major category. This is based on the high indirect costs as a consequence of traffic deaths, which often appear at younger ages. In the Friction Cost Method the indirect costs are almost entirely caused by short-term absenteeism. In this approach occupational accidents are the main cause of indirect costs, with sports injuries ranking second. This is due to the high frequency of these types of injuries among males participating in the labour force.

2.2.4 DISCUSSION

Our study has shown that injuries are an important source of medical costs (5% of the total health care budget) and economic production losses (8% of the indirect costs due to all diseases) in the Netherlands.

Almost two-thirds of the direct medical costs of injuries are the result of accidents among females, which are mainly domestic accidents among elderly women. Another main source of health care utilization are the sports injuries, causing almost twice the direct medical costs of either injuries to passenger car occupants or occupational injuries. Injuries to cyclists are a remarkable subcategory too, causing by far the highest direct medical costs of all subcategories of traffic injuries in the Netherlands.

The indirect costs of injuries are characterized by completely different patterns according to subcategory, age and sex. Contrary to the direct medical costs, more than 80% of the indirect costs are the result of injuries to males. This result remains the same independent of the method used.

In calculating the *potential* production losses for society (Human Capital Approach) traffic injuries are a major source of indirect costs, whereas occupational injuries are by far the largest subcategory when the *actual* production losses are computed (Friction Cost Method).

Estimates of both the direct medical costs and the indirect costs of injuries confirm that we are dealing with a major public health problem, which should be a priority area for research and policy. The above clearly demonstrates that cost assessment could be one of the tools in priority setting in public health policy and research. In interpreting the results of our study, however, one must be aware of some specific limitations, whereas in using this tool in general, methodological considerations have also to be taken into account.

A general comment, already made in the introduction, is the high dependency of the results of cost-of illness-studies on the elements that are taken into account and on the methods that have been used. The results from our study show the huge difference between taking the direct medical costs into consideration or considering the indirect costs. Moreover, the different approaches available for the estimation of indirect costs produce quite different rankings of injury subcategories. This should be kept in mind when using cost estimates for priority setting purposes.

In order to generate reliable cost estimates, the availability of adequate data on health care utilization, mortality, short-term absenteeism, and long-term work disability by diagnosis, age and sex is of primary importance. We used data from 1987/1988 in our study, which provided much detail on health care utilization due to diseases and injuries during that period. This enabled us to produce detailed estimates of the direct medical costs of injuries in 1987/1988. We had to use data from a few different years, which is very unlikely to have affected the main results of our study. The data on all but one of our parameters fell within a two-year period (1987/1988). The annual fluctuations of these parameters are probably too small to exert a significant influence on the calculations. More important is the fact that our cost estimates do not relate to the most recent situation in the Netherlands. Moreover, although we used the best data available, information on some important health care sectors (e.g. ambulance transport) was lacking. In interpreting the cost estimates of our study, these considerations on the available data must be taken into account.

Our calculations of the direct medical costs in the Netherlands probably slightly underestimate the present importance of injuries in comparison to other diseases. First of all, the incidence of injuries in the Netherlands displays a slight overall increase in recent years , largely due to rising numbers of domestic accidents among the elderly.[19] The importance of domestic accidents among the elderly as a cause of direct medical costs of injuries was demonstrated. Secondly, the costs of ambulance transport were not included in our study.

This sector occupies almost 1 % of the total health care budget in the Netherlands. Unpublished data from a local ambulance service have shown us that in all probability close to one quarter of the total ambulance costs should be assigned to injuries, which corresponds to 0.25% of the total direct medical costs.

Contrary to the costs of health care, the indirect costs have probably been slightly overestimated in our study, as the incidence of occupational injuries and sports injuries has fallen slightly in recent years.[19] It was shown that these are the subcategories with the highest actual production losses for society according to the Friction Cost Method.

In spite of the limitations described above, our study has produced results which are highly consistent with the results of other studies conducted on the direct medical costs of injuries, both in the Netherlands and abroad.[30-33] In estimating the indirect costs of injuries, our study has generated new information to add to existing knowledge in this area. The results from our study clearly demonstrate the value of new economic methods for assessing the production losses for society.

The application of the Friction Cost Method enforces the importance of injuries as a source of production losses in comparison to other diseases. In applying this method injuries belong to the three main causes of indirect costs (locomotor diseases, psychiatric diseases *and* injuries) and are far more important than cardiovascular diseases and cancer.

Moreover, the method sheds light on the economic impact of specific subcategories of injuries of seemingly minor importance when using traditional public health indicators (mortality and morbidity). A good example is the subcategory of occupational injuries. In the Netherlands, this is a minor cause of death, responsible for only a small proportion of the direct medical costs and a moderate proportion of the potential production losses calculated by the Human Capital Method. Occupational injuries, however, are by far the most important source of actual production losses for society within the category of injuries. The Friction Cost Method assigns a heavy weight to production losses due to short-term absenteeism, whereas in the Human Capital Approach injuries at young ages leading to death or long-term work disability are very important.

From an economic perspective, the Friction Cost Method seems to be the preferred approach in assessing the indirect costs, because this method takes the dynamics of the labour market into account. This yields better estimates of the economic production losses for society than traditional methods, such as the Human Capital Approach.

One must consider, however, that in estimating economic production losses, consequences of injuries with regard to "quality of life" (such as loss of healthy life expectancy and physical and mental sufferings) are not taken into account. For priority setting purposes, information on these "human costs" should in fact be available in addition to the information on "economic costs" as assessed in our study. Hence, research in this area should be stimulated. At present, adequate data on the quality of life of injury victims are hardly available. Moreover, the methodology should be further developed, although some interesting studies have already been performed.[34-36]

Returning to the results of our study we can conclude the following.

By estimating the health care costs, the potential economic production losses, and the actual economic production losses due to injuries in the Netherlands, it has been shown that this problem should be a major concern for both health policy makers and the medical profession. Several priority areas for further research and policy can be indicated. The assessment of direct medical costs confirms the importance of domestic accidents among the elderly and females in particular. It points to the problem of accidental fall and (hip) fractures[37-39] among the elderly, which can be seen as one of the important epidemics of western societies of today. Another priority area to be deducted from our study are the sports injuries, which appear to lead to both high direct medical costs and to high actual production losses for society.

A priority area which seems rather specific for the Dutch situation is the problem of injuries to cyclists. In the Netherlands, a country of cyclists, injury victims within this subcategory produce direct medical costs which are twice as high as the costs of injuries to passenger car occupants. Finally, from estimating the actual production losses for society, is has become clear that the prevention of occupational injuries should not be neglected.

REFERENCES

1. Ruwaard D, Kramers PGN, Berg Jeths A van den et al. Public Health Status and Forecasts: the health status of the Dutch population over the period 1950-2010. National Institute of Public Health and the Environment. The Hague; SDU Publishers: 1994.
2. Murray CJL, Lopez AD. Global and regional cause-of-death patterns in 1990. Bul WHO 1994; 72:447-480.
3. Murray CJL, Lopez AD: Quantifying disability: data, methods and results. Bul WHO 1994; 72:481-494.

4. van Beeck EF, Mackenbach JP, van Oortmarssen GJ et al. Scenarios for the future development of accident mortality in the Netherlands. Health Policy 1989;11:1-17.
5. Drummond MF. Studies in economic appraisal in health care. New York: Oxford University Press; 1986.
6. Robertson LS. Epidemiology and Economic Analyses. In: Robertson LS (ed). Injury Epidemiology. New York: Oxford University Press; 1992.
7. Koopmanschap MA, Rutten FFH, van Ineveld BM et al. The friction cost method for measuring indirect costs of disease. Journal of Health Economics 1995;14:171-189.
8. Drummond MF. Cost-of-illness studies: a major headache. PharmacoEconomics 1992;2:1-4.
9. van Roijen L, Koopmanschap MA, Rutten FFH et al. Indirect costs of disease: an international comparison. Health Policy 1995;33:15-29.
10. MacKenzie EJ, Shapiro S, Siegel JH. The economic impact of traumatic injuries. JAMA 1988;260:3290-3296.
11. Harlan LC, Harlan WR, Parsons PE. The economic impact of injuries: a major source of medical costs. Am J Public Health 1990;80:453-459.
12. Miller TR, Pindus NM, Douglass JB. Medically related motor vehicle injury costs by body region and severity. J Trauma 1993;34:270-275.
13. Miller TR, Lestina DC. Patterns in US medical expenditures and utilization for injury 1987. Am J Public Health 1996;86:89-93.
14. Hartunian NS, Smart CN, Thompson MS. The incidence and economic costs of cancer, motor vehicle injuries, coronary heart disease, and stroke: a comparative analysis. Am J Public Health 1980;70:1249-1260.
15. Max W, Rice DP, MacKenzie EJ. The lifetime cost of injury. Inquiry 1990;27:332-343.
16. Koopmanschap MA, Rutten FFH. Indirect costs in economic studies: confronting the confusion. PharmacoEconomics 1993;4:446-454.
17. Koopmanschap MA, van Ineveld BM. Towards a new approach for estimating indirect costs of diseases. Social Science and Medicine 1992;34:1005-1010.
18. Koopmanschap MA, van Roijen L, Bonneux L et al. Cost of diseases in international perspective. Eur J Public Health 1994;4:258-264.
19. van Beeck EF, Mackenbach JP. Ongevallen Signaleringsrapport 1995. (Accidents Monitoring Report 1995, in Dutch). Zoetermeer: Foundation on Future Health Scenarios;1996.
20. Koopmanschap MA, van Roijen L, Bonneux L. Kosten van Ziekten in Nederland. (Costs of diseases and injuries in the Netherlands, in Dutch). Rotterdam: Department of Public Health, Erasmus University; 1991.
21. CBS/LMR. Hospital diagnosis statistics 1988. The Hague: SDU-publishers; 1990.
22. SCV. Ongevallen in Nederland. (Accidents in the Netherlands, a survey of home and leisure, road traffic, sports and occupational accidents in the period August 1986-August 1987, in Dutch). Amsterdam: Consumer Safety Institute; 1988.
23. Ball DJ, Soby BA. Valuing consumer safety. Int J Consumer Safety 1995;2:117-132.

24. CBS. Deaths by Cause of Death by Age and Sex 1988. The Hague: Central Bureau of Statistics; 1989.
25. GMD. Incidence of Work Disabilities by Diagnosis, Age and Sex for 1988. Amsterdam: Mutual Medical Service; 1990.
26. CBS. Diagnosis Statistics on Absence from Work 1987. The Hague: Central Bureau of Statistics; 1988a.
27. CBS. Social Economic Month Statistics 1988. The Hague: Central Bureau of Statistics; 1988b.
28. LTD. Development of Terms of Employment in 1990 in the Market Sector. The Hague: Department of Social Affairs and Employment; 1992.
29. CBS. Time Use Survey for 1987 and 1988. The Hague: Central Bureau of Statistics; 1992.
30. den Toom PJ, Schuurman MIM. Een model voor de berekening van de kosten van privé-ongevallen. (A model for the calculation of the costs of home and leisure injuries, in Dutch). Amsterdam: Consumer Safety Insitute; 1988.
31. Muizelaar J. Kosten van de verkeersonveiligheid in Nederland, 1993. (The Costs of Road Traffic Accidents in the Netherlands 1993, in Dutch). Leidschendam: Foundation on Road Safety Research; 1996.
32. Rice DP, Hogson TA, Kopstein AN. The economic cost of illness: a replication and update. Health Care Financing Review 1985;7:61-80.
33. Lindgren B. The economic impact of illness. In: Abshagen U, Munnich FE (eds). Cost of Illness and Benefit of Drug Treatment. Munich: Springer Verlag; 1990.
34. Jurkovich G, Mock C, MacKenzie EJ et al. The Sickness Impact Profile as a tool to evaluate functional outcome in trauma patients. J Trauma 1995;39:625-631.
35. MacKenzie EJ, Burgess AR, McAndrew MP et al. Patient oriented functional outcome after unilateral lower extremity fracture. J Orthop Trauma 1993;7:393-401.
36. Siösteen BA, Lundqvist C, Blomstrand C. The quality of life of three functional spinal cord injury subgroups in a Swedish Community. Paraplegia 1990;28:476-488.
37. Barret-Connor E. The economic and human costs of osteoporotic fracture. Am J Med 1995;98:3-8.
38. Cox MA, Bowie R, Horne G. Hip fractures: an increasing health care cost. J Orthop Trauma 1993;7:52-57.
39. Hollingworth W, Todd CJ, Parker MJ. The costs of treating hip fractures in the twenty-first century. J Public Health Med 1995;17:269-276.

3 Determinants of injury mortality

3.1

ABSTRACT

In the Netherlands, a country with one of the lowest levels of traffic accident mortality in the world, large regional mortality differences can be observed. An analysis was performed to determine the role of regional differences in traffic mobility (kilometres travelled/person-years), injury risk (injured people/kilometre travelled) and case fatality (traffic deaths/injured people). Subsequently, possible determinants of regional differences in traffic accident mortality and its constituent parts were investigated. Both the influence of sociodemographic factors and of factors likely to be more directly related to traffic deaths (road infrastructure, medical care) were studied.

Regional differences in traffic accident mortality in the Netherlands are attributable to regional differences in traffic mobility to only a very limited extent. Far more important are regional differences in case fatality.

Of the sociodemographic factors that were used in the analysis, per capita income appears to be the strongest predictor of regional mortality differences. A higher income level is associated with lower mortality levels.

Of the factors more directly related to traffic deaths, traffic density and the availability of advanced trauma care (neurosurgery and computerized tomography (CT-scan)) in the region are the most important predictors of regional mortality differences. Both variables show an inverse relationship with case fatality. In all probability, a higher traffic density is accompanied by less severe injuries. The availability of advanced trauma care could be important in early diagnosis and treatment of head injuries.

The results of this study, based on existing data sources, must be interpreted with care. Some potential sources of bias (omitted variables, regional differences in accident reporting) are discussed.

3.1

Determinants of traffic accident mortality in the Netherlands: a geographical analysis

3.1.1 INTRODUCTION

In the industrialized world, traffic accident mortality has been decreasing since the early 1970s. Especially in the decade between 1970 and 1980 a spectacular fall could be observed in many countries.[1] One of the most impressive reductions during this period was achieved in the Netherlands, where the number of fatal injuries dropped by almost 40%,[2] leading to a mortality level which is one of the lowest in the world. Despite this development, however, traffic accident mortality still forms an important public health problem in this country,[3] which, in addition, appears to be characterized by large regional differences.[4]

In other countries, regional differences in traffic accident mortality have been shown to reflect the influence of socio-demographic variables (i.e. an inverse relationship between the regional mortality level on the one hand, and per capita income and degree of urbanization on the other).[5,6,7,8] This reported influence of socio-demographic variables can probably be attributed to regional differences in more specific characteristics describing road behaviour, road vehicles, infrastructural road safety measures and/or the accessibility and quality of medical care. It has been hypothesized that regional differences in road behaviour (e.g. less seatbelt use in lower income areas) and road vehicles (e.g. vehicles predating safety regulations used more commonly in lower income areas) could underly the inverse relationship between traffic accident mortality and income.[9]

The observed inverse relationship between traffic accident mortality and urbanization might at least in part be explained by a higher level of infrastructural road safety measures and a better accessibility and quality of medical care in the more urbanized parts of a country.

About possible specific determinants of traffic accident mortality, a certain amount of information is available, too. Alcohol consumption, vehicle speed, and vehicle age have all been found to be positively associated with motor vehicle death rates.[10] Poor road design is known to contribute to the likelihood and severity of crashes.[11] And some authors have reported a negative association between the accessibility and quality of medical care and the level of traffic accident mortality.[12,13]

It is not known which of the aforementioned or other factors account for the observed regional mortality differences in the Netherlands. The analysis to be reported here used three levels of explanation. As a first step, regional mortality differences were specified according to the model presented in figure 3.1.1.

In this model the regional level of traffic accident mortality (the number of traffic deaths per 100.000 person-years) is the product of the traffic mobility (the number of kilometres travelled per 100.000 person-years) and the fatal injury rate (the number of traffic deaths per kilometre travelled). The fatal injury rate, in turn, is the product of the injury risk (the number of injured persons per kilometre travelled) and the case fatality (the number of traffic deaths per injured person). The model was originally developed to analyze time series data on traffic accident mortality. Changes over time are known to be influenced by many different factors.[14] The spectacular fall of traffic accident mortality in the Netherlands between 1970 and 1980 referred to above, for example, resulted from a deceleration of the growth rate of traffic mobility combined with decreases in both injury risk and case fatality.[15]

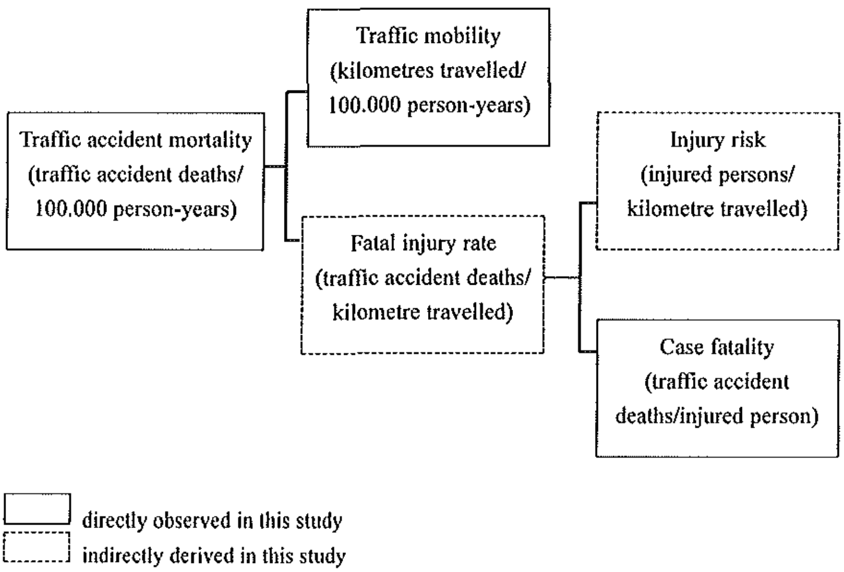
The second part of the analysis investigated the influence of socio-demographic factors. The third part tried to establish the effects of more specific determinants of regional mortality differences.

The analysis addressed the following questions:

- To what extent can regional differences in traffic accident mortality be explained by regional differences in traffic mobility, injury risk and case fatality respectively?
- Which relations can be observed between traffic accident mortality and its constituent parts on the one hand, and socio-demographic factors on the other?
- What relationships can be observed between traffic accident mortality and its constituent parts on the one hand, and variables describing road behaviour, road vehicles, infrastructural road safety measures and medical care on the other?

Figure 3.1.1

An analytical model of regional differences in traffic accident mortality.



This figure shows a modification of the model presented in figure 1.2.1 adapted to the standards of international traffic safety research. It includes the 'fatal injury rate' as one of the central concepts of this area.

3.1.2 DATA AND METHODS

Data were collected on all the parameters distinguished in the model represented in the introduction.

Information about *traffic accident mortality* was obtained in the following way. For the timeperiod 1980-1984 numbers of traffic deaths, by age (0, 1-4, 5-14, ...85-94, 95+), sex and region of residence were available from a computerfile supplied by the Dutch Central Bureau of Statistics (CBS). During this period, 9339 deaths from traffic accidents were registered in the Dutch cause-of-death-statistics. These casualties could be subdivided by mode of transport using the four-digit codes given in the 9th revision of the International Classification of Diseases (ICD).

In this way the following categories were selected: motor vehicle occupants, cyclists, pedestrians and other and unspecified modes of transport. Because in the Netherlands, as in other countries, a large proportion of traffic accident deaths fail to be specified by mode of transport in the cause-of-death statistics,[16] we also paid attention to the category "all modes of transport combined". Forty so-called COROP-regions were distinguished in the analysis, representing geographical areas serviced by one or more larger cities. Regional Standardized Mortality Ratios (SMRs) were calculated using national age- and sex-specific mortality rates of the period 1980-1984 as the standard. Population numbers by age, sex and region were available from the Dutch population register.

Data on *traffic mobility* were also obtained from the CBS, which performs annual mobility surveys in the Netherlands. We had access to information about the average annual numbers of kilometres travelled, broken down according to the mode of transport and region of residence. These figures were derived from the results of the mobility surveys over a three-year-period (1982-1984; n=51.317). The regional mobility data were standardized for age and sex using national age- and sex-specific mobility rates for the period 1982-1984 as the standard.

Subsequently, an index of the regional *fatal injury* rate was calculated by dividing the standardized regional mortality data by the standardized regional mobility data. In order to calculate the last two parameters of our model, we used a different computer file obtained from the CBS. This file contained data on the numbers of injured persons and traffic deaths by age, sex, mode of transport and region of accident occurrence, for the period 1980-1984. These data are reported by the police to the so-called Road Accident Records Office.[17]

This file enabled us to obtain an index of the *case fatality* by dividing traffic deaths by injured persons. Standardization by age and sex was reached using national age- and sex-specific case fatality data of the period 1980-1984 as the standard. Unlike the first three parameters of the model, which were calculated by region of residence, this data set offered information about the case fatality according to the region in which the accident occured. It can be assumed, however, that case fatality rates by region of residence, and by region of accident occurrence are quite similar. Most accidents occur either in the region in which the victim resides or in an adjacent region. In the Netherlands, a pattern of clusters of adjacent regions with similar case fatality levels can be observed.

Finally, an index of the *injury risk* was calculated. Because the fatal injury rate is the product of the injury risk and the case fatality, this could be done by dividing the fatal injury rate by the case fatality. In calculating this rate, case fatality by region of residence was assumed to be similar to case fatality by region of accident occurrence.

With the help of the parameters calculated above, a detailed description of the geography of traffic accidents in the Netherlands could be given.

Subsequently, using the technique of multiple linear regression,[18] two separate analyses were performed, in order to find determinants of the observed regional differences.

In the first analysis, the influence of socio-demographic factors was investigated. Four socio-demographic variables were selected for entering into a multiple linear regression model.

Per capita income and degree of urbanization were chosen because of the results of analyses of regional differences in other countries, as was mentioned in the introduction. In addition, the unemployment rate was selected because of its reported influence on traffic accidents (i.e. a high level of unemployment leads to a reduction of accident frequency and severity, because of a reduction of the proportion of young adults within the driving population[19-21]). The proportion of Roman Catholics in the population was added, as this religious dimension appeared to be an important - probably lifestyle-related - determinant of regional mortality differences in the Netherlands for many other causes of death.[22,23] The correlations between the selected variables were all below 0.60. All sociodemographic data were obtained from the CBS.

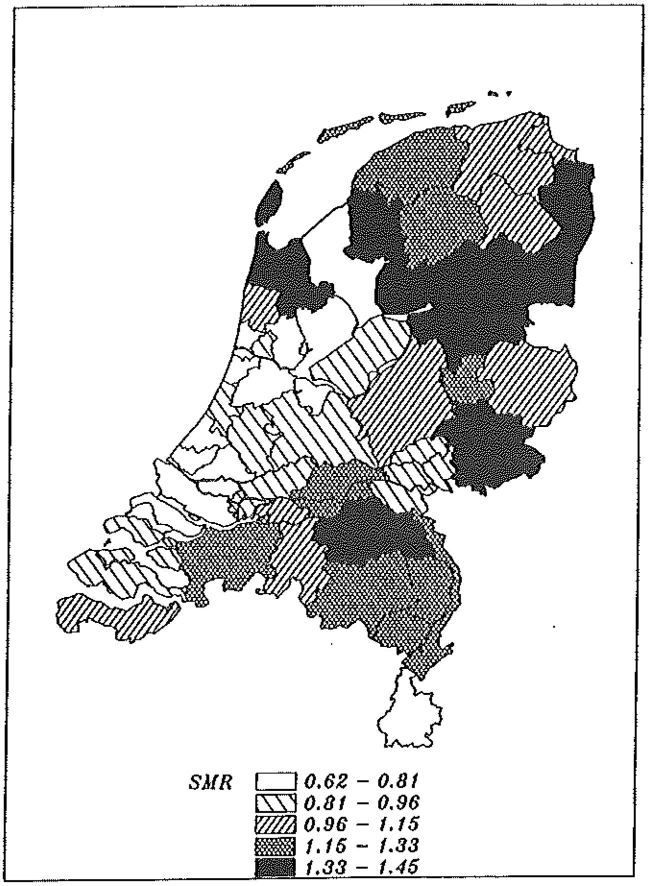
The second analysis attempted to establish the influence of a number of regional characteristics assumed to affect injury frequency, injury severity and/or injury outcome. Five variables on which data were available were selected for entering into a multiple linear regression model. Traffic density was chosen because of its hypothetical influence on both injury frequency (the chances of collision are expected to rise with increasing traffic density) and injury severity (injury severity is expected to fall with increasing traffic density, because of decreasing travel speeds). The availability of highways and of cycling tracks were used as indicators of the level of infrastructural road safety measures. The mean length of ambulance transport was used as an indicator of the accessibility of medical care. Finally, a crude measure of the quality of medical care was derived by using the availability of a hospital with computerized tomography and neurosurgery, which are essential elements in the diagnosis and treatment of head injuries (65% of all traffic deaths).[24-26]

The variables used in the first analysis can offer information about possible economic and cultural 'backgrounds' of regional mortality differences. These economic and cultural backgrounds probably exert their influence by means of more specific 'intermediate factors', such as the variables used in our second analysis.

We studied the appropriateness of the linear regression models by estimating a number of alternative equations which contained quadratic terms for each of the variables in addition to the original linear terms. Less than 5% of these alternative equations led to a better fit, and nowhere were the substantial results affected. We have therefore only reported the results of the linear regression models.

Figure 3.1.2

Regional differences in traffic accident mortality in the Netherlands, 1980-1984, both sexes, all ages, all modes of transport combined.



3.1.3 RESULTS

In the Netherlands, traffic accident mortality is low in the western regions of the country, whereas regions with high Standardized Mortality Ratios are found in the North, East and South-east (figure 3.1.2).

If traffic accidents are broken down according to mode of transport, statistically significant regional differences for all categories of road users, except pedestrians are seen (table 3.1.1).

Table 3.1.1

Regional differences in traffic accident mortality in the Netherlands, 1980-1984, by mode of transport.

Mode of transport	ICD-codes, 9th revision	Number of traffic accident deaths,1980-1984	Extreme values of Standardized Mortality Ratios	Chi-square	Product-moment correlation with all modes, combined
All modes, combined	E 800-848	9339	0.62-1.45	522**	(1.00)
Motor vehicle occupants	E 810.0-825.0, E 810.1-825.1	1848	0.34-2.22	293**	0.89
Cyclists	E 800.3-807.3, E 810.6-825.6, E 826.1-829.1	1732	0.23-1.72	252**	0.67
Pedestrians	E 800.2-807.2, E 810.7-825.7, E 826.0-829.0	1373	0.30-1.38	51	0.10
Other and unspecified modes	Other codes in the range E 800-848	4386	0.65-1.66	279**	0.87

Significance level: * $p < 0.05$ ** $p < 0.01$

Source: cause-of-death register CBS

The correlations between mortality by mode of transport with traffic accident mortality as a whole are high, again with the exception of pedestrians. This shows that for most categories of road users a pattern of regional differences can be observed which is quite similar to the pattern illustrated in figure 3.1.2.

The observed pattern of regional differences in traffic accident mortality cannot be fully explained by regional differences in traffic mobility (table 3.1.2).

Table 3.1.2

Average values of traffic mobility, fatal injury rate, injury risk and case fatality by traffic accident mortality quintile.

Mode of transport	Traffic accident mortality		Average values (as a proportion of the national level)			
	Quintile borders	Average value of SMR in quintile	Traffic mobility	Fatal injury rate	Injury risk	Case fatality
All modes, combined	0.62-0.80	0.71	0.86	0.83	1.39	0.59
	0.81-0.95	0.88	1.08	0.82	0.90	0.88
	0.96-1.15	1.04	1.01	1.03	0.96	1.07
	1.16-1.33	1.22	1.04	1.19	0.90	1.32
	1.34-1.45	1.39	1.01	1.38	0.85	1.62
- product-moment-correlation with SMR		(+1.00)	+0.32	+0.76	-0.46	+0.87
Motor vehicle Occupants	0.34-0.67	0.56	0.82	0.68	1.13	0.60
	0.67-0.92	0.81	1.08	0.75	0.70	1.07
	0.93-1.29	1.07	0.97	1.10	1.07	1.03
	1.29-1.51	1.40	1.16	1.20	0.93	1.29
	1.52-2.22	1.73	1.08	1.60	1.16	1.38
- product-moment-correlation with SMR		(+1.00)	+0.41	+0.88	+0.18	+0.74
Cyclists	0.23-0.73	0.54	0.75	0.72	1.58	0.46
	0.73-0.88	0.82	0.95	0.86	0.93	0.92
	0.89-1.02	0.96	1.10	0.87	0.78	1.12
	1.03-1.38	1.19	1.02	1.17	0.80	1.46
	1.39-1.72	1.57	1.13	1.39	0.89	1.56
- product-moment-correlation with SMR		(+1.00)	+0.62	+0.89	-0.31	+0.60

Regional differences in the fatal injury rate contribute strongly to the observed mortality differences for all modes of transport combined, and for motor vehicle occupants. In the case of cyclists, some of the variation in mortality seems to be caused by regional differences in the use of the bicycle. Even for this mode of transport, however, differences in the fatal injury rate are of more importance. The pattern of regional differences in fatal injury rate does not reflect regional differences in injury risk. Instead, differences in case fatality appear to be the underlying factor. It can even be observed that those regions with the most favourable fatal injury rates have (by far) the highest injury risks.

In examining the influence of socio-demographic factors on mortality, mobility and fatal injury rate, some interesting results were found (table 3.1.3).

Per capita income, charted by region, appears to be a strong predictor of regional traffic accident mortality differences, in the sense that a higher income level goes hand in hand with lower Standardized Mortality Ratios. The unemployment rate has been observed to exert the same influence. As was reported in the literature, a higher level of unemployment is associated with a lower level of mortality.

The proportion of Roman Catholics in the population, in contrast, shows a positive association with the level of traffic accident mortality, which is highly significant in the case of cyclists.

In the case of all modes of transport combined and of motor vehicle occupants separately, the relationships between the mentioned sociodemographic factors and regional mortality differences largely reflect associations between these factors and the fatal injury rates. For all modes of transport combined, for example, a highly significant negative association is found between per capita income and the fatal injury rate index. In quantitative terms, the effect is as follows: an increase in per capita income level of one standard deviation (1.4 x 1000 guilders) above the mean (12.2 x 1000 guilders) leads to a decrease in the fatal injury rate index of (0.123 x 1.4 =) 0.17.

In the case of cyclists, on the other hand, an important part of the influence of sociodemographic factors on mortality should be attributed to differences in the use of bicycles.

Table 3.1.3

Multiple regression of traffic accident mortality, traffic mobility and fatal injury rate on sociodemographic characteristics.

	Regression coefficients								
	Traffic accident mortality			Traffic mobility			Fatal injury rate		
	All	Motor vehicle	Bicycle	All	Motor vehicle	Bicycle	All	Motor vehicle	Bicycle
Per capita income (1000 gld)	-0.141**	-0.238**	-0.138**	+0.006	-0.004	-0.093**	-0.123**	-0.193**	-0.057*
Unemployment rate (% persons unemployed)	-0.037**	-0.058**	-0.059**	-0.008	-0.011	-0.033**	+0.024	-0.039*	-0.028*
Degree of urbanization (% persons living in large cities)[1]	-0.002	-0.003	+0.000	-0.003*	-0.005*	+0.001	+0.000	+0.000	+0.000
Proportion of Roman Catholics (% persons with Roman Catholic religion)	+0.002*	+0.004*	+0.008**	+0.000	+0.000	+0.002	+0.001	+0.003*	+0.004**
R^2	0.71	0.64	0.52	0.17	0.24	0.30	0.46	0.53	0.37

Significance level (two-sided-test) * $p < 0.05$ ** $p < 0.01$

1) calculated in the following way:

a (% living in cities with more than 100.000 inhabitants)+
0.5b (% living in cities with more than 50.000 inhabitants)

Our second model investigated the influence of characteristics describing road infrastructure and medical care (table 3.1.4). Unfortunately, regional data about road behaviour (e.g. alcohol consumption, seatbelt use) or road vehicles (e.g. vehicle age) were not available. Different sets of independent vairables were related to different outcome measures (e.g. medical care variables were not related to injury risks), or road user categories (e.g. availability of cycling tracks was not used in the case of motor vehicle occupants).

None of the selected variables appears to be a strong predictor of regional differences in the fatal injury rates of all road user categories. For some variables this might be explained by opposite effects on injury risk and case fatality respectively. Traffic density, for example, shows positive associations with the injury risk, where an inverse relationship with the case fatality is found. In spite of these opposite effects, however, a significant negative association is found between traffic density and the fatal injury rate of motor vehicle occupants.

Regional differences in injury risk appear to a certain extent to be attributable to the number of motor vehicles on the roads too. Interestingly, this variable seems to offer a better explanation for regional differences in injury risk among cyclists than for those among motor vehicle occupants.

The amount of motor vehicles on the roads also contributes to regional differences in case fatality. The observed inverse relationship indicates a shift towards less severe injuries in regions with higher traffic density. In addition, case fatality appears to be lower in regions with advanced trauma care, as measured by the availability of a hospital with neurosurgery and CT scan in the region. This association only reaches statistical significance for all modes of transport combined.

Table 3.1.4

Multiple regression of fatal injury rate, injury risk and case fatality on characteristics of traffic and/or medical care

	Regression coefficients								
	Fatal injury rate			Injury risk			Case fatality		
	All	Motor vehicle	Bicycle	All	Motor vehicle	Bicycle	All	Motor vehicle	Bicycle
Traffic density (motor vehicles/km road length)	-0.004	-0.006*	+0.003	+0.011**	+0.004	+0.009**	-0.014**	-0.010**	-0.011**
Availability of highways (km highway/100 km road length)	-0.011	-0.025		-0.062*	-0.041		+0.048	+0.018	
Availability of cycling tracks (km cycling track/ 100 km road length)	+0.007		-0.004	-0.032		-0.017	+0.028		-0.018
Mean length of ambulance transport (km ambulance transport/ transported victim)	+0.000	-0.007	-0.008				+0.004	+0.003	+0.002
Availability of hospital with computerized tomography and neuro-surgery (yes or no)	-0.044	-0.142	-0.065				-0.151*	-0.135	-0.166
R^2	0.28	0.39	0.17	0.50	0.08	0.52	0.82	0.71	0.56

Significance level (two-sided-test) * $p < 0.05$ ** $p < 0.01$

If no regression coefficient is mentioned, the variable has not been included in the model (see text for explanation)

3.1.4 DISCUSSION

In the Netherlands, a country with one of the lowest levels of traffic accident mortality in the world, remarkable regional differences can be observed. The western part of the country is characterized by low Standardized Mortality Ratios, whereas unfavourable figures are encountered in the North, East and South-east. The observed pattern of variation is not only the result of regional differences in traffic mobility, but also reflects important regional differences in the number of traffic deaths per kilometre travelled. These regional differences in so-called fatal injury rates are based on regional differences in case fatality. The findings contradict prior expectations based on the analysis of time series data on traffic accident deaths, showing injury risks to be a major determinant of changes over time.[3,15]

As in all studies based on existing data sources, the reported findings must be interpreted with care, because of possible registration artefacts. This study used several data sources, one of these being based on police records. Underreporting is a well-known phenomenon in traffic accident statistics based on police records (where the numbers of injured persons are concerned).[27] Obviously, there may be regional differences in registration threshold, in the sense that fewer injuries are reported by the police in the more rural parts of a country. If so, this would lead to an artificial decrease in injury risk combined with an increase in case fatality in these areas.

In order to find the determinants of the observed geographic varations two separate analyses were performed. The first analysis investigated the influence of socio-demographic factors. Three of the factors that were selected appear to contribute to the explanation of the observed regional differences in fatal injury rates: income, unemployment and religion. Contrary to reported findings no influence of urbanization was found. Of the selected factors income is the most prominent, showing a significant negative association with the fatal injury rates of all road user categories. As mentioned in the introduction, this association could be based on differences in road behaviour and/or road vehicles (e.g. less seat-belt use and/or older motor vehicles in lower income areas). Contrary to motor vehicle occupants, the inverse relationship between income and accident mortality for cyclists must in part be contributed to a significant negative association between income and traffic mobility.

The second analysis investigated the influence of factors more directly related to traffic accident mortality. None of the selected variables appears to be a strong predictor of the observed regional differences in fatal injury rates.

These characteristics offer a better explanation for regional differences in case fatality. It is interesting to observe that, first of all, case fatality appears to be influenced by traffic density. Case fatality is high in regions with a low traffic density, which could be the result of a higher proportion of severe injuries in these regions. This, in turn, could reflect higher travel speeds during the accidents happening here. A second important factor is the availability of a hospital with computerized tomography and neurosurgery. Case fatality is lower in regions where there is access to this facility. This result is in line with a clinical evaluation of the survival of accident victims performed in the Netherlands.[28] It could indicate that in regions without access to institutions equipped with all the facilities needed, diagnosis and treatment is delayed because patients are transported to the nearest hospital, followed by the hazards of interhospital transport.[29]

Like all studies using statistical models, the analyses reported have their limitations. An important possible source of bias is the so-called omitted-variable problem, which arises when a statistical study does not account for all explanatory variables. Our second model included no variables describing road behaviour and road vehicles. As far as case fatality is concerned, for example, these might be important explanatory variables (e.g. seat-belt use, travel speed, vehicle size, vehicle age), producing their effect through differences in injury severity. For this reason the results obtained must be interpreted with care. Whether case fatality is lower due to the availability of neurosurgery and CT scan, for example, can only be established after controlling for differences in injury severity. We tried to do so, by entering traffic characteristics which are assumed to affect injury severity into the multiple linear regression model.

Because important characteristics of road behaviour and road vehicles might be omitted, however, it would be wise to repeat the analysis after the introduction of injury severity scores[30,31] in traffic accident reporting systems in the Netherlands, as has already been recommended.[3]

In spite of their limitations the analyses that were performed have yielded valuable information. Socio-economic differences as measured by per capita income level were found to be strongly associated with regional differences in traffic accident mortality. For motor vehicle occupants and cyclists respectively, this association appeared to be based on somewhat different mechanisms. It seems worthwile to clarify the reasons behind this association, e.g. as part of the Dutch National Research Programme into socio-economic health differences.

The study offers some support for the hypothesis that the lack of necessary medical facilities in an area increases the risk of dying because of a traffic accident. This means that if plans to improve trauma care in the whole country[3] are implemented, special attention should be paid to high risk areas.

REFERENCES

1. European Conference of Ministers of Transport. Statistical report on road accident trends in 1984. Paris: OECD; 1986, p21.
2. Lamm R, Chouieri EM, Kloeckner JH. Accidents in the U.S. and Europe: 1970-1980. Accid Anal Prev 1985;17:429-38.
3. Lapré RM, Mackenbach JP (Eds.). Accidents in the year 2000; accident and traumatology scenarios 1985-2000. Dordrecht: Kluwer; 1989, p24.
4. Mackenbach JP. Mortality and medical care: studies of mortality by cause of death in the Netherlands and other European countries (thesis). Rotterdam: Erasmus University; 1988, p.64.
5. Baker SP, Whitfield RA, O'Neill B. County mapping of injury mortality. J Trauma 1988; 28:741-45.
6. Anonymus. Regional variation in mortality from motor vehicle accidents. Metrop Stat Bull 1987;68:27-31.
7. Balarajan R, McDowall ME. Regional socio-economic differences in mortality among men in Great Britain today. Public Health 1988; 102:33-43.
8. Bentham G. Proximity to hospital and mortality from motor vehicle traffic accidents. Soc Sci Med 1986;23:1021-26.
9. Baker SP, Whitfield RA, O'Neill B. Geographic variation in mortality from motor vehicle crashes. N Engl J Med 1987;316:1384-87.
10. Zlatoper TJ. Models explaining motor vehicle death rates in the United States. Accid Anal Prev 1989;21:125-154.
11. Wright PH, Robertson LS. Priorities for roadside hazard modification. Traffic Engin 1976; 8:24-30.
12. Brodsky H, Hakkert AS. Highway fatal accidents and accessibility of emergency medical services. Soc Sci Med 1983;17:731-40.
13. Simpson D, North B, Gilligan J et al. Neurological injuries in South Australia: the influence of distance on management and outcome. Aust N Z J Surg 1984;54:29-35.
14. Smeed RJ. Variation in the pattern of accident rates in different countries and their causes. Traffic Engin Control 1968;11:364-71.
15. van Beeck EF, Mackenbach JP, van Oortmarssen GJ, Barendregt JJM, Habbema JDF, van der Maas PJ. Scenarios for the future development of accident mortality in The Netherlands. Health Policy 1989;11:1-17.
16. Hutchinson TP. Reliability of motor vehicle fatality statistics: an international perspective. Can J Publ Hlth 1985; 76:413-14.

17. Maas MW, Harris S. Police recording of road accident inpatients. Accid Anal Prev 1984; 16:167-84.
18. Kleinbaum DG, Kupper LL, Morgenstern H. Epidemiologic research principles and quantitative methods. London: Lifetime Learning Publications; 1982.
19. Mercer GW. Influences on passenger vehicle casualty accident frequency and severity: unemployment, driver gender, driver age, drinking driving and restraint device use. Accid Anal Prev 1987; 19:231-36.
20. Partyka SC. Simple models of fatality trends using employment and population data. Accid Anal Prev 1984;16:211-222.
21. Muller A. Business recession, alcohol consumption, drinking and driving laws: impact on Oklahoma motor vehicle fatalities and fatal crashes. Am J Public Health 1989;79:1366-70.
22. Mackenbach JP, Kunst AE, Looman CWN, Habbema JDF, van der Maas PJ. Gezondheidszorg en vermijdbare sterfte: voorbeelden van het gebruik van sterftegegevens voor nationaal en regionaal gezondheidszorgbeleid. (Health care and avoidable mortality: examples of the use of mortality figures for national and regional health policy, in Dutch) Rotterdam: Erasmus University, 1988.
23. Mackenbach JP, Kunst AE, Looman CWN. Cultural and economic determinants of regional mortality patterns in the Netherlands. J Epidemiol Comm Health 1991;45:231-237.
24. Rose J, Valtonen S, Jennet B. Avoidable factors contributing to death after head injury. Br Med J 1977;2:615-18.
25. Jones JJ, Jeffreys RV. Relative risk of alternative admission policies for patients with head injuries. Lancet 1981; 2:850-52.
26. Jennet BJ, Briggs M, Clarke P et al. Guidelines for initial management after head injury in adults. Br Med J 1984;288:983-85.
27. Hutchinson TP. Road accident statistics. Adelaide: Rumsby Scientific Publishing;1987, p77.
28. Draaisma JMTh. Evaluation of trauma care: with emphasis on hospital trauma care (thesis). Meppel: Krips Repro; 1987, p156.
29. Gentleman D, Jennet BJ. Hazards of interhospital transfer of comatose head-injured patients. Lancet 1981;2:853-55.
30. Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-96.
31. Champion HR, Sacco WJ, Carnazzo AJ et al. Trauma score. Crit Care Med 1981;9:672-76.

3.2

ABSTRACT

Objective: To examine the association between prosperity and traffic accident mortality in the industrialized world in a long-term perspective.

Methods: We calculated traffic accident mortality, traffic mobility and the fatal injury rate of 21 industrialized countries in the years from 1962 until 1990. We used mortality and population data of the World Health Organization (WHO), and figures on motor vehicle ownership of the International Road Federation (IRF). We examined cross-sectional and longitudinal associations of these traffic-related variables with the prosperity level per country, derived from data of the Organization for Economic Cooperation and Development (OECD).

Results: We found a reversal from a positive relation between prosperity and traffic accident mortality in the 1960s to a negative association currently. At a certain level of prosperity, the growth rate of traffic mobility decelerates and the fatal injury rate continues to decline at a similar rate as in earlier phases.

Conclusion: In a long-term perspective, the relation between prosperity and traffic accident mortality appears to be non-linear: economic development first leads to a growing number of traffic-related deaths, but later becomes protective.

3.2

Economic development and traffic accident mortality in the industrialized world, 1962-1990

3.2.1 INTRODUCTION

The national economy is known to be an important background factor in relation to the health of individuals and populations.[1-2] Economic development can be considered one of the main determinants of changing patterns of mortality and disease.[3,4] Rising living standards of the population have probably made a major contribution to the transition away from a cause-of-death-pattern dominated by infectious diseases with very high mortality to a pattern dominated by chronic diseases with lower mortality.[5] Over the last century, this "epidemiologic transition"[6,7] has been completed in all countries of the industrialized world, whereas in developing countries it is still under way.[8] General evidence shows that economic growth is associated with improvements in the health of populations. On a global scale, growing prosperity and increasing life expectancy are strongly related.[9]

In spite of this relationship, however, economic growth sometimes leads to a deterioriation of the population health status. In the industrialized world, for example, the post-world war II period (1945-1970) was not only characterized by the most favourable economic development of this century, but also by a rapid increase of cardiovascular diseases and traffic accidents.[10-12] Because of these developments the concept of "diseases of affluence" or "western diseases" was introduced,[13-14] pointing to growing prosperity as a possible determinant of specific disorders.

More recent findings have shown the weaknesses of this concept. In the "western" world the rising trends in cardiovascular mortality of the 50s and 60s were later reversed in spite of growing prosperity.[15] In the former socialist economies, on the other hand, cardiovascular mortality surged upwards in the face of the poor economic development in this part of the world.[16]

3.2

Currently, at the regional level within industrialized countries, a strong inverse relationship exists between prosperity and cardiovascular mortality. This is based on a differential onset of decline in cardiovascular mortality in affluent and less affluent regions respectively.[17-18] Trend reversals first took place in the more affluent regions, once again demonstrating the association of growing prosperity with improved health.

Traffic accidents are another important cause of mortality and morbidity, where the concept of "diseases of affluence" needs further clarification. In order to examine this relation, several cross-sectional studies have been performed so far. These have produced results which were more or less contradictory. It has been found that on the scale of the whole world (including low-income, middle-income and high-income countries), the gross national product per capita shows a positive correlation with traffic accident mortality (the number of trafic deaths per 100.000 person-years). Adjustment for variation in traffic mobility (the number of motor vehicles per 100.000 person-years), however, leads to a strong negative association.[19] On a global scale, therefore, prosperity appears to be a determinant of traffic accident mortality with the level of traffic mobility as a major intermediate factor.

A positive association between prosperity and traffic accident mortality has also been found in cross-sectional studies focusing on low-income and middle-income countries.[20] But studies dealing with high-income countries have produced different findings. Ecological analyses into regional variation in traffic accident mortality in high-income countries have consistently shown the highest mortality levels in the least affluent regions.[21-24] This negative association between prosperity and traffic accident mortality does not disappear after adjustment for variation in traffic mobility.[24] In high-income countries, therefore, prosperity seems to be protective against traffic accident mortality intermediated by other factors than traffic mobility. Variation in the fatal injury rates (the number of traffic deaths per motor vehicle) appears to be more important in these countries.

So, no uniform relation between prosperity and traffic accident mortality can be derived from cross-sectional studies. Perhaps the key to understanding can be found in a long-term perspective. The cross-sectional associations between economic factors and traffic accident mortality in high-income countries may well have changed over time due to non-linear longitudinal relationships between these variables. This would resemble developments in the field of cardiovascular diseases mentioned above.

To date hardly any attention has been paid to the role of traffic accidents in the epidemiologic transition and its backgrounds. Therefore, it could be worthwile to examine the relationship between prosperity and traffic accident mortality and its underlying parameters (i.e. traffic mobility and fatal injury rate) in a long-term perspective, using data from several decades. This would allow cross-sectional associations to be studied at several points of economic development, and examination of the longitudinal relationships between the relevant variables.

This article reports the results of an analysis of developments in traffic accident mortality within the framework of the epidemiologic transition theory. In order to examine the relation between prosperity and traffic accident mortality in a long-term perspective we analyzed developments in 21 industrialized countries between 1962 and 1990. Our study addressed the following questions:

- How have the cross-sectional associations between prosperity and traffic accident mortality been developing since the early 1960s, and what has been the influence of the traffic mobility and the fatal injury rate on those associations?

- What is the general shape of the longitudinal relationship between prosperity and traffic accident mortality , and how can it be explained in terms of developments in the traffic mobility and the fatal injury rate?

3.2.2 DATA AND METHODS

Our analysis used data from the member countries of the Organization for Economic Cooperation and Development (OECD). In these countries , often referred to as the "industrialized world"[19] or the "established market economies"[25], the epidemiologic transition has been completed. This provides the opportunity to study changes during the final part of this transition, which started after the second world war.

We were able to collect data from the 21 OECD-countries with a population size of more than one million inhabitants for each year from 1962 until 1990. This allowed us to analyze developments over a time-span of 29 years.

Data were acquired on traffic accident mortality (the number of traffic deaths per 100.000 person-years), traffic mobility (the number of motor vehicles per 100.000 person-years), and the fatal injury rate (the number of traffic deaths per motor vehicle in the population).

In addition, data on the prosperity levels of the OECD-countries were available.

The figures on traffic accident mortality were obtained in the following way. The number of traffic deaths by age (0-4, 5-14,....,65-74, 75+), sex, year (1962-1990) and country of residence was available from a computer file on mortality from external causes-of-death supplied by the World Health Organization (WHO). From this file the following codes were selected: AE 138-139 according to the ICD 6, 7 and 8; E470-474, E479 according to ICD-9. Both the crude and standardized traffic accident mortality figures (the numbers of traffic deaths per 100.000 person-years) could be calculated for individual countries and separate years. We used population numbers broken down according to age, sex, year, and country of residence, which were also supplied by the WHO. The figures were adjusted for differences in the composition of the population (by country and time period) with the help of direct standardization, using the European Standard Population of 1976.[26] For the analyses reported in this paper only the standardized traffic accident mortality figures were used.

The data on traffic mobility were extracted from annual publications of the International Road Federation.[27] These publications included information on several measures of traffic mobility: the number of passenger kilometres, the number of vehicle kilometres, and the number of motor vehicles in the population. Only with the help of the latter measure (motor vehicle ownership) were we able to construct complete time series in all 21 OECD-countries from 1962 onwards. The data on the other measures were incomplete, in particular for the earlier years of the period under review. Therefore, in the analyses reported in this paper we used motor vehicle ownership as a proxy of traffic mobility.

Subsequently, an index of the fatal injury rate by year and country was calculated by dividing the standardized mortality figures by the corresponding data on motor vehicle ownership.

In order to study the association between traffic accident mortality and prosperity we used economic data supplied by the OECD. As an indicator of the prosperity levels of countries we calculated Purchasing Power of Currencies (PPC)-estimates of the gross domestic product per capita. This is a measure of the national income per capita, adjusted for differences in purchasing power between national currencies and between time periods. It was specifically developed in order to make cross-national comparisons of prosperity differences, expressed in "international" dollars.[28]

We calculated the levels of traffic accident mortality, traffic mobility, fatal injury rate and prosperity of the 21 individual OECD-countries for each year between 1962 and 1990.

For each separate year the cross-sectional relation between the level of prosperity on the one hand, and the traffic accident mortality, traffic mobility and fatal injury rate on the other, was modeled using linear regression analysis.

The variables included were right-skewed and were thus log-transformed before insertion into the models.

In addition, the longitudinal relationship between prosperity and the three traffic-related variables was examined by fitting regression models using the pooled data from all 21 countries during the whole period of 29 years. It turned out that cubic regression models produced an adequate fit, significantly better than lower order models. Interaction terms between prosperity and country were examined, indicating the existence of a sizeable variation among countries. Therefore, the longitudinal relationship between prosperity and the three traffic-related variables was also established for 21 countries separately. This helped to identify specific countries with developments deviating from the general picture.

3.2.3 RESULTS

Table 3.2.1 shows that the cross-sectional relation between prosperity and traffic accident mortality has changed in the industrialized world since the early 1960s . There is currently a negative association, which originated in the second half of the 1970s. At that time a reversal from a positive association occurred. During the whole period under review, there was a positive association between prosperity and traffic mobility. Nevertheless, this relation has somewhat changed, in the sense that the slope of the regression line has levelled off. The association between prosperity and the fatal injury rate, on the other hand, was negative and has remained more or less stable over time.

The combined effect of prosperity on traffic mobility on the one hand, and on fatal injury rate on the other, underlies the observed relation between prosperity and traffic accident mortality. The reversal of this relation was a direct consequence of the observed change in the association between prosperity and mobility.

Table 3.2.1

Slope parameters from linear regressions of traffic accident mortality, traffic mobility and fatal injury rate on the level of prosperity in cross-sectional data of separate years between 1962 and 1990

Log PPC on	1962	1965	1970	1975	1980	1985	1990
Log Traffic Accident Mortality (deaths/1000 person-years)	+0.58**	+0.56**	+0.45*	-0.05	-0.05	-0.30	-0.53*
Log Traffic Mobility (motor vehicles/1000 person-years)	+2.16**	+2.06**	+1.94**	+1.63**	+1.28**	+1.11**	+1.06**
Log Fatal Injury Rate (deaths/motor vehicle)	-1.50**	-1.50**	-1.49	-1.68**	-1.32**	-1.42**	-1.59**

* $p < 0.05$ Log Traffic Accident Mortality = Log (Traffic Mobility x Fatal Injury Rate)
** $p < 0.01$ = Log Traffic Mobility + Log Fatal Injury Rate

The reversal and its underlying developments is also made visible in figure 3.2.1.

It is shown that in the 1960s, when prosperity levels were still relatively low in all industrialized countries, a positive cross-sectional association existed between prosperity and traffic accident mortality (figure 3.2.1a). This was based on large rises in motor vehicle ownership with increasing wealth at a low range of prosperity levels (figure 3.2.1b).

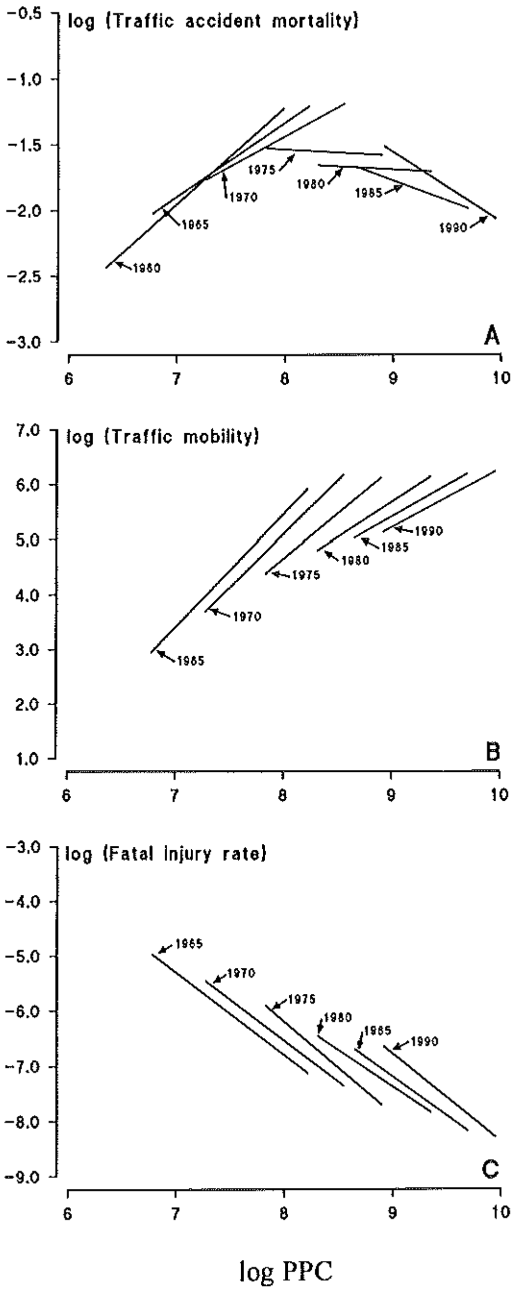
In the 1990s, at high prosperity levels in all industrialized countries, an inverse cross-sectional association is found (figure 3.2.1a). Compared to the 1960s the growth of motor vehicle ownership with increasing wealth has become small at this high range of prosperity levels (figure 3.2.1b).

It is illustrated that the strength of the inverse association between prosperity and the fatal injury rate remained more or less unchanged at all levels of prosperity (figure 3.2.1c).

The cross-sectional association between prosperity and traffic accident mortality in the industrialized world has changed between the 1960s and the 1990s, because of slower increases in motor vehicle ownership (combined with unchanged declines in the fatal injury rates) at higher levels of prosperity.

Figure 3.2.1

The relationship between traffic accident mortality, traffic mobility and the fatal injury rate with the level of prosperity in 21 OECD-countries, 1962-1990



The longitudinal relation between prosperity and the three traffic-related variables is shown in figure 3.2.2. It appears that, when the pooled data of all 21 countries during the whole period of 29 years are used, a cubic regression model can be fitted that includes a reversal at a prosperity level of around 3000 international dollars per capita (i.e. LogPPC 8). At this level prosperity becomes protective against traffic accident mortality. It can be derived from figure 3b and 3c that this is due to the fact that the mobility growth levels off, while the fatal injury rate continues to decline at the same rate as in an earlier phase of economic development.

The models shown in figure 3.2.2 were applicable to the majority of countries included in this analysis. The relation between prosperity and trafic accident mortality showed a reversal in 19 of the 21 countries. In 16 of these countries the reversal took place at a prosperity level between 2400 and 3600 international dollars per capita (i.e. LogPPC 7.8-8.2). Nevertheless, when testing interaction a significant influence of the country involved was found.

We identified several countries with trends deviating from the general picture. There are two countries in which no reversal was found, despite having achieved prosperity levels in excess of 3000 international dollars per capita: Greece and Spain. Figures 3.2.3 and 3.2.4 show that the backgound mechanisms of this observation are completely different for those two countries.

In Greece, the growth rate of motor vehicle ownership has not levelled off so far. In this country (i.e. the poorest country of the analysis) growing prosperity is still resulting in an increasing number of traffic deaths because of rapidly growing numbers of motor vehicles in the population (figure 3.2.3). In Spain, on the other hand, the decline of the fatal injury rate levelled off after reaching the point where prosperity is expected to become protective (figure 3.2.4).

There are a few countries for which the models have indicated that the decline in traffic accident mortality ceased after surpassing a prosperity level of around 14000 international dollars per capita (i.e LogPPC 9.5). An important example among these countries is the USA.

This country has always been a "forerunner" with respect to developments in traffic and traffic-related mortality. Figure 3.2.5 shows that the less favourable developments are the result of the following trend: the decline in the fatal injury rate has gradually levelled off. Similar trends were also found in Japan (see figure 3.2.6), Denmark and Finland.

Figure 3.2.2

Cubic regression of traffic accident mortality, traffic mobility and the fatal injury rate on the level of prosperity (pooled data from 21 OECD-countries)

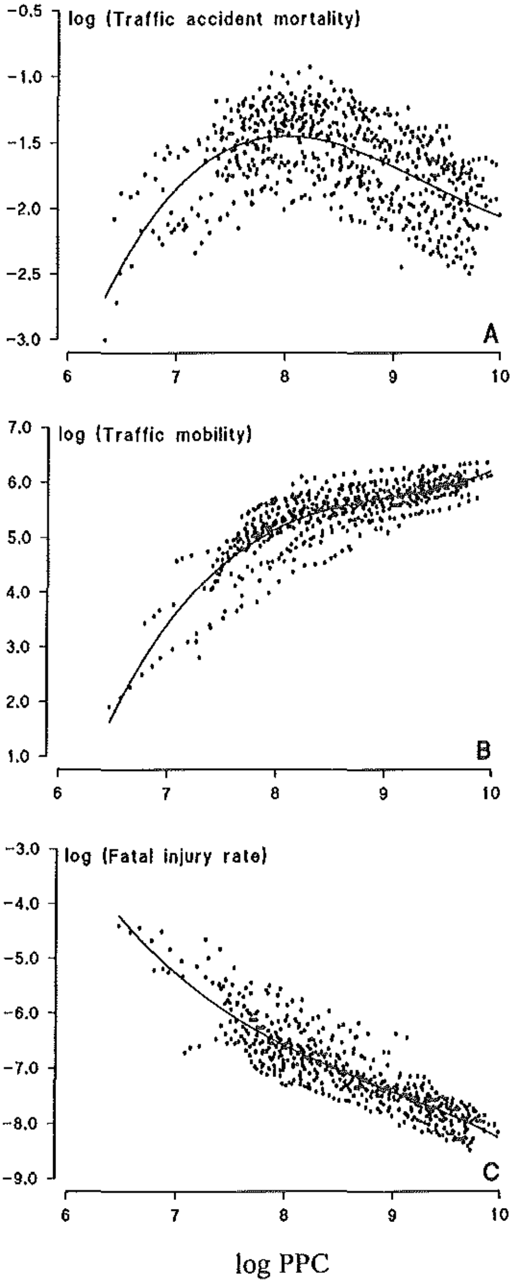


Figure 3.2.3

Cubic regression of traffic accident mortality, traffic mobility and the fatal injury rate on the level of prosperity in Greece

Figure 3.2.4

Cubic regression of traffic accident mortality, traffic mobility and the fatal injury rate on the level of prosperity in Spain

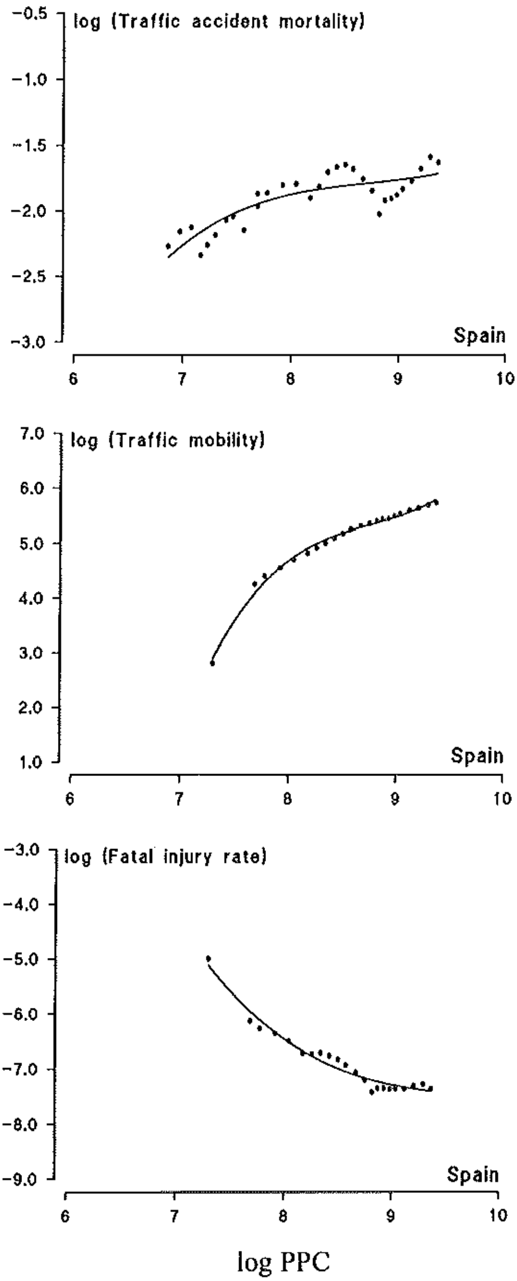


Figure 3.2.5

Cubic regression of traffic accident mortality, traffic mobility and the fatal injury rate on the level of prosperity in the USA

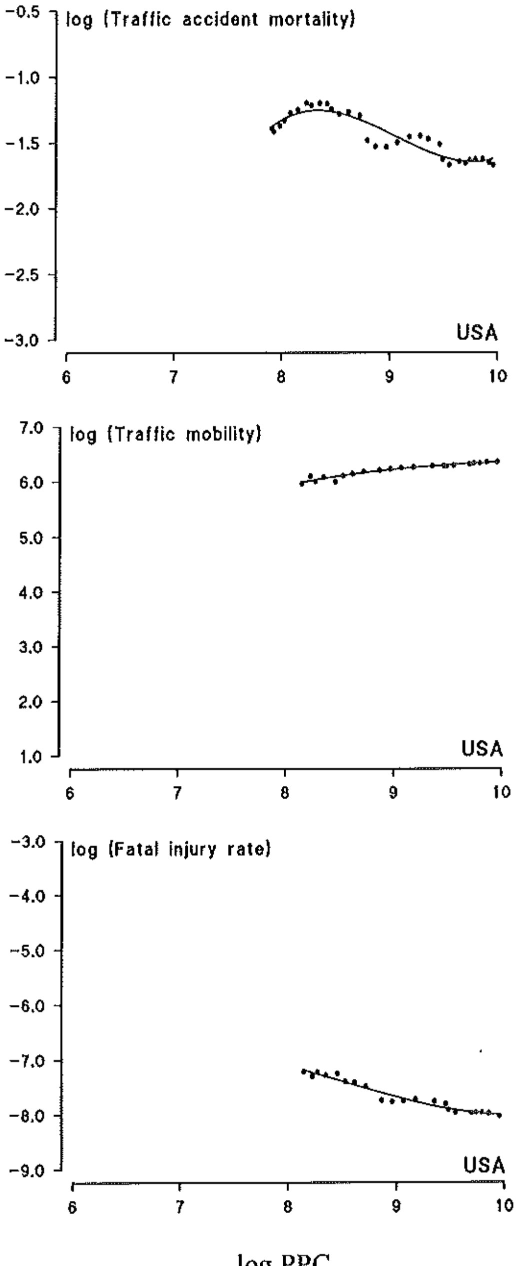
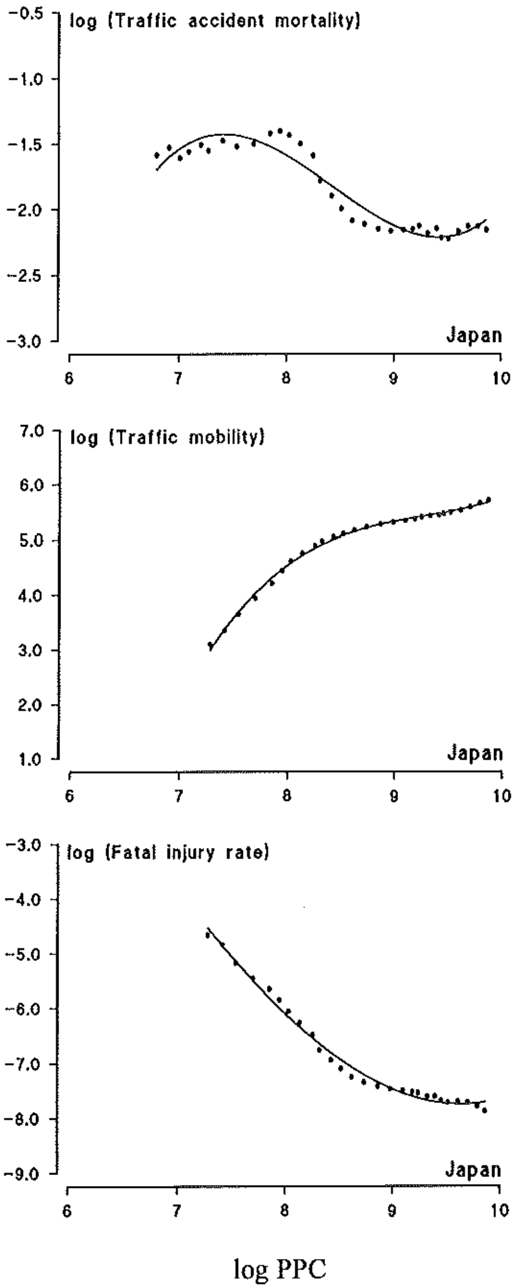


Figure 3.2.6

Cubic regression of traffic accident mortality, traffic mobility and the fatal injury rate on the level of prosperity in Japan



3.2.4 DISCUSSION

In the industrialized world, the cross-sectional relation between prosperity and traffic accident mortality has changed since the early 1960s. A positive relation has disappeared. We moreover found indications that it has been reversed into an inverse association currently. The observed changes were based on non-linear longitudinal relations. At lower prosperity levels, increasing wealth gave rise to rapidly growing numbers of motor vehicles in the population. This led to increasing numbers of traffic deaths. However, mobility growth has the tendency to level off after reaching a certain level of prosperity. At that point increasing prosperity becomes protective against traffic accident mortality. This is due to the phenomenon, that, at all prosperity levels, increasing wealth is acompanied by a declining number of traffic deaths per motor vehicle or "fatal injury rate". This could be an indirect effect of growing prosperity, which might facilitate several adaptations, including improvement of the traffic infrastructure and the medical care for injury victims. Adaptations stimulated by growing prosperity have in the literature been referred to as "assets for health", leading to general improvements of the population health.[9]

Our results indicate that prosperity is an important "autonomous" factor behind developments in traffic accident mortality. In a long-term perspective, it seems to have both positive and negative effects with respect to the number of traffic deaths in the population. It leads to mobility growth but could simultaneously stimulate adaptations. This shows that the concept of traffic accidents as a "disease of affluence" is too simple. The final effect results from the balance between positive and negative developments. Currently, in the industrialized world the balance appears to be weighed in favour of the positive effects, as mobility growth has levelled off. This balance, however, is not observed in every country. We identified a few countries where the balance has dipped in favour of the negative effects.

As in all studies based on existing data sources, our results must be interpreted with care. In the first place, possible registration bias caused by differences in coding of mortality between countries, and on changes in coding practices over the years, must be examined. Differences between countries are probably limited, because we restricted our study to a rather homogeneous set of countries: the industrialized world. Possible changes in coding practices over time could be assessed, because our file contained data on all external causes of mortality.

We found that the declines in traffic accident mortality since the 1970s were combined with declines in non-traffic accident mortality. We could not identify shifts from traffic accidents into non-traffic accidents. Our major finding, the trend reversal in mortality due to traffic accidents, is therefore highly unlikely to be the result of changing coding practices over time.

A second issue concerns the use of data on motor vehicle ownership as a proxy of traffic mobility. Data on passenger or vehicle miles would have been preferable, because they provide a better measure of exposure.[29] However, we were not able to extract a complete set of reliable data on these parameters for all countries since the early 1960s. Therefore, we had to rely on figures on motor vehicle ownership, as was done in previous studies.[19] It cannot be excluded that one of our major findings, mobility growth levelling off at higher prosperity levels, is partly based on registration error. This could be the case if a lower growth rate of motor vehicle ownership is compensated by a faster growth rate of the number of passenger kilometres per motor vehicle.

Probably, however, we are dealing with a real phenomenon. A potential saturation of mobility growth has previously been modeled for several countries, using data on the development of vehicle miles in the population.[30,31]

The results obtained with our study have provided us with information on the relation between prosperity and traffic accident mortality in a long-term perspective. These results, however, must be interpreted only as indications of the possible influence of prosperity on traffic accident mortality. We have found plausible results that should be further analyzed with the help of additional data and more sophisticated models.

In our analysis we used only simple univariate models without adjusting for possible confounders. The cross-sectional associations were established with only a limited number of countries included. Moreover, the relations were investigated in a rather superficial way. For example, it was not tested whether the consistent inverse relation between prosperity and the fatal injury rate was due to a negative relation with either the injury risk (the number of traffic injuries per motor vehicle) or the case fatality (the number of traffic deaths per 100 injuries).

For the aim of our study, i.e. examining the possible role of prosperity on traffic accident mortality within the framework of the epidemiologic transition theory, we have already found some interesting results. Prosperity seems to act on traffic accidents in the same way as on other major diseases. In the long run it becomes protective, as with infectious and cardiovascular diseases.[9,32]

In particular, the similarity with cardiovascular diseases is striking: the reversal from a positive into a negative cross-sectional relation reported in our study had previously been found in the field of cardiovascular diseases.[17,18]

As in the case of cardiovascular diseases, prosperity growth could stimulate adaptation mechanisms leading to reductions in the incidence and the case fatality. And as for cardiovascular diseases, these adaptation mechanisms could include preventive public health measures and improvements of medical care.[33-36]

In addition, the results have some importance from a health policy perspective. The concept of traffic accidents as a "disease of affluence" , although too simple, cannot be rejected completely.

Up to a certain prosperity level, increasing wealth gives rise to more traffic deaths. World-wide only a limited number of countries has already reached this level. This means that on a global scale an enormous increase in public health damage due to traffic injuries could still be expected, as has been reported previously.[37] The results of our study bring forward that, in general, adaptations leading to reductions in the fatal injury rates might be expected as well with growing prosperity. Recent developments in individual countries have indicated, however, that adaptations are not always succesful. Examples were shown of declines in fatal injury rates that have recently levelled off. This demonstrates that, although prosperity growth in the long run would appear to have an "autonomous" protective effect on traffic accident mortality, health policy makers should always be alert to avoid unneccesary public health damage in this field.

REFERENCES

1. Brenner MH. Mortality and the national economy. A review, and the experience of England and Wales, 1936-76. Lancet 1979;i;568-573.
2. Brenner MH. Relation of economic change to Swedish health and social well-being, 1950-1980. Soc Sci Med 1987;25(2):183-195.
3. McKeown T, Record RG, Turner RD. An interpretation of the decline of mortality in England and Wales during the nineteenth century. Pop Studies 1975;29:391-422.
4. Rogers RG, Wofford S. Life expectancy in less developed countries: socioeconomic development or public health? J Biosoc Sci 1989;21:245-252.
5. Omran AR. Epidemiologic transition in the United States: the health factor in population change. Pop Bull 1980;32:whole issue.
6. Omran AR. The epidemiologic transition: a theory of the epidemiology of population change. Millbank Memorial Fund Quarterly 1971;49:509-538.

7. Omran AR. The epidemiologic transition theory. A preliminary update. J Trop Ped 1983;29: 305-316.
8. Mackenbach JP. The epidemiologic transition theory. J Epid Comm Health 1994;48:329-332.
9. Murray CJL, Chen LC. In search of a contemporary theory for understanding mortality change. Soc Sci Med 1993;36(2):143-155.
10. Thom TJ, Epstein FH, Feldman JJ, Leaverton PE. Trends in total mortality and mortality from heart disease in 26 countries from 1950 to 1978. Int J Epidemiol 1985;14:510-520.
11. Oppe S. Development of traffic and traffic safety: global trends and incidental fluctuations. Accid Anal Prev 1991;23(5):413-422.
12. van Beeck EF, Mackenbach JP, van Oortmarssen GJ et al. Scenarios for the future development of accident mortality in the Netherlands. Health Policy 1989;11:1-17.
13. Trowell HC, Burkitt DP. Western diseases: their emergence and prevention. London: Arnold; 1981.
14. Barker DJP. Rise and fall of western diseases. Nature 1989;338:371-372.
15. Uemura K, Pisa Z. Trends in cardiovascular disease mortality in industrialized countries since 1950. World Health Stat Q 1988;41:155-178.
16. Feachem RGA. Health decline in eastern Europe. Nature 1994;367:313-314.
17. Wing S, Hayes C, Heiss G et al. Geographic variation in the onset of decline of ischemic heart disease mortality in the United States. Am J Epidemiol 1986;76:1404-1408.
18. Mackenbach JP, Looman CWN, Kunst AE. Geographic variation in the onset of decline of male ischemic heart disease mortality in the Netherlands. Am J Public Health 1989;79:1621-1627.
19. Söderlund N, Zwi AB. Traffic-related mortality in industrialized and less developed countries. Bull WHO 1995;73:175-182.
20. Wintemute GJ. Is motor vehicle-related mortality a disease of development? Accid Anal Prev 1985;17(3):223-237.
21. Baker SP, Whitfield RA, O'Neill B. Geographic variation in mortality from motor vehicle crashes. N Engl J Med 1987;316:1384-1387.
22. Baker SP, O'Neill B, Ginsburg MJ, Li G. The Injury Fact Book; second edition. New York: Oxford University Press; 1992.
23. Balarajan R, McDowall ME. Regional socioeconomic differences in mortality among men in Great Britain today. Public Health 1988;102:33-43.
24. van Beeck EF, Mackenbach JP, Looman CWN, Kunst AE. Determinants of trafffic accident mortality in the Netherlands: a geographical analysis. Int J Epid 1991;20:698-706.
25. Murray CJL, Lopez AD. Mortality by cause for eight regions of the world: Global Burden of Disease study. Lancet 1997;349:1269-1276.
26. Waterhouse J (ed). Cancer incidence in five continents. Lyon: IARC; 1976.
27. International Road Federation. World Road Statistics. Genève: IRF; 1962,65,70,75,80,85,90,94.
28. World Bank. World Development Report 1993. Washington: World Bank; 1993.
29. Hutchinson TP. Road Accident Statistics. Adelaide: Rumsby Scientific Publishing; 1987.
30. Broughton J. Predictive models of road accident fatalities. Traff Engng Control 1988;29:296-300.
31. Oppe S. Macroscopic models for traffic and traffic safety. Accid Anal Prev 1989;21:225-232.

32. Powles J. Changes in disease patterns and related social trends. Soc Sci Med 1992;35((4): 377-388.
33. Sytkowski P, Kannel W, D'Agostinho R. Changes in risk factors and the decline in mortality from cardiovascular disease. N Engl J Med 1990;322:1635-1641.
34. McGovern PG, Pankow JS, Shanar E et al. Recent trends in acute coronary heart disease-mortality, morbidity, medical care, and risk factors. The Minnesota Heart Survey Investigators. N Engl J Med 1996;334:884-890.
35. Goldman L, Cook E. The decline in Ischemic Heart Disease mortality rates. Ann Intern Med 1984;101:825-836.
36. Bonneux L, Looman CW, Barendregt JJ, van der Maas PJ. Regression analysis of recent changes in cardiovascular mortality and morbidity in the Netherlands. Br Med J 1997;314: 789-792.
37. Murray CJL, Lopez AD. Alternative projections of mortality and disability by cause 1990-2010: Global Burden of Disease Study. Lancet 1997;349:1498-1504.

4 Forecasting and monitoring of injuries

4.1 The use of the Delphi method in forecasting injuries between 1985 and 2000

4.2 Scenarios for the future development of injury mortality in the Netherlands, 1985-2000

4.3 Future health scenarios as a tool in the surveillance of unintentional injuries : an evaluation

4.1

ABSTRACT

Within the framework of the Health For All by the year 2000-strategy of the World Health Organisation, we explored autonomous developments in the epidemiology of injuries in the Netherlands. In addition, we estimated the potential effects of different strategies to reduce the amount of public health damage due to injuries.

In 1986 we performed a Delphi study among 80 Dutch experts, which was divided into four areas: traffic safety, occupational safety, home and leisure safety, and medical care for injury victims. The experts were asked to give estimates of the rate of change of relevant parameters in the epidemiology of injuries between 1985 and 2000 under different sets of possible external conditions. These parameters included the exposure and injury risk by type of activity, and the case fatality by type of injury. In addition, they had to list policy measures that could be implemented between 1985 and 2000 and were asked to assess their potential impact. The Delphi study used a structured questionnaire and consisted of two rounds.

The response rate to both questionnaires was 82%. A high level of consensus on nearly all questions was reached in two rounds. Only a few questions led to considerable disagreement. The principal expectations of the respondents (assuming modest economic growth and minimal government intervention) implied that health policy makers would have to anticipate on combinations of favourable and unfavourable developments. In addition, alternative autonomous conditions (e.g. rapid economic growth and economic stagnation) were expected to result in increasing public health damage due to injuries. The results showed that the very favourable trends of the preceding period (1970-1985) would probably not continue without strong government intervention. On the other hand, many policy measures were put forward, which were expected to lead to a substantial further reduction of the incidence of injuries and its consequences.

4.1

The use of the Delphi method in forecasting injuries between 1985 and 2000

4.1.1 INTRODUCTION

Long-term planning is an important part of health policy. Many policy measures in this area are characterised by a long time-lag between development and implementation, and, after being implemented, may need a long time before they ultimately achieve their desired effect. Therefore, some strategies should be prepared far in advance, e.g. to keep the supply and demand of health care facilities in balance and to reduce the major health problems facing modern society.

In the process of long-term planning, the application of forecasting techniques (e.g. the Delphi Method) can be of value.[1] This paper describes the methodology, the approach and the results of a Delphi study into the future burden of injuries in the Netherlands. This study was initiated by the Steering Committee on Future Health Scenarios,[2] a body advising the Dutch government on long-term developments in health and health care.

Injuries were selected because of their frequent occurrence and serious consequences. They constitute one of the major health problems in the industrialized world.[3-5] At the time the study was conducted, in the mid 1980s, there were almost 4.000 deaths and 100.000 hospital admissions per annum from traffic injuries, occupational injuries or home and leisure injuries in the Netherlands (see Table 4.1.1).

Table 4.1.1

Annual numbers of deaths and hospital admissions related to injuries, by type of activity, the Netherlands, 1984

	Deaths		Hospital admissions	
	Absolute number	Per 100.000 of population	Absolute number	Per 100.000 of population
Traffic	1752	12.1	23.500	162.6
passenger car	774	5.4	5500	38.0
moped	125	0.9	3300	22.8
bicycle	360	2.5	6400	44.3
pedestrian	212	1.4	2600	18.0
other traffic	281	1.9	5700	39.5
Occupation	75	0.6	3000	20.7
manufacturing	12	0.1	800	5.5
building trade	10	0.1	800	5.5
service sector	24	0.2	1000	6.9
other occupations	29	0.2	400	2.8
Home and leisure	2068	14.2	71.500	494.7
house keeping	157	1.0	3000	20.7
do-it-yourself activities	62	0.4	1500	10.4
sports	78	0.5	16.500	114.2
other home and leisure activities	1771	12.3	50.500	349.4
Total	3895	26.9	98.000	678.0

Source: Adapted from data published in various CBS publications[6-11]

Home and leisure injuries accounted for more than half of the accidental deaths and for almost three quarters of the hospital admissions due to injuries. Many of these accidental deaths and hospital admissions concerned elderly people who sustained a hip fracture (without performing a specific activity). Although traffic injuries accounted for fewer victims than home and leisure injuries, they also constituted a large problem. Most road traffic casualties were passengers in private cars or cyclists. On the other hand, occupational injuries appeared to be a public health problem of relatively minor importance, if only deaths and hospital admissions are taken into account.

In the period directly preceding the study, there had been a remarkable reduction in the number of injuries in the Netherlands. As in many other countries between 1970 and the mid 1980s, a tremendous drop in mortality due to traffic, occupational and home and leisure injuries was observed.[12] However, despite this development, injuries still constituted a major health problem in the industrialized world. This is why in 1984 the European Member States of the World Health Organisation formulated as a target a 25% reduction in injury mortality between 1980 and the year 2000.[13] The Delphi study on 'Injuries and Traumatology in the Future' was set up to investigate the possibility of achieving this reduction. Because of the potential influence of both autonomous developments and policy measures, the study had two aims:

1. to explore those autonomous developments that might take place before the year 2000, and their likely effects on the incidence and outcome of injuries;
2. to list policy measures which might be implemented before the year 2000, and estimate the potential effects of different strategies on the incidence and outcomes of injuries.

4.1.2 METHODOLOGY

The Delphi study was undertaken between June and November 1986. The subject was divided into four areas: traffic injuries, occupational injuries, home and leisure injuries and medical care for injury victims.

In selecting the panellists, priority was given to obtaining a balanced distribution of expertise in the four specific subject areas. In order to avoid 'common bias', experts belonging to different sections of society (government, trade unions, business, private organisations, research institutes, etc.) were chosen.

Eighty Dutch experts were asked to participate. Anticipating potential non-response, four samples of twenty panellists were formed. Our intention was to achieve panels of about 15 respondents, on which experts from all important sections of society were represented.

Considerable attention was paid to the design of the questionnaire. Four questionnaires were designed, all of which had the same structure. They included the following variables:

- Exposure (e.g., the number of passenger kilometres travelled in the population).
- Injury risk (e.g., the number of injured persons per passenger kilometre).
- Case fatality (the number of accidental deaths per 100 injured persons).
- Probability of disability (the number of newly disabled persons per 100 injured persons).

The questionnaires presented to the experts asked them to assign probabilities to one or more of the variables concerned, under a number of different conditions:

1. A combination of minimal government intervention (no new initiatives in the fields of injury prevention and medical care for accident victims in the period 1985-2000); modest economic growth (1-1.5% per year, at that time regarded by experts as the most likely economic development); the respondent's assessment of the socio-cultural and (medical) technological developments resulting from this situation.

2a. A combination of minimal government intervention; rapid economic growth (4% per year); the respondent's assessment of socio-cultural and (medical) technological developments resulting from this situation.

2b. A combination of minimal government intervention; economic stagnation (0% growth per year); the respondent's assessment of the socio-cultural and (medical) technological developments resulting from this situation.

3. As (1) but with strong government intervention in the fields of injury prevention and/or medical care for injury victims (assuming the implementation of a number of policy measures mentioned by the respondent).

All the combinations had to be based on the demographic 'middle variant' of the population forecast of the Dutch Central Bureau of Statistics of 1985,[14] featuring an increase in the number of people over the age of 65 years between 1985 (12% of the total population) and the year 2000 (14% of the total population).

Combination 1 aimed to display the most likely development according to the Delphi respondents (the so-called principal expectation). The possibilities classed under combination 2 were meant to give a picture of the likely range of autonomous developments. Combination 3 aimed to give an impression of the maximum that government policy could achieve.

The experts were asked to give quantitative estimates of the rate of change of the variables concerned, as well as verbal statements. The experts on traffic, occupational and home and leisure injuries were asked to express their opinions on possible changes in exposure (where other sources of information did not exist), and injury risk. Both variables were subdivided according to the principal activities in which injuries occur. The experts in the field of medical care for injury victims were asked for their expectations of the case fatality and the probability of disability. These two variables were divided according to the principal types of injury. In giving their quantitative estimates the experts were asked to use the scale represented in table 4.1.2.

Table 4.1.2

The answer categories in the questionnaires used in the Delphi study

	Annual rate of change	Situation at 31/12/1999 compared with 1/1/1986
++	> 5% increase	+100% or higher
+	1-4% increase	between +15 and +80%
0	< 1% increase/decrease	+/- 15%
-	1-4% decrease	between -15 and -45%
--	> 5% decrease	-50% or lower

In designing the questionnaire, we tried as follows to avoid aggregating developments for which quite different future trends might be expected:

- by constructing a separate questionnaire for each of the four areas;
- by distinguishing exposure, injury risk, case fatality and the probability of disability;
- by distinguishing a large number of separate activities (see tables 4.1.3-4.1.5) and separate types of injury (see table 4.1.6).

This does not mean, however, that aggregation could always be avoided. For example, the questions did not specify different age groups. Considerable attention was also given to avoiding ambiguity. The questionnaires were accompanied by a pack of explanatory material, containing definitions of the terms used and detailed instructions on how to complete the questionnaire. In the first round, the Delphi study used a structured questionnaire. After the results of the first round were analysed, a second questionnaire was given to the respondents, who were given the opportunity to redefine or to elaborate upon their earlier responses. The second questionnaire provided the respondents with information about their own answers and the group's collective opinion, as expressed in the first round.

4.1.3 RESULTS

The response to the two questionnaires was highly satisfactory. Of the panellists (all panels combined), 82% returned both questionnaires. No important differences in response rates (variation from 75%- 85%) were seen among the four panels. All panels consisted of 15 or more respondents.

We present the expectations of the experts in the fields of traffic injuries, occupational injuries, home and leisure injuries and medical care for injury victims for a selection of questions. The group's collective opinions on different questions are set out in the tables below. In describing the results, the verbal statements given by respondents are also referred to. The group's collective opinion was defined as the smallest number of contiguous categories chosen by at least two-thirds of the respondents. If, for example, a two-thirds majority of the panellists chose two contiguous categories, these answers indicate the group's collective opinion (e.g. 0/- if 5 of the 15 respondents chose 0, and 6 of the 15 respondents chose -).

In nearly all the questions, a high level of consensus was reached after the first round. Although the second questionnaire led to changes in individual answers, e.g. by respondents who interpreted certain terms correctly only in the second round, it had little influence on the collective opinions of the group. Only a few questions led to considerable disagreement. In a few cases, two groups of about equal size could be identified, choosing quite different (not contiguous) categories: e.g. where 7 of the 15 respondents chose + and 8 of the respondents chose -. These cases are indicated by the term "disagreement".

Traffic injuries

The panel's expectations of developments in exposure and injury risks, as expressed by experts in the field of traffic safety, are presented in table 4.1.3.

Table 4.1.3

Expected trends in exposures and injury risks in traffic, under different conditions, 1985-2000 (group answers of the Delphi panel on traffic safety, second round (n=15))

	Principal expectation	Alternative autonomous developments		Strong government intervention
		Rapid growth	Stagnation	
	1	2a	2b	3
Exposure (passenger km per inhabitant per year)				
passenger car	+	++/+	+/0	not asked
moped	0/-	0/-	0/-	not asked
bicycle	+/0	+/0	+	not asked
Injury risk (injured persons per passenger km)				
passenger car	-	+/0/-	0/-	-/--
moped	+/0	+/0	0	0/-
bicycle	0/-	+/0	0	0/-/--
pedestrian	0/-	+/0	0/-	-

Let us comment first on the principal expectations. The panel thought that modest economic growth would lead to growing use of passenger cars, and that a growing attention to 'health' would lead to a shift from the use of mopeds to the use of bicycles. According to the panellists, for most traffic modes the injury risk would be reduced by the introduction of new safety technologies. The only exception was moped drivers, where the injury risk was expected to rise because panellists expected that the use of mopeds would be more and more restricted to people in the 16-17 year-old age group who are inexperienced in traffic and exhibit a high propensity for risk taking.

According to the panel, rapid economic growth would lead to some unfavourable developments. A higher level of economic activity would not only lead to a growing use of passenger cars, but also to a rise in the risk of injuries, because of a higher level of risk acceptance in society under these circumstances. Economic stagnation would have quite different results. The use of passenger cars would be restricted. The risk of injuries would increase compared to a situation of modest economic growth, because no new safety technologies would be introduced.

This panel expected that the risk of injuries would be substantially reduced by strong government intervention. In particular, occupants of passenger cars would profit from a number of policy measures aimed at improvements in road behaviour, roads and road vehicles. These might include a national policy in the field of traffic safety education, the introduction of new safety technologies, and measures aimed at the separation of traffic modes.

Occupational injuries

Table 4.1.4 shows the expectations of trends in injury risks for occupational injuries. The experts in the field of occupational safety were not asked for their expectations regarding changes in exposure, because estimates of this variable were already available from the Dutch Central Planning Bureau.[15]

Table 4.1.4

Expected trends in injury risks at work, under different conditions, 1985-2000 (group answers of the Delphi panel on occupational safety, second round (n=15))

	Principal expectation	Alternative autonomous developments		Strong government intervention
		Rapid growth	Stagnation	
	1	2a	2b	3
Injury risk (injured persons per man-year at labour)				
manufacturing	0/-	0/-	+/0	-/--
building trade	0/-	+/0/-	+/0/-	-/--
service sector	0	0	0	0/-

According to the principal expectations of this panel, the injury risks of workers in manufacturing and the building trade would fall on account of the introduction of new technologies for controlling work-related injuries. Rapid economic growth would lead to the same developments, whereas economic stagnation would result in the absence of investment in new technologies and lead to increasing injury risks in manufacturing. The panel was optimistic about the influence of strong government intervention. Many policy measures which could reduce the injury risks were mentioned, e.g. compulsory occupational safety services, extension of the capacity and powers of safety inspectors, and extension of the powers of work councils.

Home and leisure injuries

Table 4.1.5 sets out the opinions of the experts in the field of home and leisure injuries. This panel expressed the following principal expectations: people would spend less time on housekeeping; do-it-yourself activities and sports would grow in importance. In contrast to the expectations in the fields of traffic safety and occupational safety, unfavourable trends in injury risks were anticipated to accompany modest economic growth.

Injury risks at home were expected to rise because of the ageing of the population. The injury risk associated with do-it-yourself activities was expected to grow because of the use of more dangerous equipment. Sports would be accompanied by higher injury risks because of a shift towards more hazardous types of sporting activity and because people were expected to exhibit more 'aggressive' behaviour.

Both rapid economic growth and economic stagnation were expected to have effects on exposure. Contrary to what was expected in the fields of traffic safety and occupational safety, injury risks would hardly be influenced by alternative economic conditions.

Table 4.1.5

Expected trends in exposures and injury risks at home and during leisure activities, under different conditions, 1985-2000 (group answers of the Delphi panel on home and leisure safety, second round (n=17))

	Principal expectation	Alternative autonomous developments		Strong government intervention
		Rapid growth	Stagnation	
	1	2a	2b	3
Exposure (activity hours per inhabitant per year)				
house keeping	0/-	-	+/0	not asked
do-it-yourself activities	+	+/0	+	not asked
sports	+/0	+	0	not asked
Injury risk (injured persons per activity hour)				
house keeping	+/0	+/0	+/0	0/-
do-it-yourself activities	+	+	+	0/-
sports	+/0	+/0	0	0/-

This panel was also optimistic about the effect of strong government intervention. Whereas without government intervention injury risks were expected to rise, according to this panel the implementation of a number of policy measures aimed at changes in behaviour and improvements in product safety would lead to a reduction of these injury risks: for example, a national policy in the field of safety education, legislation in the fields of product recall and product liability.

Medical care for injury victims

The expectations of trends in case fatality and the probability of disability, as expressed by the experts in the field of medical care, are represented in table 4.1.6. This table only shows the expectations under the condition of modest economic growth, either with or without government intervention. The experts in medical care were not asked to consider the consequences of alternative economic conditions.

Table 4.1.6

Expected trends in case fatalities and probabilities of disability, under different conditions, 1985-2000 (group answers of the Delphi panel on medical care for injury victims, second round (n=16))

	Principal expectation	Strong government intervention
Case fatality (deaths per 100 injured persons)		
skull fractures and intracranial injury	0	-
spinal cord injuries	0	0/-
hip fractures	-	-/--
burns	-	-/--
internal injuries of abdomen, chest and pelvis	0/-	-/--
multiple injuries	0/-	-/--
Probability of disability (disabled persons per 100 injured persons)		
skull fractures and intracranial injury	0	disagreement
spinal cord injuries	0	0/-/--
peripheral nerve damage	0/-	disagreement
hip fractures	0/-	0/-/--
other fractures	0/-	-/--
soft tissue injuries	0/-	-/--

It was expected that, even without government intervention, the case fatalities for most types of injury would drop as a result of progress in the field of medical technology. All injuries except those of the central nervous system would benefit from new diagnostic and therapeutic methods. With the exception of injuries of the central nervous system, this panel had an equally optimistic view about the future probability of disability.

It was expected that case fatalities of severely injured patients, especially those with injuries of the central nervous system, would be greatly reduced by the introduction of policy measures aimed at improving the system of trauma care in the Netherlands. This would consist of measures in the fields of pre-hospital care - such as introducing a national emergency phone number and staffing ambulances with nurses who have supplementary training in trauma care; in-hospital care, such as regionalization of trauma care; and rehabilitation, such as increasing the volume of rehabilitation medicine.

Little agreement was reached about the influence of these measures on the probability of disability resulting from some types of injury. For example, in the case of skull fractures and intracranial injury, about half the panellists expressed the opinion that a reduction of case fatality would be accompanied by an increase in the probability of disability based on an increasing number of very severely injured patients as survivors. The other half expected a decrease in the probability of disability, based on the prevention of secondary brain damage by the new policy measures.

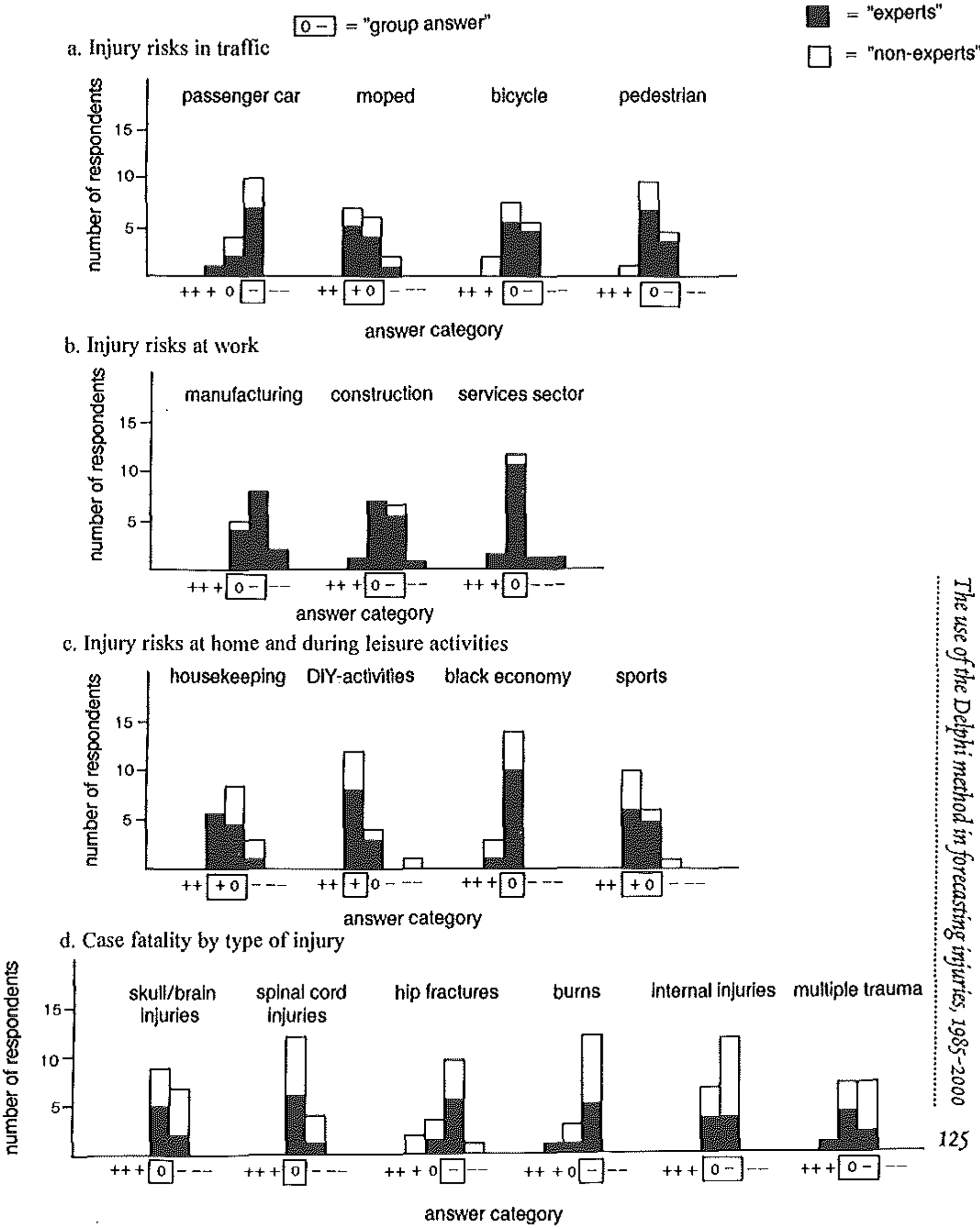
Variation

In our description of the results of the Delphi study, we have focused on the opinions of two-thirds majorities of the panels. These panels showed a high level of consensus in their expectations of the future under four different combinations of autonomous developments and policy strategies.

Only a few items causing considerable disagreement were identified. For example, the panel on medical care could not agree on the changes occurring in the probability of disability arising from some types of injury in response to improvements in the system of trauma care. The lack of consensus may, however, provide important information for health policy, since it can show where further research is needed.

Figure 4.1.1

The distribution of answers to questions about the development of injury risks, by type of activity (Delphi panels on traffic, occupational, and home and leisure safety) and case fatality, by type of injury (Delphi panel on medical care for injury victims), under conditions of modest economic growth and minimal government intervention.



In addition, in nearly every case there were one or two respondents who formulated answers which were quite different from the group's collective opinion.

This is illustrated in figure 4.1.1 which shows the distribution of opinions on the expected trend in injury risks (by activity type) and case fatalities (by type of injury), assuming the most likely course of economic development (modest economic growth) and minimal government intervention.

In the field of traffic safety, two respondents expressed more pessimistic views concerning the development of injury risks. Contrary to the group's collective opinion, these respondents believed that risk consciousness would be reduced as a result of favourable trends in the preceding period, and that this would lead to increasing risk behaviour. In the other panels, small minorities with quite different opinions were also found.

These 'dissident opinions' might also be useful in health policy making, as they help identify 'low probability/high-impact developments'; that is, future developments which are not very likely but which might have a very high impact on the problem if they did occur.

4.1.4 DISCUSSION

To facilitate long-term health planning, a Delphi study was carried out on possible future developments in the field of injuries and traumatology. The results of this study provided information about autonomous developments which might take place between 1985 and the year 2000, as well as about policy measures which could be implemented in this period.

The Delphi study resulted in interesting new information to be used in formulating a national strategy in the framework of the World Health Organisation's 'Health for All by the Year 2000' strategy.

However, the results were obtained by a method which is not beyond criticism.[16] The Delphi method is characterised by a number of problems concerning the selection of panellists, the size of the sample, the design of the study and the structure of the questionnaire. The ways in which these problems were dealt with have been described above, but none of these problems could completely be solved.

When selecting panellists, the problem is that there are really no 'experts on future developments'. This probably explains why many respondents stressed that their opinions were to be regarded as 'speculations' rather than as 'predictions'.

In considering the size of the samples, it must be recognised that most panellists did not have expert knowledge of all the subjects in the questionnaire. For a few specific questions, the number of true experts was probably far lower than the number of overall respondents.

In a Delphi questionnaire it is very difficult to avoid aggregation and ambiguity. In conducting our study, considerable attention was given to this problem. The questionnaires were designed with care, using a conceptual model of the processes underlying injuries and their consequences. Although many different subareas were distinguished, and all key variables in injury epidemiology were treated separately, aggregation could not be entirely avoided; that is, no questions were asked about specific age groups. Moreover, it is quite possible that some questions may have had more than one interpretation.

A final problem concerns the structure of the Delphi questionnaire. In order to reduce the number of panel rounds, we started with a preselected set of questions. This may have reduced the number of ideas obtained.

These methodological problems indicate that the results obtained in our study should be viewed as 'well-informed speculations on the future'. Treated as such, they nevertheless provide valuable information.

A Delphi study, if executed with care, represents a well-developed and systematic procedure for tapping expert opinion. It avoids some of the problems of group processes which employ face-to-face interaction. Our Delphi study illustrated consensus, but also displayed disagreement where this arose. It paid attention to the group's collective opinion as well as to 'dissident' opinions of individual participants. And because the questionnaires used rather 'extreme' combinations of autonomous developments and policy strategies, its results provided a good picture of the range of possible future developments which could be considered by health policy makers.

A disadvantage not mentioned so far concerns the inherently fragmented nature of the results. A Delphi study leads to many separate estimates of different variables in different subareas. In our study, experts were asked about their expectations on exposures, injury risks, case fatalities and the probability of disability for 13 activities in the fields of traffic safety, occupational safety and home and leisure safety. Possible interactions between the different subareas were not investigated, raising the problem of possible inconsistent results. We therefore decided to conclude the Delphi study with a workshop for subsamples of panellists, who could then check the consistency and critically review the methods and results of the enquiry.

No inconsistencies were, however, identified by the participants, who regarded the results as plausible and coherent descriptions of future developments under different sets of conditions.[17]

Another problem resulting from the fragmented nature of the procedure is that a Delphi study provides information on developments of separate variables without providing a clear view of the 'net effects' of these developments; for example, injury mortality in the population. In order to calculate these net effects, we constructed a computer model.[18] The model consisted of two parts: a demographic submodel which simulated changes in the population structure as forecasted by the Central Bureau of Statistics, and an epidemiological submodel. In the latter model, the injury mortality of a future year, to take one example, was calculated by multiplying the population numbers by age and sex as computed in the demographic submodel, and the exposures, injury risks and case fatalities of the principal types of activities and principal types of injuries. The data on exposures, injury risks and case fatalities were derived from routinely available statistical information from the Netherlands. For future years, these data were adapted as suggested by the Delphi panels.

The results of these calculations confirmed the impression based upon inspection of the separate calculations. The principal expectations of the respondents implied that health policy makers would have to anticipate a combination of developments both favourable (e.g., technological progress) and unfavourable (e.g., the consequences of an ageing population, a growing amount of traffic and a growing participation in hazardous sports). The net effect of these developments would, according to our computer calculations, be a stabilisation of injury mortality rates at 1985 levels. It was further shown that rapid economic growth and economic stagnation both would probably lead to 'trend reversals'. Rapid economic growth, for example, was expected to lead to increasing risk behaviour in society while economic stagnation was expected to result in the absence of (medical) technological progress.

We calculated that the net effect of both situations would be a rise in injury mortality between 1985 and the year 2000.[19]

Thus, the results of our Delphi study were used as input for computer model calculations, and formed the basis for a number of 'future health scenarios', both with and without government intervention.

These scenarios were presented to health policy makers in 1988. It was demonstrated that the favourable trends of the period 1970-1985 would probably not continue if the government abstained from new policy measures in the fields of injury prevention and/or medical care for injury victims.

This pointed to the necessity of developing new policy strategies. It was shown that the vigorous continuation of government policies in the field of injury prevention and the implementation of new initiatives in the field of medical care for injury victims both could lead to a reduction of injury mortality, as the World Health Organisation had stipulated as a goal.

The Delphi study yielded a number of ideas about policy measures, which at that time had not yet found a place in policy documents. Since then, many of the ideas obtained in the study have been incorporated into policy plans on the part of the government. For example, in 1989 the government announced its intention to implement measures aimed at the improvement of trauma care, as formulated by the Delphi respondents.[20] Before the study, no policy document had been formulated in this field. In 1997 the government decided to implement the majority of those measures.[21] We therefore conclude that our Delphi study probably made some contribution to health planning in the Netherlands. But our example also illustrates the long-term nature of developing and implementing policy measures as referred to at the beginning of this paper. This only stresses the value of anticipating on possible future developments. Our study illustrates that in this process, the Delphi method can be of help.

REFERENCES

1. Brouwer JJ, Schreuder RE (eds). Scenarios and Other Methods to Support Long-Term Health Planning. Utrecht: Uitgeverij Jan van Arkel; 1986.
2. Steering Committee on Future Health Scenarios. STG: Structure and Terms of Reference. Utrecht: Uitgeverij Jan van Arkel; 1986.
3. Committee on Trauma Research. Injury in America: A Continuing Public Health Problem. Washington, DC: National Academy Press; 1985.
4. European Conference of Ministers of Transport. Statistical Report on Road Accident Trends in 1984. Paris: OECD; 1986.
5. Geus GH de. An Inventory of Surveillance Systems and Studies on Home and Leisure Accidents in the European Community. Amsterdam: ECOSA.; 1987.
6. CBS. Diagnosestatistiek ziekenhuizen 1983. (Hospital diagnosis statistics 1983, in Dutch). Voorburg: CBS; 1986.
7. CBS. Overledenen naar doodsoorzaak, leeftijd en geslacht serie A1, diverse jaartallen. (Deaths by cause of death, age and sex, series A1, in Dutch) Voorburg: CBS; several years.
8. CBS. Statistiek der bedrijfsongevallen 1984. (Occupational accident statistics 1984, in Dutch). Voorburg: CBS; 1985.
9. CBS. Statistiek der bedrijfsongevallen, diverse jaartallen. (Occupational accident statistics, in Dutch) Voorburg: CBS; several years.

10. CBS. Statistiek van de verkeerongevallen op de openbare weg 1984. (Statistics on road accidents on public highways 1984, in Dutch). Heerlen: CBS; 1985.
11. CBS. Overledenen naar doodsoorzaak, leeftijd en geslacht in het jaar 1984, serie A1. (Deaths by cause of death, age and sex in 1984, series A1, in Dutch) Voorburg: CBS; 1984.
12. Lamm R, Chouieri EM, Kloeckner JH. Accidents in the US and Europe: 1970-1980. Accid Anal Prev 1985;17:429-438.
13. World Health Organisation. Targets for Health for All. Copenhagen: WHO Regional Office for Europe; 1985.
14. Cruijssen HGJM. Bevolkingsprognose voor Nederland 1985-2035 (Population forecast for the Netherlands 1985-2035, in Dutch). Mndstat Bev CBS 1986;3:33-41.
15. Centraal Planbureau. De Nederlandse economie op de langere termijn. (The economy of the Netherlands in the future, in Dutch). Den Haag: CPB; 1985.
16. Sackman H. Summary evaluation of Delphi. Policy Analysis 1975;20:694-718.
17. van Beeck EF, Mackenbach JP, Habbema JDF, van der Maas PJ. Delphi Study: accidents and traumatology in the future. In: Lapré RM, Mackenbach JP(eds). Accidents in the Year 2000. Dordrecht: Kluwer Academic Publishers; 1989.
18. Mackenbach JP, Van Oortmarssen GJ, van Beeck EF, Barendregt JJM, Habbema JDF, van der Maas PJ. Projections of the epidemiology of accidents: a computer model for calculating the future incidence of accidents and their consequences. In: Accidents in the Year 2000. Lapré RM, Mackenbach JP (eds). Dordrecht: Kluwer Academic Publishers; 1989.
19. van Beeck EF, Mackenbach JP, van Oortmarssen GJ, Barendregt JJM, Habbema JDF, van der Maas, PJ. Scenarios for the future development of accident mortality in the Netherlands. Health Policy 1989;11:1-17.
20. Ministerie van WVC. Ontwerp kerndocument Gezondheidsbeleid; dicussienota Ongevallen en Traumatologie. (Draft Basic Document on Health Policy; discussion paper on accidents and traumatology, in Dutch). Rijswijk; 1989.
21. Ministerie van Volksgezondheid, Welzijn en Sport/Ministerie van Binnenlandse Zaken. Met zorg verbonden; naar een nieuwe structuur voor ambulancezorg, traumazorg en geneeskundige hulpverlening bij ongevallen en rampen. (Improving the chain of medical care for injury victims, in Dutch). Den Haag; 1997.

4.2

ABSTRACT

Injuries are a major health problem. In the Netherlands almost 4000 people are killed each year by traffic injuries, occupational injuries or home and leisure injuries. In this country in 1985 a research project was started exploring possible future developments in this field. The technique of scenario analysis was used. With the help of a Delphi study, 8 different scenarios with and without public health intervention were generated. To calculate the effects of these scenarios on the frequency and outcomes of injuries, a computer model was used. The results of the project show that a substantial reduction of injury mortality will probably only be reached by way of public health intervention. According to experts, both a forceful continuation of primary prevention and an improvement of the system of trauma care could reduce injury mortality by (almost) 25% between 1985 and the year 2000.

4.2

Scenarios for the future development of injury mortality in the Netherlands, 1985-2000

4.2.1 INTRODUCTION

Injuries are one of the major health problems of the industrialized world.[1-3] In North America and Europe traffic injuries, occupational injuries and home and leisure injuries together account for 3-7% of total mortality. In the United States of America more than 100,000 people are killed by injuries each year. In Europe the annual numbers of accident deaths are impressive too, especially in larger countries like France (38,000), West Germany (28,000) and England/Wales (14,000). Even in a small country like the Netherlands almost 4000 people are fatally injured each year.

Within the framework of the "Health for all by the year 2000"-strategy, the European member states of the World Health Organization (WHO) have decided to aim at a 25%-reduction of injury mortality between 1980 and the year 2000.[4] In order to investigate the possibilities of this reduction an exploration of future developments, both with and without intervention, is necessary. An exploration of this kind was launched in the Netherlands in 1985. In that year the Steering Committee on Future Health Scenarios,[5] a body advising the Dutch government on long term developments in health and health care[6-8] initiated a research project with the following two aims:[9]

- exploration of "autonomous" developments which might take place between 1985 and 2000, influencing the frequency and outcome of injuries; and
- exploration of policy measures which might be taken between 1985 and 2000, in order to reduce the frequency and severity of outcome of injuries.

This article presents a selection of the main findings of the project. Although effects of future developments other than those on mortality were also studied, for the sake of clarity only the latter are described here. In the next section a description will be given of the methods that were applied, followed by a presentation of the main results of the project. In the final section the consequences of the findings for health policy will be discussed.

4.2.2 EXPLORATION OF THE FUTURE: METHODS

In our exploration of possible future developments in the field of injuries we used the technique of scenario analysis.[10] This is a forecasting technique that provides a set of "plausible descriptions how the present could possibly evolve into the future".[11] By using this technique, uncertainty about the future can partly be reduced. Scenarios can be generated in different ways. This research project used the following approach.

Expectations on future developments were generated with the help of a Delphi study.[12,13] This is a method which samples the opinions of a group of experts through a series of questionnaires, and which has 3 specific features:

- anonymity (the participants do not know who else is in the group);
- iteration and controlled feedback (two or more successive questionnaires are used which also inform the participants about the group's collective opinion, as expressed in the preceding questionnaire); and
- statistical group response (both the center of the distribution of answers and the degree of variation are presented).

Eighty Dutch experts were asked to participate in this project. Four groups of 20 panellists were formed, each covering a different subarea: traffic injuries, occupational injuries, home and leisure injuries, and medical care for injury victims. Each group received a different questionnaire.

First of all, the experts were asked to give their opinions on the "most likely development" between 1985 and the year 2000 under the following conditions:

- no new policy measures in the fields of injury prevention and medical care for accident victims;
- demographic evolution as predicted by the Central Bureau of Statistics;[14]
- modest economic growth as described by the Central Planning Bureau.[15]

The panellists had to give quantitative estimates of the development of different types of exposures, injury risks and case fatalities. In addition, a verbal explanation of these quantitative estimates had to be given (e.g. expectations about socio-cultural developments, expectations about technology).

Secondly, the experts were asked about their expectations under "alternative autonomous conditions" (e.g. absence of economic growth, rapid economic growth or other conditions with a "low probability, high impact"-character). Again, both quantitative estimates and verbal explanations had to be given.

Finally, the participants were asked to list policy measures that could possibly be implemented before the year 2000, and to give quantitative estimates of their effects.

The Delphi study was structured into two rounds. Of the panellists, 82% responded in both rounds. The Delphi study resulted in a number of sets of verbal descriptions and quantitative estimates, out of which 8 different scenarios were constructed. In generating these scenarios, the opinions about specific items of a two-thirds majority of the Delphi panellists were used. The scenarios covered the whole field of unintentional injuries.

In order to be able to calculate the effects of different scenarios on injury mortality, a computer model was constructed. The computer model consisted of two parts, a demographic submodel simulating changes in the population structure as forecasted by the Central Bureau of Statistics, and an epidemiologic submodel. In the epidemiologic submodel, the injury mortality of a future year is calculated by multiplying the population numbers by age and sex as computed in the demographic submodel, and the exposures, injury risks and case fatalities of 13 different activities and 5 different types of injury. The data on exposures, injury risks and case fatalities in 1985 were derived from routinely available statistical information from the Netherlands. For future years the data were adapted as suggested by the Delphi panels.

4.2.3 EXPLORATION OF THE FUTURE: RESULTS

The scenarios that were constructed are shown in table 4.2.1. All scenarios share the assumption that the population structure will change as forecasted by the Central Bureau of Statistics. Most important feature of this forecast is a growing number of people above the age of 65 years between 1985 (12% of the total population) and the year 2000 (14% of the total population).

Table 4.2.1

The scenarios that were generated and their characteristics

Scenario	Characteristics
Demographic scenario	Ageing of the population
Most likely autonomous scenario	
- reference scenario	Modest economic growth (1.5%)
	Modest increase of risk behaviour
Alternative autonomous scenarios	
- high growth scenario	Rapid economic growth (4%)
- stagnation scenario	Economic stagnation (0%)
- risk-seeking scenario	Strong increase of risk behaviour
- risk-avoiding scenario	Strong decrease of risk behaviour
Health policy scenarios	
- injury prevention scenario	Forceful continuation of primary prevention
- medical care scenario	New system of trauma care
- combination scenario	Forceful continuation of primary prevention combined with new system of trauma care

To show the separate effects of an ageing population the outcomes of a so-called demographic scenario were calculated. This scenario assumes that apart from changes in population structure, there will be no differences with the present situation.

The opinions of more than two-thirds of the Delphi experts on the most likely "autonomous" development between 1985 and the year 2000 underlie the so-called reference scenario.

Four alternative autonomous scenarios are based on the expectations of the Delphi panellists assuming alternative autonomous conditions.

The lists of policy measures and the estimates of their quantitative effects provided the elements for three health policy scenarios.

Reference scenario

The reference scenario occupies a central place among the scenarios that were generated. This scenario reflects the most likely development between 1985 and the year 2000 assuming that no new policy measures are taken.

According to a two-third majority of the Delphi panellists exposures, injury risks and case fatalities will develop as shown in table 4.2.2.

The amount of traffic (especially the use of passenger cars) will rise. Injury risks, however, will decrease almost proportionally, because of technological progress improving the safety of vehicles and road environment.

Table 4.2.2

The development of exposures, injury risks and case fatalities in the reference scenario, 1985-2000

	Exposure	Injury risk	Case fatality
Activity			
- travelling by passenger car	+	-	
- travelling by moped	0/-	+/0	
- cycling	+/0	0/-	
- walking	0	0/-	
- other travelling	0	0/-	
- working in agriculture, manufacturing or building trade	0/-	0/-	
- working in the service sector	0	0	
- housekeeping	0/-	0	
- do-it-yourself-activities	+	+	
- other activities at home	0	0	
- outdoor activities	0	0	
- sports	+/0	+/0	
- other leisure activities	+/0	0	
Type of injury			
- skull fractures and intracranial injuries			0
- internal injuries of chest, abdomen, and pelvis			0/-
- fractures of the lower extremity			-
- other fractures, luxations, distortions and contusions			0/-
- other injuries			0/-

Key: + = +3% per year; +/0 = +1.5% per year; 0= +0% per year; 0/- = -1.5% per year; - = -3% per year

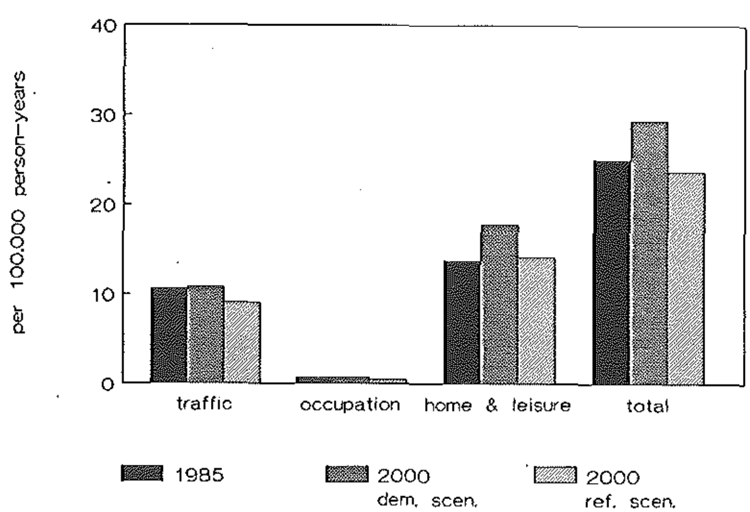
Less manpower will be required in hazardous jobs (manufacturing, agriculture, building trade) due to widespread automation of work. In addition, occupational injury risks will decrease due to the availability of new technologies for controlling work-related injury. Home and leisure injury will show a more unfavourable development. Most Delphi experts believe that activities with relatively high injury risks (do-it-yourself-activities, sports and other leisure activities) will grow in importance and that within these activities there will be a shift to the more risky ones (leading to even higher injury risks). According to most Delphi experts case fatality will decrease for all types of injury, except injury of the central nervous system. Progress in medical technology is the most important factor influencing this development.

Injury mortality resulting from the developments described above can be calculated with the help of the computer model (Fig. 4.2.1).

Figure 4.2.1 presents the mortality in the fields of traffic injuries, occupational injuries, home and leisure injuries and the sum of all injuries in 3 different situations: the situation in 1985 (left bars), the situation in the year 2000 according to the demographic scenario (middle bars) and the situation in the year 2000 according to the reference scenario (right bars).

Figure 4.2.1

Mortality caused by traffic injuries, occupational injuries and home and leisure injuries in 1985 and the year 2000 (demographic scenario, reference scenario)



It is clear that if the reference scenario is fulfilled, injury mortality will remain almost at the level of 1985. Experts anticipate both favourable and unfavourable developments. Moreover, the aging of the population will tend to increase injury mortality.

Alternative autonomous scenarios

Apart from the reference scenario, 4 alternative autonomous scenarios were constructed. Two scenarios were built on alternative assumptions about economic growth: a high growth scenario and a stagnation scenario. These scenarios describe what will happen according to more than two-thirds of the Delphi panellists in case of an annual economic growth of 4% and 0%, respectively. The high growth scenario is characterized by unfavourable developments in the area of traffic injuries and occupational injuries. The amount of traffic for instance, is thought to rise even faster than in the reference scenario. Moreover, injury risks will rise because people will show a higher level of risk acceptation. This scenario will hardly influence the field of home and leisure injuries. The stagnation scenario is characterized by unfavourable developments within all 3 subcategories. Because of the poor economic situation, technologies that would be able to improve traffic and occupational safety will not penetrate on a large scale. Injury risks at home will rise because of poor living conditions. In addition, a lack of progress in the field of medical technology will ensure that the case fatality is not reduced for any type of injury.

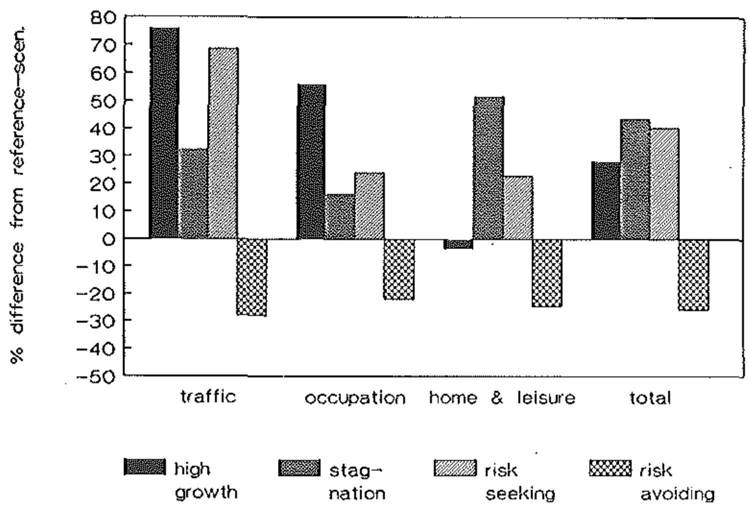
Two scenarios were built on alternative assumptions about risk behaviour: a risk-seeking scenario and a risk-avoiding scenario. These scenarios reflect what will happen if socio-cultural changes characterized by a substantial increase or decrease of the level of risk acceptation in society occur. The risk-seeking scenario assumes that, because of the favourable trends in the recent past, risk consciousness will decrease, leading to a tremendous increase in risk behaviour in society. (A minority of the Delphi experts believes that this is the most likely scenario.)

The risk-avoiding scenario assumes that risk consciousness will increase, causing people to avoid hazardous activities such as motor vehicle driving, sports and do-it-yourself-activities.

The effects of the alternative autonomous scenarios on injury mortality by the year 2000 are shown in figure 4.2.2, which illustrates the differences between these scenarios and the reference scenario. It is important to keep in mind that in the reference scenario, injury mortality remains almost at the level of 1985.

Figure 4.2.2

Mortality caused by traffic injuries, occupational injuries and home and leisure injuries in the year 2000, according to 4 alternative autonomous scenarios



In 3 of the 4 alternative autonomous scenarios injury mortality will tend to rise. The high growth scenario is characterized by unfavourable developments in the fields of traffic and occupational injuries. In the stagnation scenario the unfavourable development in the field of home and leisure injuries would appear to be the most important factor. Special attention for traffic injuries is called for in the risk-seeking scenario. Only the risk-avoiding scenario has a better outcome than the reference scenario.

Health policy scenarios

In order to demonstrate to health policy makers the potential effects of alternative strategies, 3 scenarios were generated assuming different types of policy measures.

The injury prevention scenario consists of a great number of preventive policy measures, aimed at the reduction of traffic injuries, occupational injuries and home and leisure injuries (table 4.2.3). According to more than two-thirds of the Delphi panellists all these measures can be implemented before the year 2000, and will lead to a reduction of the injury risks in all fields.

Table 4.2.3

The policy measures of the injury prevention scenario

Traffic safety

- Implementation of a national policy in the field of traffic safety education
- Implementation of a national policy to improve the visibility of vehicles
- Continuation of measures aimed at the separation of traffic modes
- Continuation of the removal of "black spots"
- Reduction of the maximum speed in residential areas
- Stimulation of the use of technology which improves traffic safety
- New alcohol legislation aimed at a reduction of alcohol distribution and alcohol consumption

Occupational safety

- Introduction of the duty for companies with more than 500 employees
  - to compose an annual occupational safety plan
  - to develop an occupational safety service
- Extension of the Working Conditions Act to include the whole working population
- Extension of the capacity and the powers of the labour inspection
- Introduction of legislation regulating working with toxic substances
- Extension of the powers of works councils where problems of occupational safety are concerned
- Development of a consultancy for small and medium-sized businesses
- Introduction of the duty for companies with potential dangers for their environment
  - to report and registrate all system failures and near-accidents
  - to perform risk analyses
- Introduction of legislation in the field of risk liability

Home and leisure safety

- Implementation of a national policy plan in the field of safety education
- Introduction of safety education at primary schools
- Development of safety requirements for the products that are most often involved in injuries
- Introduction of legislation in the field of "product-recall"
- Introduction of legislation in the field of "product-liability"
- Extension of the capacity and responsibility of the inspection services
- Stimulation of the development of safety hallmarks
- Improvement of information about consumer products
- Introduction of legislation aimed at child proof safety packaging of drugs
- Taking into account which effect drugs can have in case of overdosing, when considering a permit for a new drug
- Adaptation of the rules of some sports in order to meet safety requirements
- Improvement of information about the prevention of sports injuries

The medical care scenario consists of a number of measures aimed at the improvement of the organization of the care for trauma victims (Table 4.2.4). According to more than two-thirds of the Delphi panellists these measures can be implemented before the year 2000, and will lead to a reduction of the case fatalities of all types of injury (including injuries of the central nervous system). Most of these measures are derived from other countries (U.S.A., West Germany), reporting favourable experiences with them, both in respect of prehospital care[16-19] and hospital care.[20-23]

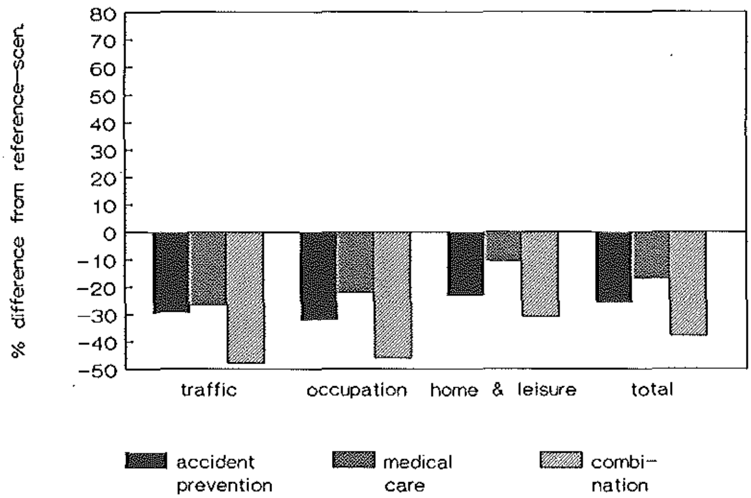
Table 4.2.4

The policy measures of the medical care scenario
- Introduction of a nation-wide emergency phone number - Introduction of the requirement that every ambulance is staffed with at least one qualified nurse with supplementary training in the care of trauma victims - Development of treatment protocols for ambulance attendants - Clustering of the facilities in hospitals that are needed in the process of diagnosis and treatment of trauma victims - Obligatory presence in hospitals of a medical staff member who coordinates all actions around trauma victims - Regionalization of trauma care

The combination scenario assumes the implementation of both the measures relating to the injury prevention scenario and to the medical scenario, leading to the reduction of both injury risks and case fatalities. Figure 4.2.3 shows that the 3 health policy scenarios all lead to a substantial reduction of injury mortality.

Figure 4.2.3

Mortality caused by traffic injuries, occupational injuries and home and leisure injuries in the year 2000, according to 3 health policy scenarios



4.2.4 DISCUSSION

Expectations on autonomous developments

The reference scenario shows very clearly that Dutch health policy makers must take both favourable and unfavourable developments into account. Experts expect progress in the field of (medical) technology. On the other hand, unfavourable trends are anticipated. Some examples are the consequences of ageing of the population, a rising amount of traffic and a growing participation in hazardous sports and other leisure activities. In this scenario, injury mortality remains at the level of 1985.

The reference scenario can be used in answering the question whether it would be possible to reach the 25%-reduction of injury mortality between 1980 and the year 2000, aimed at by the WHO. When attempting to answer this question, it should be borne in mind that between 1980 (the base year of the WHO-targets), and 1984 (the year of adoption of those targets), injury mortality in the Netherlands had already dropped by 17%. If the reference scenario is fulfilled, the total reduction of injury mortality between 1980 and 2000 would be 20%. From the perspective of the "Health for all"-strategy this seems a very reasonable result, which could be reached without any interference.

An important consideration is, however, that between 1985 and 2000 hardly any further reduction of this major health problem would be realized, making it essential to adjust the WHO target. Aiming at a 25%-reduction of injury mortality between 1985 and the year 2000 should be recommended for the Netherlands.

The reference scenario is not the only possible autonomous scenario. Health policy makers can be confronted with conditions leading to even more unfavourable outcomes. Both rapid economic growth and economic stagnation would lead to a substantial rise in injury mortality. Moreover, the level of risk acceptation in society might increase, also leading to a rise in injury mortality. A scenario assuming the avoidance of hazardous activities, however, would lead to a decline in injury mortality.

The alternative autonomous scenarios show the necessity of continuous monitoring in this field. Through continuous monitoring, undesired effects can be discovered at an early stage of their development, allowing health policy makers to change their strategy in time.

Possible strategies to reduce injury mortality

Three health policy scenarios offer the elements for possible strategies to reduce injury mortality between 1985 and the year 2000.

The first possible strategy is injury prevention. Dutch health policy has a tradition in this field. Probably because of this tradition, injury mortality in the Netherlands is already low compared with other industrialized countries. Despite this, it is believed that the number of injuries can still be greatly reduced. According to experts, a forceful approach consisting of new measures aimed at the improvement of road behaviour, road vehicles and road environment will lead to further impressive reductions of road traffic casualties. Occupational injury mortality can be further reduced by implementing new measures within the framework of recent legislation in this field (Working Conditions Act 1980). Home and leisure injury mortality can be reduced by a number of initiatives aimed at improving human behaviour and product safety.

According to calculations based on the experts' estimates, a combination of all these measures could lead to a 30%-reduction of injury mortality between 1985 and the year 2000.

A second strategy lies in the field of medical care for injury victims. The results of the scenario project show that experts expect much from an improvement of the Dutch system of trauma care. This system has been criticized.[24]

Minimal qualifications required for the professionals delivering medical care on the spot of the accident and during transport (ambulance attendants) are one of the features of the Dutch system. Another is that most patients are transported immediately to the nearest hospital (even if this hospital lacks the facilities which are needed, such as a neurosurgery department in case of injury of the central nervous system).

These characteristics show that in the Netherlands the field of medical care for injury victims - contrary to the field of injury prevention - is not very well developed in comparison with other countries.

For that reason a new system of trauma care is proposed which is based on experiences from abroad (U.S.A., West Germany). The proposed new system has as most important features that all ambulance attendants must be highly trained and skilled and that hospital trauma care is regionalized. In a system of regionalized trauma care all critically injured patients will be transported immediately to hospitals equipped with all facilities needed. Experts believe that trauma victims - especially those with injuries to the central nervous system - will benefit highly from the new approach.

Calculations based on the experts' estimates show that by implementing this strategy a 20%-reduction of injury mortality between 1985 and the year 2000 could be reached, especially by its impressive effects on traffic accident mortality.

The third strategy combines new measures in the field of injury prevention with an improvement of the system of trauma care. By implementing this strategy a 40%-reduction of injury mortality between 1985 and the year 2000 could be reached.

It can be concluded from the above that if one aims at a 25%-reduction of injury mortality between 1985 and 2000, several strategies can be chosen.

The results of the scenario project, however, do not make clear which strategy should be preferred. Although the calculations show that the injury prevention scenario has greater effects than the medical care scenario this information is not sufficient to set priorities. A point requiring further attention is the lack of knowledge about the cost-effectiveness of the different strategies. For this reason cost-effectiveness analyses in this area are recommended.

Injury mortality after the year 2000

The strategies discussed above are meant to reduce the problem of injury mortality before the year 2000. However, even if a strategy is chosen which combines new measures in the field of injury prevention with improvements in the field of medical care, the problem of injury mortality will not be solved by the year 2000; our calculations show that in the Netherlands over 2200 people will still be killed by accidental injuries each year. This demonstrates the need for a strategy aiming at a further reduction of this health problem after the year 2000. Because of the long time-lag between development and implementation of policy measures, this strategy should be prepared in the coming years.

In the first place, policy measures which influence exposure to injury risks should be considered. The injury prevention scenario does not contain measures of this type, because it is believed that they cannot be implemented before the year 2000. Because of their influence on the beginning of the "chain" leading to injury mortality, these measures could be very effective. For example, less hazardous traffic modes, sports or other leisure activities could be stimulated.

In the second place legislation could be prepared which permits products to penetrate the consumer market only if they contain all available safety technology. An example of such a product is the so-called "research safety vehicle". This is a motor vehicle into which all available technology in the fields of crash avoidance, side crash protection and the protection of pedestrians has been built.[25]

In the third place, initiatives are needed that will provide health policy makers with better facilities for decision making. Registration of injuries and their consequences should be improved. The pace at which changes occur makes a continuous monitoring of developments in this field essential. In the process of long-term health planning, the generated scenarios can be a very important tool. These scenarios draw attention to undesired effects at an early stage of their development.

In order to formulate effective strategies for the long term, it is necessary to increase te scientific knowledge about this health problem. Finally, cooperation between health policy makers responsible for different subareas should be stimulated.

Concluding remarks

Possible future developments in injury mortality in the Netherlands were explored with the help of scenario analysis. The results of the project are mainly based on "speculations" by a great number of Dutch experts. For that reason they do not "predict" the future. Nevertheless, they provide health policy makers with an important tool for long-term health planning.

In the first place, uncertainty about the future is partly reduced. Knowledge about the possible effects of different sets of "autonomous" conditions has become available. This information can stimulate health policy makers to develop strategies which will turn autonomous conditions with undesired effects into "self-denying prophecies".

Secondly, a great number of Dutch experts has formulated an opinion on the possible effects of different strategies aimed at a further reduction of injury mortality. This information can also be of value. Expert opinion can be taken into account when discussing possible strategies.

In the third place, the scenarios that were generated can be used as part of an "early warning system". Continuous monitoring facilitates unfavourable trends and their causes to be detected at an early stage in their development, allowing health policy makers to react in time.

It may be concluded that health policy makers have been provided with information which might help them in decision making. The future will show whether this information has contributed to a reduction of injury mortality in the Netherlands.

REFERENCES

1. Committee on Trauma Research. Injury in America: a continuing public health problem. National Academy Press: Washington DC; 1985.
2. European Conference of Ministers of Transport. Statistical report on road accident trends in 1984. Paris: OECD; 1986.
3. de Geus GH. An inventory of surveillance systems and studies on home and leisure accidents in the European Community. Amsterdam: ECOSA; 1987.
4. World Health Organization. Targets for health for all. Copenhagen: WHO Regional Office for Europe; 1985.
5. Steering Committee on Future Health Scenarios. STG: Structure and terms of reference. Utrecht: Uitgeverij Jan van Arkel; 1986.
6. Banta HD, Gelijns AC, Griffioen J, Graaf PJ. An inquiry concerning future health care technology: methods and general results. Health Policy 1987;8:251-264.

7. Hollander CF, Becker HA. (eds.). Growing Old in the Future. Dordrecht: Martinus Nijhoff; 1985.
8. Dunning AJ, Wills WIM (eds.). The Heart of the Future, the Future of the Heart. Dordrecht: Martinus Nijhoff; 1986.
9. Lapré RM, Mackenbach JP (eds.). Ongevallen in het jaar 2000; Scenario's over Ongevallen en Traumatologie 1985-2000. Utrecht/Antwerpen: Bohn, Scheltema en Holkema; 1988.
10. Brouwer JJ, Schreuder RF (eds.). Scenarios and Other Methods to Support Long-Term Health Planning. Utrecht: Uitgeverij Jan van Arkel; 1986.
11. Schnaars SP. How to develop and use scenarios. Futures 1986;10:122-142.
12. Linstone HA, Turoff M. The Delphi-Method; Technique and Applications. Addison Wesley, MA, 1985.
13. Martino JP, Delphi. In: Martino JP. Technological Forecasting for Decision making. New York: American Elsevier; 1972.
14. Cruijssen HGJM. Bevolkingsprognose voor Nederland 1985-2035. (Population forecast for the Netherlands, 1985-2035, in Dutch) Maandstat Bev CBS 1986;3:33-41.
15. Centraal Planbureau. De Nederlandse economie op de langere termijn. (The economy of the Netherlands in the future, in Dutch). Den Haag: CPB; 1985.
16. Copass MK, Oreskovich MR, Bladergroen MR, Carrico CJ. Prehospital cardiopulmonary resuscitation of the critically injured patient. Am J Surg 1984;148:20-26.
17. Fortner GS, Oreskovich MR, Copass MK, Carrico CJ. The effects of prehospital trauma care on survival from a 50-meter fall. J Trauma 1983;23:976-981.
18. Jacobs LM, Sinclair A, Beiser A. Prehospital advanced life support: benefit in trauma. J Trauma 1984;24:8-13.
19. Oestern HJ. The German model for rescue of traumatized patients. Can J Surg 1985;28:486-489.
20. Becker DP, Miller JD, Ward JD, Greenberg RP, Young HF, Sakalas R. The outcome from severe head injury with early diagnosis and intensive management. Journal of Neurosurgery 1977;47:491-502.
21. Ornato JP, Craven EJ, Nelson NM, Kimball KF. Impact of improved emergency medical services and emergency trauma care on the reduction in mortality from trauma. J Trauma 1985;25:575-579.
22. West JG, Trunkey DD, Lim RC. Systems of trauma care; a study of two counties. Arch Surg 1979;114:455-460.
23. West JG, Cales RH, Gazzaniga AB. Impact of regionalization; the Orange county experience. Arch Surg 1983;118:740-744.
24. Draaisma JMTh. Evaluation of Trauma Care (thesis). Meppel: Krips Repro; 1987.
25. Robertson LS. Motor vehicle injuries. Public Health Reports 1985;100:580-581.

4.3

ABSTRACT

Health policy needs effective public health surveillance systems. In order to support injury control in the Netherlands, we established a surveillance system which monitors trends in the epidemiology of injuries due to traffic accidents, occupational accidents and home and leisure accidents. We introduced the combination of traditional monitoring methods with a new tool: the use of future health scenarios. Trends in the epidemiology of injuries since 1985 were compared to observations from the preceding period (1970-1985) and to future health scenarios (1985-2000). These scenarios were based on the opinions of 80 Dutch experts, which had been collected with the help of a Delphi study. We identified interruptions of the actual injury mortality trends in the Netherlands. In the second half of the 1980s the rapidly declining injury mortality trends of the period 1970-1985 slowed down (traffic accidents), slightly reversed (occupational accidents) or stabilized (home and leisure accidents). The transitions into less favourable developments were foreseen by Dutch experts. The future health scenarios appear to have added value for health policy. They offer a well-defined conceptual framework for monitoring and facilitate the early detection of trend interruptions. Moreover, they provide information on the most likely future development and on the feasibility of health policy goals. The results of our study show that health policy goals of the Dutch government will not be reached and that new initiatives in injury control are needed.

4.3

Future health scenarios as a tool in the surveillance of unintentional injuries: an evaluation

4.3.1 INTRODUCTION

The recognition of unintentional injuries as a major health problem in industrialized countries[1,2] has led to the need for developing surveillance systems in this area.

Unintentional injuries are injuries sustained by the victims of traffic accidents, occupational accidents and home and leisure accidents. They are caused by sudden events which were not intended to happen. They must be distinguished from intentional injuries, which are either self-inflicted (suicide and attempted suicide) or the result of deliberate harm by other people (homicide and assault).[3]

Surveillance, which is one of the main activities of public health, might be defined as "the ongoing systematic collection, analysis and interpretation of health data essential to the planning, implementation and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know".[4]

It is an important instrument for health policy makers, for it serves the assessment of the burden of disease in society, helps in identifying changes of disease frequency, and generates hypotheses on the main determinants of these changes. In this way it has the potential to suggest hypotheses for etiologic research as well as of triggering control activities.[5]

Public health surveillance has its origin in the field of infectious diseases.[6,7] Important applications are employed in this area, as illustrated by the worldwide use of surveillance systems for influenza mortality[8] or AIDS.[9] For many other public health problems, however, surveillance systems have also been established, such as, for example, in the fields of congenital malformations,[10-12] cardiovascular diseases,[13,14] cancer[15-17] and unintentional injuries.[18-20]

In all these areas, public health surveillance systems have in common that they primarily aim at detecting changes in disease frequency.[4] This main element might be described as trend monitoring. It is the process of data collection and analysis in order to detect and explain any unexpected deviation in disease trends.[21] Monitoring may lead to the identification of trend interruptions or even reversals. In making these identifications, the use of statistical methods is of great value.[22-28]

This article reports the findings of a public health surveillance system in the Netherlands which has monitored trends in the area of traffic accidents, occupational accidents and home and leisure accidents since 1985. This system combines traditional monitoring methods with a new tool: the use of future health scenarios. This combination was introduced because we assumed that it could make monitoring more effective from a health policy perspective. The initiative for this surveillance system was taken by the Dutch Steering Committee on Future Health Scenarios, subsequent to an investigation into possible future developments.[29] The results of this investigation were reported earlier in an article offering information on anticipated developments in the Netherlands in the period 1985-2000.[30]

The present article reports the results of analyses which addressed the following questions:

- which trends can be observed in the numbers of injuries and deaths due to traffic accidents, occupational accidents and home and leisure accidents in the Netherlands since 1985?
- how do these trends compare with trends of the preceding period (1970-1985) and to anticipated developments (1985-2000)?
- which factors could explain any differences between the development of injuries and deaths since 1985 and trends of the preceding period (1970-1985) or anticipated developments (1985-2000)?
- what is the most likely future development of the frequency of injuries and deaths in the Netherlands?
- what are the implications of the observed developments for injury control in the light of health policy goals in this area?

4.3.2 DATA AND METHODS

Surveillance data

The Netherlands has a long tradition for collecting injury data. Our public health surveillance system is primarily based on the different data sources which are available.

First of all, mortality data can be derived from national cause-of-death statistics, including all types of unintentional injuries.[31] These mortality data stretch across decades, and are still of principal value in injury surveillance.

Unlike the situation in the field of many other diseases, mortality figures are not the only available surveillance data. The ongoing systematic collection of data on the incidence of traffic injuries and occupational injuries started over 40 years ago already,[32,33] and was more recently extended to home and leisure injuries.[34] In addition, some data are available on the exposure to injury risks, such as the traffic mobility data derived from annual mobility surveys[35] and employment figures.[33]

Our public health surveillance system uses data from all the sources mentioned above. By combining data from these different sources detailed analyses can be made. This is done with the help of a conceptual model of the processes behind accidental injuries and deaths, which distinguishes the following levels of explanation.

Developments in mortality (the number of accidental deaths per 100.000 person-years) are the result of developments in the incidence of injuries (the number of injured people per 1000 person-years) and developments in the case fatality (the number of deaths per 100 injured persons). Trends in the incidence of injuries are based on developments in exposure (e.g. the number of passenger car kilometres per 1000 person-years) and developments in injury risks (e.g. the number of injured people per passenger car kilometre). Trends in exposure, injury risk and case fatality in turn are influenced by demographic, economic, socio-cultural and technological developments (all "autonomous" from the point of view of health policy makers), as well as by policy measures aimed at the prevention of injuries or the improvement of trauma care.

Scenario construction

With the help of the aforementioned model, expectations on possible future developments had been generated in the first phase of our project[30]. These anticipated developments play an important role in our public health surveillance system. Expectations on the future had been generated with the help of a Delphi study,[36-37] which sampled the opinions of 80 Dutch experts. Four panels of 20 experts each had been formed in the following areas: traffic safety, occupational safety, home and leisure safety and trauma care. These experts were asked to give quantitative estimates of developments in the following parameters in the epidemiology of injuries between 1985 and 2000: exposure by type of activity, injury risk per unit of exposure and case fatality by type of injury.

They had to express their opinions under varying assumptions on autonomous background factors (i.e. demographic, economic, socio-cultural and technological trends) and health policy efforts (i.e. level of activities with respect to injury prevention and organization of trauma care).

The results of this Delphi study were first of all used to construct a "reference scenario". This scenario builds on the combination of autonomous and policy developments to be regarded as "most likely" according to the interrogated experts.

Main assumptions of this scenario for the period 1985-2000 were:

- a slight ageing of the population (an increase of the proportion of elderly people from 12% to 14%)
- a modest economic growth of 1.5% per year on the average
- no alterations in risk behaviour in society
- rapid progress in safety enhancing technology and medical technology
- absence of new policy measures in injury prevention and organization of trauma care.

We were able to calculate the net effects of this scenario on public health indicators at the population level (e.g. the crude accident mortality rate) with the help of a computer model, which used the quantitative estimates of the Delphi panels on specific epidemiological parameters as its input.[29] Apart from the reference scenario, a number of scenarios with a lower probability could be constructed as well. These scenarios differ from the reference scenario in either their expected level of economic growth (high growth scenario, stagnation scenario), or their anticipated development of risk behaviour in society (risk seeking scenario, risk avoiding scenario), or their implementation of policy measures (prevention scenario, medical care scenario, combined prevention/medical care scenario).

The construction of scenarios in the first phase of our project led to the conclusion that developments in the epidemiology of injuries should probably be less favourable between 1985 and 2000 than in the preceding period. Without health policy intervention, no further substantial declines in deaths and injuries due to traffic accidents, occupational accidents and home and leisure accidents were anticipated.[29,30]

Trend monitoring

The analyses of our surveillance system, as reported in this article, were performed in the following way. First of all, both the mortality and the incidence of injuries due to traffic accidents, occupational accidents and home and leisure accidents were calculated (with 95% confidence intervals) for each separate year from 1985 until 1994. These figures were compared to observations made in the preceding period (1970-1985) as well as to anticipated developments (1985-2000, according to the reference scenario and the other abovementioned scenarios). The figures were not adjusted for changes in the demographic composition of the population. From a health policy perspective the crude rates must be preferred above the adjusted rates because they better indicate changes in the burden of disease in society.

Possible changes in temporal trends of accidental injuries and deaths were identified by comparing mean annual changes in different time periods. Mean annual changes were calculated by dividing the sum of the changes of each separate year by the number of years in that period. In order to obtain information on the factors which could be responsible for these changes more detailed analyses were performed. In the area of traffic accidents, the mean annual changes of the exposure, injury risk and case fatality by mode of transport were calculated (for passenger car occupants, moped riders, cyclists, pedestrians, and users of other modes of transport). In the field of occupational accidents more detailed analyses were performed by branch of industry (for workers in manufacturing/construction and the service sector respectively). Lack of data on the exposure to injury risks by type of activity made it impossible to apply the same procedure in the area of home and leisure accidents. Developments in this field were somewhat further analyzed by distinguishing different age categories.

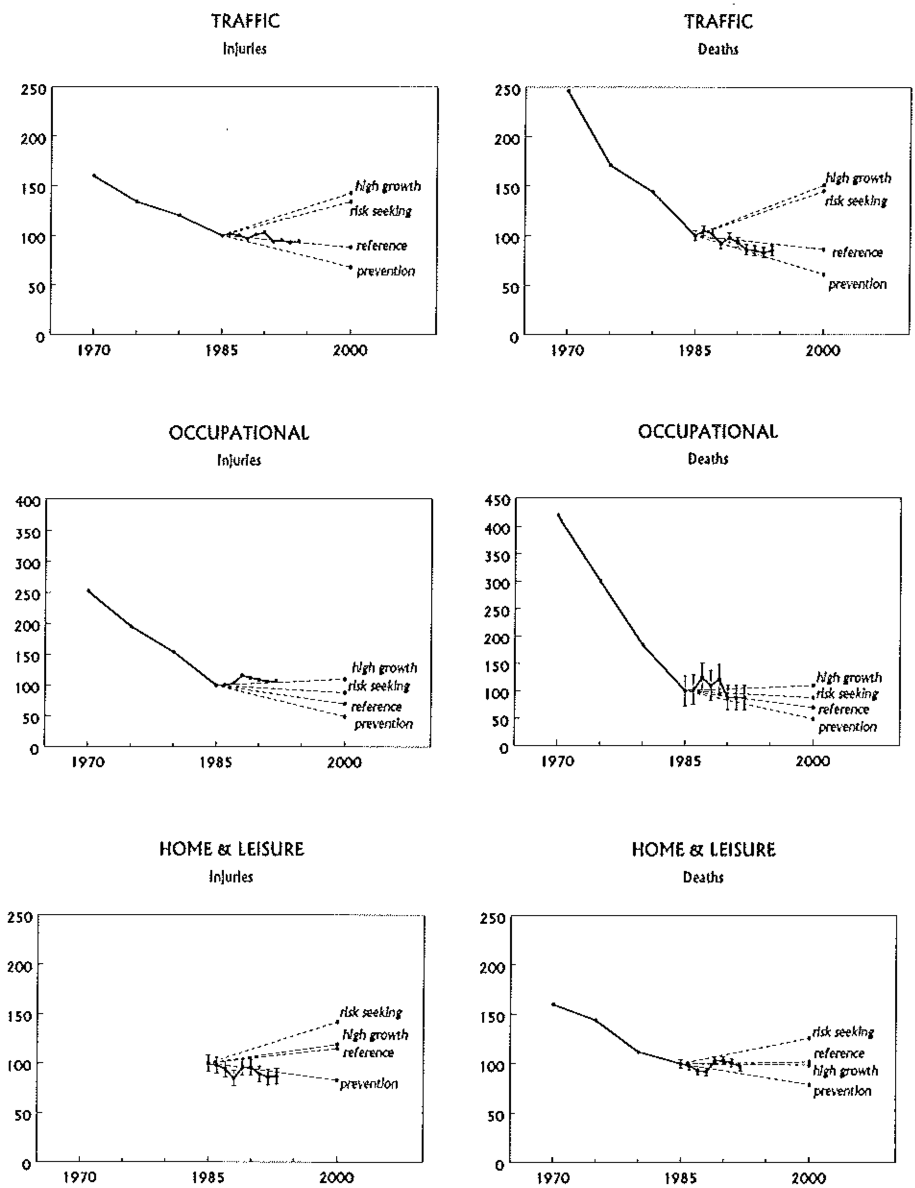
4.3.3 RESULTS

Figure 4.3.1 is composed of a set of graphs showing trends in both the incidence of injuries and the mortality due to traffic accidents, occupational accidents and home and leisure accidents. The figures shown in these graphs are all indexed at the level of 1985, which is the base year of the future health scenarios. An occupational accident mortality level of more than 400 in 1970, for example, means that in that specific year occupational accident mortality was more than 4 times as high as in 1985. The figure shows that between 1970 and 1985, tremendous drops occurred in the levels of injuries and deaths from accidents in the Netherlands. According to the "most likely" or reference scenario, the rapidly declining trends in traffic and occupational injuries and deaths throughout the period 1970-1985 were expected to level off between 1985 and 2000. And in the field of home and leisure accidents, growing numbers of injuries and deaths were anticipated. In addition to the effects of the reference scenario, figure 4.3.1 shows the results of two even more unfavourable possibilities: the high growth scenario and the risk seeking scenario. Moreover, the results of the prevention scenario are shown, which are based on experts' estimates of the effects of possible preventive strategies.

The actual developments in the epidemiology of injuries since 1985 are quite interesting, both in comparison to trends of the preceding period (1970-1985) and to anticipated developments (1985-2000). Figure 4.3.1 shows that recent trends in both the incidence of injuries and the accident mortality in general are less favourable than in the period 1970-1985. In the area of traffic accidents the number of injuries has decreased only gradually since 1985. Traffic accident mortality shows a somewhat more favourable trend (a mortality reduction of 3% per year), which however also implies a change as compared to the rapidly declining figures of the preceding period (a mortality decline of 6% per year). A change in temporal trend was also observed in the area of occupational accidents, an area in which the number of injuries and deaths has failed to drop any further since the second half of the 1980s. The field of home and leisure accidents shows striking differences between developments in the incidence of injuries and developments in accident mortality. The incidence of injuries in this area has fallen since 1985. Accident mortality, on the contrary, has more or less remained at the level of 1985, which is a change in comparison to the declining figures (mortality reductions of 3% per year) of the preceding period.

Figure 4.3.1

Comparison of trends in traffic, occupational and home and leisure injuries since 1985 with historical data (1970-1985) and future health scenarios (1985-2000), (figures indexed at 1985, I = 95% confidence interval)



If recent observations are compared to anticipated developments, we find many similarities between the actual trends and the expectations of the "reference scenario", which predicted interruptions of the rapid declines of the preceding period. An important exception to this general observation, however, is the development of the incidence of home and leisure injuries, which has shown a reduction since 1985 instead of the predicted increase.

Table 4.3.1

Mean annual changes (%) of exposure, injury risk, incidence of injuries, case fatality and accident mortality of traffic accidents by mode of transport (in different time periods)

	Exposure (passenger km/ inhabitants)	Injury Risk (injuries/ passenger km)	Incidence of injuries (injuries/ inhabitants)	Case Fatality (deaths/ injuries)	Accident mortality (deaths/ inhabitants)
Passenger car occupants					
-70-85, observed	+2.0	-4.5	-2.5	-2.0	-4.5
-85-94, observed	+1.0	-1.0	0.0	-2.5	-2.5
-85-2000, ref.scen.	+3.0	-3.0	0.0	-1.5	-1.5
Moped riders					
-70-85, observed	-7.5	+2.0	-5.5	-4.5	-10.0
-85-94, observed	-4.0	+2.0	-2.0	0.0	-2.0
-85-2000 ref.scen.	-1.5	+1.5	0.0	0.0	0.0
Cyclists					
-70-85, observed	-1.0	+3.0	+2.0	-5.5	-3.5
-85-94, observed	0.0	-1.5	-1.5	-2.0	-3.5
-85-2000, ref.scen.	+1.5	-1.5	0.0	0.0	0.0
Pedestrians					
-70-85, observed	n.a.	n.a	-5.0	-3.5	-8.5
-85-94, observed	n.a	n.a	-3.5	0.0	-3.5
-85-2000, ref.scen.	n.a	n.a	-1.5	0.0	-1.5
Other traffic					
-75-85, observed	n.a	n.a	-0.5	-4.0	-4.5
-85-94, observed	n.a	n.a	+3.5	+1.0	+4.5
-85-2000, ref.scen.	n.a	n.a	-1.5	0.0	-1.5

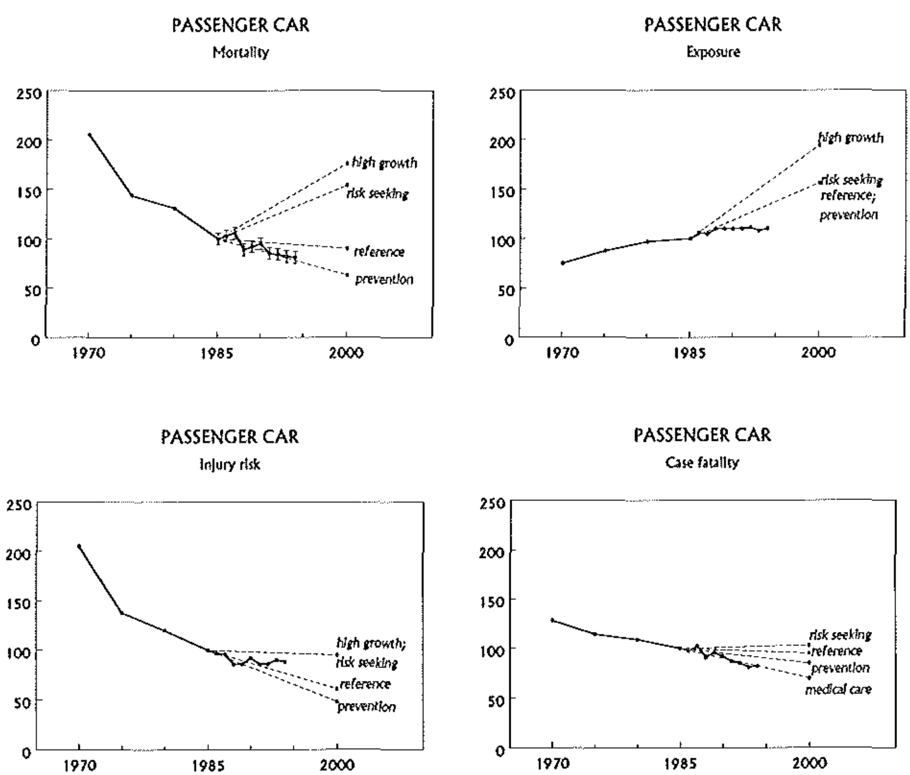
n.a. = not available ref.scen. = reference scenario

Results of more detailed analyses in the field of traffic accidents are summarized in table 4.3.1, which offers a picture of the mean annual changes of several parameters in different time periods. The table shows the specific developments which caused the rapid decline of traffic accident mortality to level off recently.

It appears that since 1985, all modes of transport, with the exception of cyclists, show less favourable developments in accident mortality than in the preceding period. The main factors behind these trend alterations differ according to mode of transport. A major factor in the case of passenger car occupants is the fact that the injury risk no longer exhibits the spectacular decrease of the period 1970-1985. Noteworthy in the case of moped riders, pedestrians and "other traffic" is the fact that no further declines in case fatality were observed.

Figure 4.3.2

Comparison of trends in mortality, exposure, injury risk and case fatality of passenger car occupants since 1985 with historical data (1970-1985) and future health scenarios (1985-2000), (figures indexed at 1985, I = 95% confidence intervals).



Although many of the observed developments were more or less anticipated, in general the actual trends since 1985 tend to be somewhat more favourable than the expectations. The specific trends with respect to passenger car occupants have been made visible in figure 4.3.2, which clearly shows differences and commonalities of actual trends with expected trends according to the reference scenario. The figure shows that the injury risk of passenger car occupants ceased to decline at the end of the 1980s.

Table 4.3.2 shows specific developments in the field of occupational accidents. It illustrates a "trend interruption" in different branches of industry. This is based on increasing employment figures in combination with injury risks showing more gradual decreases than observed in the period 1970-1985. The trend interruptions in this area were already foreseen by experts.

Table 4.3.2

Mean annual changes (%) of exposure, injury risk, incidence of injuries, case fatality and accident mortality of occupational accidents by branch of industry (in different time periods)

	Exposure (workers/ inhabitants)	Injury Risk (injuries/ workers)	Incidence of injuries (injuries/ inhabitants)	Case Fatality (deaths/ injuries)	Accident mortality (deaths/ inhabitants)
Manufacturing/Construction					
-70-85, observed	-3.0	-4.5	-7.5	-0.5	-8.0
-85-94, observed	+1.0	-1.5	-0.5	0.0	-0.5
-85-2000, ref.scen.	-1.5	-1.5	-3.0	0.0	-3.0
Service sector					
-70-85, observed	+0.5	-3.0	-2.5	-7.5	-10.0
-85-94, observed	+4.5	-1.5	+3.0	-2.0	+1.0
-85-2000, ref.scen.	+1.5	-1.5	0.0	0.0	0.0

ref.scen. = reference scenario

Table 4.3.3 shows that in the area of home and leisure accidents the favourable mortality trends of the period 1970-1985 have continued after 1985, with the exception of the elderly. In the case of people under the age of 65 years, mortality trends are far more favourable than expected in the reference scenario. This is based on rapidly decreasing numbers of injuries in the population, instead of the increases which were forecasted. For elderly people, however, a slight increase of the incidence of injuries can be observed, which is accompanied by a less favourable development of the case fatality than anticipated.

Table 4.3.3

Mean annual changes (%) of incidence of injuries, case fatality and accident mortality of home and leisure accidents by age (in diferent time periods)

	Incidence of injuries (injuries/inhabitants)	Case fatality (deaths/injuries)	Accident mortality (deaths/inhabitants)
0-14			
-70-85, observed	n.a.	n.a.	-7.5
-85-94, observed	-1.5	-2.0	-3.5
-85-2000, ref.scen.	+1.5	-1.5	0.0
15-24			
-70-85, observed	n.a.	n.a.	-2.0
-85-94, observed	-2.0	-3.0	-5.0
-85-2000, ref.scen.	+3.0	-1.5	+1.5
25-64			
-70-85, observed	n.a.	n.a.	-1.5
-85-94, observed	-1.5	-2.0	-3.5
-85-2000, ref.scen.	+3.0	-1.5	+1.5
65+			
-70-85, observed	n.a.	n.a.	-3.5
-85-94, observed	+1.0	-1.5	-0.5
-85-2000, ref.scen.	+1.0	-3.0	-2.0

n.a = not available ref.scen. = reference scenario

4.3.4 DISCUSSION

In this article findings are reported from a public health surveillance system in the area of unintentional injuries. With the help of this system we could identify interruptions of the actual injury mortality trends in the Netherlands. In the second half of the 1980s the rapidly declining injury mortality trends of the period 1970-1985 slowed down (traffic accidents), were slightly reversed (occupational accidents) or stabilized (home and leisure accidents). The surveillance system offers information on specific subcategories, where unfavourable trends are met, and affords an impression of the mechanisms behind these unfavourable trends. We see, for example, that passenger car occupant mortality has displayed a less favourable trend since 1985 than in the preceding period. This is largely based on adverse developments relating to the injury risks of this mode of transport, which ceased to become smaller in recent years.

The above demonstrates that our surveillance system has the potential to produce valuable health policy information. One of the main results is the identification of trend interruptions. When using this information, the fact that injury surveillance is based on routinely collected data should be kept in mind. Important data are derived from injury reporting systems based on police records[32] or occupational registers.[33] It is known that these systems may suffer from underreporting as well as from changing registration procedures over time.[38-40] In our study, however, trend interruptions could be identified with different data sources (e.g. police records and cause-of-death statistics). It is therefore highly unlikely that the reported developments are based on registration artefacts.

As we mentioned in the introduction, unintentional injuries must be distinguished from intentional injuries. In some cases this leads to registration error (e.g. a suicide by passenger car may be registered as a traffic accident if the authorities do not discover the intentional character of the event). It is very unlikely that this type of registration error has affected the main results of our surveillance system. The unfavourable developments reported in the field of unintentional injuries since 1985 were accompanied by slight decreases in the suicide figures.[41] And in spite of recent increases, homicide and assault comprise too small a proportion in the total incidence and mortality due to injuries in the Netherlands (3%) to exert a significant influence on the trends of the other categories.[41] If recent developments in the fields of both unintentional and intentional injuries are included it can be observed that the total burden of morbidity and mortality due to injuries in the Netherlands has more or less stabilized since 1985.[41]

4.3

We introduced a new tool in the surveillance of unintentional injuries: working with future health scenarios. In our view, this tool has a fourfold added value.

First of all, it offers a well-defined conceptual framework at the start of the monitoring activities. This conceptual framework helps to find and explain trend interruptions by establishing the respective contributions of trends in exposure, injury risk and case fatality by type of activity, and by assessing the role of important background factors (like demographic trends, technological developments and policy initiatives). With the help of available scenarios hypotheses on the main determinants of observed trends can rapidly be generated.

The conceptual framework has led, for example, to the identification of an unfavourable trend in the injury risks of passenger car occupants. Comparison with the scenarios shows that the actual trend in injury risk does not follow the prevention scenario (which assumes new preventive policy measures to be implemented) nor the reference scenario (which assumes rapid progress in safety enhancing technology). This comparison leads to the hypothesis that the unfavourable development of the injury risk of passenger car occupants could be the result of absence of new preventive measures in combination with too little progress in the implementation of new safety enhancing technology. This seems an important health policy issue which should be further analyzed.

Working with a well-defined conceptual framework as explained above, however, is not specific to the use of future health scenarios. More specific is the following added value to be mentioned. Future health scenarios may fulfill the function of an "early warning system". From a health policy perspective it is important to detect unfavourable trends and their determinants at an early stage of their development. We have found some indications that the availability of scenarios might indeed lead to the more early detection of trend interruptions. In our case, the future health scenarios did predict the evolution of trend interruptions. Therefore, in our first disseminations of surveillance results to health policy makers[42,43] we interpreted the available data (which were only dealing with developments until 1989) as "first signs" of possible trend interruptions. At the same time other documents, which were based on traditional monitoring or trend extrapolations[44,45] still reported a continuation of the favourable developments of the 1980s. This shows that future health scenarios might stimulate the early detection of trend interruptions by offering an "alternative framework of thought" in addition to knowledge on past trends.

In principle, this is a major advantage of the use of future health scenarios in addition to traditional monitoring. One must consider, however, that apart from raising true positive alarm signals, the method might produce "false alarms" as well. In the dissemination of our first results, for example, we especially drew attention to unfavourable trends with respect to cyclists which seemed to develop according to the (pessimistic) expectations of the reference scenario.[43] The results as presented in this article, which are based on a longer monitoring period, show the contrary. Cyclists appear to be the only subcategory in traffic where the favourable trends of the past seem to have continued. This shows that, although future health scenarios have the potential to fulfill the function of an "early warning system", methodological progress still has to be made.

The third advantage of the use of future health scenarios in injury surveillance is its ability to assess the prognosis of this public health problem in the medium and long term. From a health policy perspective this ability is very important, especially if a trend interruption has been detected. Traditional monitoring can only be of limited value in this aspect, in the sense that observed trends in accident mortality and its underlying parameters can be extrapolated into the future. The findings of our surveillance system, however, clearly indicate that in the dynamic area of unintentional injuries actual developments are in most cases not simple extrapolations of past trends. Future health scenarios, as based on expert opinion, seem to offer more valuable information. The comparison of actual developments with a number of future health scenarios provides information on the kind of scenario that is in fact under way. In our case we found many similarities between the actual epidemiological trends and the expectations of the reference scenario. In studying demographic, economic, socio-cultural and technological developments in the Netherlands, we further found that the main assumptions of the reference scenario with regard to these background factors have been correct so far.[41] Moreover, no major new policy strategies have been implemented, just as was assumed in the reference scenario. This means that the findings of our surveillance system still point to the reference scenario as the most likely development for the future, although at some specific points adaption seems necessary (e.g. injury risks in the area of home and leisure accidents). This means that in the near future, important further reductions in both the incidence of injuries and accident mortality in the Netherlands will probably not be achieved without intensifying health policy in this area. This had already been concluded by the end of the 1980s.[29,30]

This result is directly related to the fourth, and probably most important, health policy advantage of the use of future health scenarios in injury surveillance: it offers information on the feasibility of health policy goals. Subsequent to the "Health-for-all by the year 2000"-strategy of the WHO,[46] the Dutch government formulated quantitative health policy goals in many disease areas.[47] In the field of unintentional injuries, the aim of a 25%-reduction of accident mortality between 1985 and 2000 was formulated. Specific goals were formulated for separate types of accidents and for separate age categories.[48] In order to assess the possibility of achieving those goals, injury surveillance is necessary. At this point the use of future health scenarios makes a major contribution, clearly showing that the aims of the Dutch government will probably not be reached. This is a strong indication for the need to intensify injury prevention policies and to implement major improvements in the Dutch system of trauma care.

We conclude that the applied combined approach of using future health scenarios in addition to traditional trend monitoring seems to have added value, whereas it has become clear too, that injury control in the Netherlands needs new initiatives.

REFERENCES

1. Committee on Trauma Research. Injury in America: a continuing public health problem. Washington DC: National Academy Press; 1985.
2. Champion HR, Dunham CM. Trauma, the disease of the 20th century. In: Siegel JH (ed). Trauma; emergency surgery and critical care. New York: Churchill Livingstone; 1987.
3. Baker SP, O'Neill B, Ginsburg MJ, Li G. The Injury Fact Book, second edition. New York: Oxford University Press; 1992.
4. Centers for Disease Control. Comprehensive plans for epidemiologic surveillance. Atlanta: Centers for Disease Control; 1986.
5. Thacker SB, Berkelman RL. Public health surveillance in the United States. Epidemiologic Reviews 1988;10:164-190.
6. Langmuir AD. The surveillance of communicable diseases of national importance. N Engl J Med 1963;268:182-192.
7. Langmuir AD. William Farr: founder of modern concepts of surveillance. Int J Epidemiol 1976;5:13-18.
8. Lui KJ, Kendal AP. Impact of influenza epidemics on mortality in the United States from October 1972 to May 1985. Am J Public Health 1987;77:712-715.
9. Chamberland ME, Allen JR, Monroe JM. Acquired immunodeficiency syndrome. New York, city, evaluation of an active surveillance system. JAMA 1985;253:383-386.

10. Edmonds LD, Layde PM, James LM. Congenital malformations surveillance: two American systems, Int J Epidemiol 1981;10:247-250.
11. Cornel MC, de Walle HEK, ten Kate LP. Ten years of experience with registration of congenital anomalies in the northern Netherlands by EUROCAT; methodology. Tijdschrift voor Sociale Gezondheidszorg 1992;70:637-644.
12. Gallus G, Mandelli C, Marchi M, Radaelli G. On surveillance methods for congenital malformations. Stat Med 1986;5:567-572.
13. Gillum RF, Feinleib M, Margulis JTR. Community surveillance for cardiovascular disease: the Framingham cardiovascular disease survey. Journal of Chronic Diseases 1976;29:289-299.
14. Fortmann SP, Haskell WL, Williams PT. Community surveillance of cardiovascular diseases in the Stanford Five-City Project. Am J Epidemiol 1986;123:656-669.
15. Swerdlow AJ. Cancer registration in England and Wales: some aspects relevant to interpretation of the data. J Royal Stat Soc 1986;149:146-160.
16. Wynne Griffith G. Cancer surveillance with particular reference to the use of mortality data. Int J Epidemiol 1976;5:69-76.
17. Coebergh JWW. Incidence and prognosis of cancer in the Netherlands: studies based on cancer registries (thesis). Rotterdam: Erasmus University; 1991.
18. Ing RT. Surveillance in injury prevention. Public Health Reports 1985;100:586-588.
19. Berkelman RL, Herndon JC, Vallaway JL. A surveillance system for alcohol- and drug-related fatal injuries. Am J Prev Med 1985;1:21-26.
20. Janson BR, Svanström L. Evaluation of a system for injury surveillance in Swedish emergency care. Scand J Soc Med 1989;17:7-11.
21. Fraser PA, Beral V, Chilvers C. Monitoring disease in England and Wales: methods applicable to routine data-collecting systems. J Epidemiol Comm Health 1978;32:294-302.
22. Berkelman RL. Summary remarks: symposium on statistics on surveillance. Stat Med 1989;8:393.
23. MacDonald IL, Lever LB. A time-series analysis of trends in firearm-related homicide and suicide. Int J Epidemiol 1994;23:66-72.
24. Choi K, Thacker SB. An evaluation of influenza mortality surveillance, 1961-1979; time series forecasts of expected pneumonia and influenza deaths. Am J Epidemiol 1985;113:215-221.
25. Helfenstein V. Box-Jenkins modelling of some viral infectious diseases. Stat Med 1986;5:37-47.
26. Stroup. DE, Williamson GD, Herndon JL. Detection of aberration in the occurrence of notifiable surveillance data. Stat Med 1989;8:322-329.
27. Raubertas RF. An analysis of disease surveillance data that use geographic locations of the reporting units. Stat Med 1989;8:267-271.
28. Nobre FF, Stroup DF. A monitoring system to detect changes in public health surveillance data. Int J Epidemiol 1994;23:408-414.

29. Lapré RM, Mackenbach JP (eds). Accidents in the year 2000 - accident and traumatology scenarios 1985-2000. Dordrecht: Kluwer; 1989.
30. van Beeck EF, Mackenbach JP, van Oortmarssen GJ, Barendregt JJM, Habbema JDF, van der Maas PJ. Scenarios for the future development of accident mortality in the Netherlands. Health Policy 1989;11:1-17.
31. CBS. Overledenen naar doodsoorzaak, leeftijd en geslacht, serie A1, 1970-1994. (Mortality by cause of death, age and sex, series A1, 1970-1994, in Dutch). Voorburg: CBS; 1970-1994.
32. CBS/VOR. Statistiek van de verkeersongevallen op de openbare weg. (Statistics on traffic accidents on public roads, in Dutch). The Hague: SDU-publishers; 1970-1994.
33. CBS/BOR. Statistiek der bedrijfsongevallen. (Statistics of occupational accidents, in Dutch) The Hague: SDU-publishers; 1970-1991.
34. Stichting Consument en Veiligheid. Jaaroverzicht Privé Ongevallen Registratie Systeem. (Annual Report Home and Leisure Accident Surveillance System, in Dutch). Amsterdam: Consumer Safety Institute; 1985-1994.
35. CBS. De mobiliteit van de Nederlandse bevolking. (The mobility of the Dutch Population, in Dutch). The Hague: SDU-publishers; 1970-1994.
36. Sackman H. Summary evaluation of Delphi. Policy Analysis 1975:694-718.
37. van Beeck EF. Application of the Delphi Method in the forecasting of accidents in the Netherlands. In: Adler M, Ziglio E (eds). Gazing into the oracle: the Delphi Method and its application to social policy and public health. London: Jessica Kingsley Publishers; 1996.
38. Hutchinson TP. Road accident statistics. Adelaide: Rumsby Scientific Publishing; 1987.
39. Shinar D. The validity of police reported accident data. Accid Anal Prev 1983;3:15-18.
40. ILO/WHO. Epidemiology of work-related diseases and accidents, Report of the joint ILO/WHO committee on occupational health. WHO Technical Series 1989;777:1-71.
41. van Beeck EF, Mackenbach JP. Ongevallen Signaleringsrapport 1995. (Accidents Monitoring Report 1995, in Dutch). Zoetermeer: STG; 1996.
42. van Beeck EF, Mackenbach JP. Ongevallen signaleringsrapport 1989. (Accidents Monitoring Report 1989, in Dutch). Rijswijk: STG; 1989.
43. van Beeck EF, Mackenbach JP. Accidents monitoring report 1992: developments since 1985. Rijswijk: STG; 1992.
44. Ministerie van Verkeer en Waterstaat. Meerjarenplan Verkeersveiligheid 1989-1993. (Long-range plan on traffic safety 1989-1993, in Dutch). The Hague: SDU-publishers; 1989.
45. Oppe S. Macroscopic models for traffic and traffic safety. Accid Anal Prev 1989;21:225-232.
46. World Health Organization. Targets for health for all. Copenhagen: WHO regional office for Europe; 1985.
47. Ministerie van WVC. Ontwerp-Kerndocument Gezondheidsbeleid. (Draft Basic Document on Health Policy, in Dutch). Rijswijk; 1989.
48. Ministerie van WVC. Discussienota Ongevallen en Traumatologie. (Discussion Paper on Accidents and Traumatology, in Dutch). Rijswijk; 1989.

5 General Discussion

5.1

Summary of the main findings

In this thesis the results are reported of quantitative analyses focusing on the societal burden of injuries in the Netherlands, its changes over time, and the major determinants of these changes and of the current size of the problem. These analyses were performed as part of a public health surveillance system initiated in 1985. This system has monitored epidemiologic developments both prospectively and retrospectively and has provided us with information dealing with a time-span of 50 years (1950-2000). This paragraph summarizes the main results of the separate studies.

5.1.1 ASSESSMENT OF THE FREQUENCY AND SOCIETAL BURDEN OF INJURIES

The first part of this thesis addressed the following question:

- which trends can be observed in the frequency of injuries in the Netherlands since 1950, how can they be explained, and what is the current societal burden of injuries?

We analyzed trends in the mortality, incidence and case fatality of unintentional injuries in the Netherlands since 1950 (see chapter 2.1). As reported in other studies,[1-6] we found that this field is characterized by rapid changes. Between 1950 and 1970 accident mortality rose because of an increasing incidence of injuries. This was followed by a sharp mortality decline resulting from a decreasing incidence combined with a rapidly falling case fatality.

We found that since the second half of the 1980s, a third phase in the post-world war II development emerged in the Netherlands: the decline in accident mortality has levelled off, mainly due to new rises in the incidence of injuries in several sectors.

These dynamic trends are based on several factors. The population exposure to specific hazards is of primary importance. More or new types of exposure tend to increase the incidence of injuries, and therefore their burden on society. The development in amount or type of exposure over time is dependent on autonomous factors, of which economic growth seems the most important. Rapid economic growth leads to rising population exposure in relevant areas (e.g traffic mobility, employment). The analyses have shown, on the other hand , that societies are capable of compensating the unfavourable public health effects of exposure growth. In the 1970s and first half of the 1980s both autonomous adaptatation mechanisms (e.g. growing familiarity with motorized traffic) and policy adaptations (preventive measures and improvements of medical care) contributed to the spectacular decreases of the injury risk, injury severity and severity-adjusted case fatality. Since the second half of the 1980s, however, this compensation has proven insufficient in the Netherlands. Rises in the incidence of traffic injuries (passenger car occupants and motor cyclists), occupational injuries and home and leisure injuries (accidental fall) have recently been observed.

Our study has made it clear that favourable trends in accident mortality can be accompanied by unfavourable trends in the incidence of injuries. Obviously, therefore, an assessment of the societal burden of injuries should include incidence figures, because systems restricted to mortality data could easily miss unfavourable public health developments. The analysis further shows the necessity of new policy measures in injury prevention and trauma care.

A potentially powerful instrument for priority setting in injury prevention and trauma care is an assessment of the costs of this public health problem (see chapter 2.2). We estimated the direct medical costs with the help of available data on health care utilization as a consequence of injuries. We calculated indirect costs with the help of two alternative approaches. We used the traditional human capital approach, which calculates all potential production losses of the victims from the time of injury until their mean age of retirement. In addition, we applied the friction cost method which was recently developed as an attempt to measure the actual production losses to society.

This method assumes that all workers can be replaced after a so-called "friction period", and in its calculations restricts the production losses to this period.

It was shown that injuries are an important source of medical costs (almost 5% of the Dutch health care budget in 1988) and economic production losses (about 8 % of the indirect costs resulting from all diseases, independent of the method used).

Almost two-thirds of the medical costs are the result of injuries among females. This reflects the high incidence of domestic accidents among the elderly, and females in particular. It points to the fact that accidental fall and (hip) fractures among the elderly are one of the most important epidemics of western societies today. Their importance is further stressed by the findings of our long-term analysis, where accidental fall was identified as one of the subproblems with an increasing incidence. These findings are similar to the results of cost-of-injury studies of other industrialized countries.[7-10]

The economic production losses to society, or indirect costs, have other major contributors than the direct medical costs. More than 80% of the indirect costs are the result of injuries among males, arising mainly due to the high incidence of traffic injuries, occupational injuries and sports injuries among young males. Traffic injuries generate a very high level of potential production loss to society, because of their high case fatality and disability rate, even at younger ages. A huge number of productive life-years can subsequently be lost, as also reported in other studies.[11-14]

Occupational and sports injuries, on the other hand, yield the highest actual production losses to society. They are characterized by a very high incidence of injuries among the workforce leading to a huge number of productive days lost because of sickness absenteeism.

By estimating the health care costs, the potential economic production losses, and the actual economic production losses resulting from injuries in the Netherlands the high burden of injuries to society has been confirmed and quantified. Moreover, several priority areas for further research and policy have become apparent (see chapter 2.2).

A priority area that seems rather specific for the Netherlands is the problem of injuries to cyclists. The medical costs resulting from cycling injuries are twice as high as those resulting from injuries to passenger car occupants. This reflects the high incidence of cycling injuries, accounting for half of all traffic injuries in the Netherlands.

This is the effect of the frequent use of the bicycle, which is a clear example of the major influence of population exposure on the relative importance of specific injury subclasses. In addition, it shows that the protection of cyclists should be further improved.

5.1.2 RESEARCH INTO DETERMINANTS OF INJURY MORTALITY

The second part of this thesis addressed the following question:
- what are the determinants of injury mortality at the population level, and of traffic accident mortality in particular?

We performed two studies focusing on the role of population exposure as an intermediate factor between socio-economic determinants and traffic accident mortality.

In an analysis of regional variation in traffic accidents within the Netherlands during the first half of the 1980s (see chapter 3.1) we found large regional mortality differences. These differences could be explained only to a limited extent by regional differences in exposure.

Regional differences in the case fatality of injuries to motor vehicle occupants seem the major factor behind the observed mortality differences. On the other hand, in the case of cyclists some of the variation in mortality seems to be caused by regional differences in the use of the bicycle. But even with regard to this mode of transport, which accounts for 20% of all traffic deaths in the Netherlands, differences in case fatality are of more importance.

In studying the underlying socio-economic determinants we found that the prosperity level of a region is a strong predictor of mortality, in the sense that a higher income level goes hand in hand with lower traffic accident mortality levels. This finding is similar to observations made in other industrialized countries.[15-18] Our study, however, provided more detail on this relationship by studying separate modes of transport. We found that in the case of motor vehicle occupants, exposure does not act as major intermediate factor between prosperity and traffic accident mortality at the regional level. An important part of the influence of prosperity on mortality for cyclists, however, must be attributed to differences in bicycle use, as this is more frequent in the poorer regions of the country.

The study showed that, in particular in the case of motor vehicle occupants, variation in the case fatality is the major factor behind regional mortality differences, and not variation in exposure.

This variation in case fatality can to a large extent be explained by variation in traffic density and the availability of advanced trauma care. Both variables show an inverse relationship to case fatality. A higher traffic density probably leads to a reduction in the mean injury severity, whereas the availability of advanced trauma care could reduce the severity-adjusted case fatality.

We also studied the role of exposure and socio-economic factors in relation to international variations in traffic accident mortality within the industrialized world. We analyzed the relation between prosperity and traffic accident mortality in a long-term perspective, looking at developments between 1962 and 1990 (see chapter 3.2). It was found that there is currently a negative association between the level of prosperity and the traffic accident mortality level of a country. This finding is compatible with the results of our cross-sectional analysis into regional mortality differences within the Netherlands. The current inverse relation was preceded by a positive association between prosperity and traffic accident mortality in an earlier phase of the epidemiologic transition. This reversal took place around 1975. The observed changes are based on non-linear longitudinal relationships. At lower prosperity levels, increasing wealth gives rise to rapidly growing numbers of motor vehicles in the population. This leads to increasing numbers of traffic deaths. However, mobility growth would appear to have a tendency to level off after reaching a certain level of prosperity. At that point, increasing prosperity starts to protect against traffic accident mortality. This is due to the phenomenon that - at all prosperity levels - increasing wealth is accompanied by declines in the fatal injury rates. This is probably the result of adaptations that are stimulated by growing prosperity, such as improvement of the traffic infrastructure and the medical care for injury victims. It is likely that, at the regional level within the Netherlands, similar longitudinal developments have taken place as well. This could explain our finding of a minor role of traffic mobility in relation to regional mortality differences among motor vehicle occupants.

Our analyses have shown that the concept of traffic accidents as a "disease of affluence" is too simple. This concept has already been questioned by the results of previous studies.[19,20] But although too simple, the concept cannot be fully rejected. Increasing wealth gives rise to more traffic deaths up to a certain level of prosperity. And worldwide, only a limited number of countries has already succeeded in reaching this level.

These conclusions underline that the role of economic factors in relation to traffic accident mortality is rather complex. In the short term economic growth appears to have a detrimental effect on the burden of traffic injuries because of rising exposure. In the long term, however, it seems to facilitate adaptations leading to a reduction of the damage to public health.

It must, however, be borne in mind that these adaptations are not always successful. Several countries were identified which had (very) high prosperity levels, yet in which fatal injury rates showed an adverse development.

5.1.3 FORECASTING AND MONITORING OF INJURIES

In the final part of this thesis we addressed the following question:

- what is the value of expert based quantitative future health scenarios for forecasting and monitoring of injuries?

In the second half of the 1980s we made projections of the burden of injuries in the Netherlands between 1985 and 2000. We developed an approach for calculating the public health impact of different future health scenarios, both with and without government intervention.

A major determinant included in the scenarios was the growth of the national economy.

Information on possible future developments with respect to separate variables (exposure, injury risk, injury severity, and severity-adjusted case fatality) was obtained with the help of a Delphi study (see chapter 4.1). A survey was conducted of possible future developments by means of written questionnaires to eighty Dutch experts, divided among four panels on traffic safety, occupational safety, home and leisure safety, and medical care for injury victims.

The main results of this Delphi study were as follows. A majority of experts expressed as the 'most likely' development for the period 1985-2000 a combination of modest economic growth, no significant changes in risk behaviour, a slight ageing of the population, and absence of major new policy measures from the government. Under these circumstances, the experts anticipated a mixture of favourable and unfavourable developments. They anticipated a number of rising types of exposure and expressed that without vigorous new efforts in injury prevention, many reductions in injury risk would level off. But they were rather optimistic about developments in injury severity and severity-adjusted case fatality.

The results of the Delphi study were used as input for scenario calculations. These were made with the help of a computer model developed by our department. In this way the combined effects of the separate trends in the aforementioned variables could be calculated (see chapter 4.2). The combination of developments referred to as 'most likely' according to a majority of the Delphi experts was elaborated as the 'reference scenario'. Calculation of the combined effects of the expected trends under the conditions of this scenario led to the following conclusion: without major new policy measures, accident mortality (which had fallen tremendously between 1970 and 1985) would remain more or less at the level of 1985. This result was different from the predictions of models based on historical data alone, which computed substantial further mortality declines, both in the Netherlands[21-22] and abroad.[23-25]

The quantitative results of the future health scenarios were reported to policy makers in 1988 and subsequently used as a framework for continuous monitoring of unintentional injuries in the Netherlands. Trends in the epidemiology of injuries since 1985 were compared with observations from a previous period (1970-1985) and with the future health scenarios (1985-2000) developed. This revealed actual transitions towards the less favourable developments foreseen by the Delphi experts, and moreover contributed to the early identification of interruptions in the actual injury mortality trends in the Netherlands (see chapter 4.3).

This ability to monitor actual trends in the epidemiology of injuries for more than ten years amply demonstrated the added value of quantitative future health scenarios based on expert opinion. Our new tool offers a well-defined conceptual framework for continuous monitoring and facilitates the early detection of trend interruptions or reversals. Moreover, it provides valuable information on possible future developments and on the feasibility of health policy goals.

5.2

Possibilities and limitations of data and methods

The studies reported in this thesis have produced results which are important from both a scientific and a health policy perspective. For an adequate interpretation of these results a review is necessary. We introduced some innovations, of which the possible added value will be discussed. On the other hand, the fact that our analyses were performed within the frame work of a public health surveillance system collecting routinely available data from several sources, must also be taken into account. Therefore we will briefly discuss the major limitations of the data and methods of the separate studies. We will focus on those issues that could have affected our main findings, as summarized in chapter 5.1.

5.2.1 ASSESSMENT OF THE FREQUENCY AND SOCIETAL BURDEN OF INJURIES

Trend analysis

Our long-term analysis of trends in accident mortality revealed several data limitations (see chapter 2.1). The main problems are related to the data on non-fatal injuries. The incidence of injuries is underreported in all accident sectors and the available incidence figures are poorly comparable between these sectors on account of differences in registration procedures and criteria. Another limitation is the almost complete lack of information on injury severity available from most data sources. There are still no national registries which include information on the Abbreviated Injury Scale (AIS), which is the international standard in severity scoring[26].

The acquisition and/or improvement of data on the incidence and severity of injuries would certainly lead to a better assessment of the societal burden of this important public health problem. These are major challenges in injury surveillance which will be further dealt with in chapter 5.4.1.

In spite of these data limitations we were able to analyze long-term trends in the epidemiology of injuries in the Netherlands in some detail, using the central conceptual framework of this thesis. A major advantage of this approach is its potential to gain indications on the contribution of autonomous factors, preventive measures and improvements of trauma care on mortality reductions, by distinguishing empirically the role of exposure, injury risk, injury severity and severity-adjusted case fatality (see chapter 2.1).

The question remains, however, whether the existing data limitations may have influenced the main findings of our trend analysis. There are at least two major points in which registration bias cannnot be excluded: the rising incidence of several classes of injuries seen during the latest period examined, and the rapidly declining severity-adjusted case fatality of traffic injuries since 1970.

A key finding is the rising incidence of injuries found during the latest period reviewed (injuries to passenger car occupants and motorcyclists, occupational injuries, accidental fall among the elderly). Could this development (in part) be due to recent improvements in reporting?

The assertion that the incidence of injuries is on the rise is supported by a number of findings. Population surveys on injuries taken in 1986/1987 and 1992/1993 also identified rising incidence figures during this period, in particular for traffic injuries and for home and leisure injuries among the elderly.[27] The latter mentioned subclass is also characterized by rising figures in two independent data sources: the National Medical Registry and the National Home and Leisure Injury Surveillance System.[6] Moreover, the rising incidence figures relating to injuries to passenger car occupants, motor cyclists, and workers in construction and the service sector were accompanied by (rapidly) rising exposure figures. All these observations combined make registration bias unlikely.

The severity-adjusted case fatality is an important measure to establish the contribution of improved medical care to mortality reductions. Our analysis showed that after adjustment for changes in injury severity, the case fatality of traffic injuries had nonetheless declined since 1970.

This supports the argument that medical care has contributed to this favourable development. It must be considered ,however, that a rather crude adjustment procedure was used. No information on the Abbreviated Injury Scale (AIS) was available. A conversion of ICD-codes to AIS-codes[28,29] could also not be performed because this would have needed more refined information, in particular on hospital data from the 1970s. The crude adjustment procedure could have led to an overestimation of the reduction in severity-adjusted case fatality. This means that the evidence on the contribution of medical care to the observed decline in traffic accident mortality since 1970 -while plausible- is not very strong. This shows the need for refined information on injury severity in continuous surveillance systems.

Cost assessment

We performed an assessment of medical costs and economic production losses due to injuries in the Netherlands which identified additional data limitations (see chapter 2.2). In spite of these a detailed study could be made, including the first comprehensive application of the friction cost method[30] in the field of injury control. The added value of this innovation is manifested by its ability to shed light on the impact of the socalled "minor" injuries. Injuries with low chances of hospital admission or death (from this perspective they are regarded as "minor") may have high rates of sickness absenteeism, and may therefore result in high economic production losses. Our study showed the high economic impact of occupational injuries and sports injuries (see chapter 2.2), which seems only limited if the traditional human capital approach is used. Methods to assess the impact of "minor" injuries are urgently required, because of the very high frequency of those events.[27]

Our cost assessment produced results that might be valuable for priority setting in injury prevention and control. In interpreting these results the question to be answered is whether the main findings could be affected by registration bias. The study produced estimates of the costs of injuries in comparison to the costs of other diseases, as well as estimates for a number of broad subclasses of injuries. Could our comparisons be biased by differences in registration or reporting by type of disease and/or accident?

In assessing the direct medical costs this is not very likely. The main data came from hospital statistics (which have an almost 100% coverage rate in the Netherlands and a similar inclusion criterion for all diseases and accident sectors) and a large population survey (which included 25.000 households in the Netherlands and used a similar inclusion criterion for all accident sectors).

In assessing the indirect costs one must consider whether the level of reporting of sickness absenteeism could be higher for occupational injuries than for other subclasses. This is probably the case in countries with social security systems where workers' compensation is dependent on the cause of the disease or the injury. In the Netherlands, however, the social security system does not make a difference between "professional risks" (e.g occupational injuries) and "social risks" (e.g. sports injuries). The workers' compensation is the same for all diseases and injuries. Therefore differential registration and reporting is not very likely in the Netherlands.

Although registration bias has probably not affected the cost comparisons we made, the results must nevertheless be interpreted with care.

As a general limitation, one must consider that cost assessment still knows no standard methodology. Different choices can be made on the inclusion of cost elements and the applied methods, which may strongly influence the estimates that are produced. This was illustrated once again by the results of our study (see chapter 2.2). Therefore, in reporting cost estimates to health policy makers the underlying choices should be explained very clearly. And policy makers using cost information should be informed about the basic methodology of cost assesment.

In addition, in reviewing our study it must be taken into account that it was based on data from 1988 or even previous years. This means that the results do not reflect the current situation in the Netherlands. We therefore assessed whether the main findings of our study would be different if more recent data were used. This was done by comparing our findings with the results from a comprehensive study on the costs of diseases and injuries in the Netherlands in 1994, which used a similar approach as our analysis.[31] This comparison was restricted to the direct medical costs, as no indirect costs were presented in the more recent study.

This comparison indicated that the main findings of our study have maintained their applicability. According to the more recent study, injuries are an important source of medical costs as well. It was confirmed that almost two-thirds of these costs result from accidents among females, which is related to the high use of health care due to domestic injuries among elderly women, and accidental fall in particular. Surprisingly, the more recent study also made clear that -contrary to our expectations- the share of injuries in the health care budget has fallen somewhat (from 4.7% in 1988 to 4.1% in 1994).

We expected the share of injuries to have expanded in view of the absolute increases in the incidence of domestic injuries among the elderly. Although this development has actually taken place,[6] an even more rapid increase in the use of health care was seen in relation to some other major diseases, including dementia, stroke and heart failure.

This once again demonstrates that developments in the incidence (and related health care use) of diseases and injuries are highly dynamic. Within periods of 5-10 years the share of a certain disease or injury subclass in the total amount of health care costs can change substantially. For priority setting purposes therefore the regular monitoring of costs is advisable. In fact, cost assessment should preferrably be embedded in continuous surveillance activities. This is a challenge for the future which will be further discussed in chapter 5.4.1.

Another necessity is the application of novel methods to assess the societal burden of injuries. An important step forward would be the calculation of "disability adjusted life years" (DALYs)[32] resulting from injuries and its subclasses in the Netherlands. Within the framework of this thesis this step has not yet been made. It will need the acquisition of empirical data on disabilities and handicaps resulting from injuries. This topic will be further dealt with in chapter 5.4.2.

5.2.2 RESEARCH INTO DETERMINANTS OF INJURY MORTALITY

Regional differences in traffic accident mortality within the Netherlands

We were able to perform a detailed analysis of regional differences in traffic accident mortality within the Netherlands (see chapter 3.1). Compared with similar research in other countries[15-18] our focus on separate modes of transport has been a major innovation. This focus was made possible by the availability of regional data on the population exposure and on the incidence of traffic injuries by mode of transport, in addition to mortality figures. In particular, the regional data set on passenger kilometres by mode of transport (derived from mobility surveys among more than 50.000 persons) was relatively unique. Our focus on separate modes of transport enabled us to demonstrate that regional differences in traffic accident mortality have somewhat different patterns and underlying determinants for motor vehicle occupants and for cyclists respectively (see chapter 3.1).

This shows the importance of data specified by mode of transport. It must be kept in mind, however, that our study revealed several data limitations. These included, first of all, the mortality figures by mode of transport from the cause-of-death statistics. As in other countries,[33] a large proportion (47%) of traffic deaths is unspecified by mode of transport in this data source in the Netherlands. Did this lead to bias in regional patterns of mortality due to specific modes of transport because of regional differences in registration practice?

This is not very likely for a number of reasons. We found a high correspondence of the regional mortality figures of motor vehicle occupants on the one hand, and of unspecified modes of transport on the other. In fact, the "unspecified" category showed the same regional mortality pattern as motor vehicle occupants. When we compared mortality figures from the cause-of-death statistics with traffic deaths recorded by the police, the vast majority of victims within the "unspecified" category were shown to be motor vehicle occupants. No indications on regional differences in classification error were provided for motor vehicle occupants. And our specific findings on cyclists were probably not affected by classification error at all. We found a high correspondence between the cause-of-death statistics and the police registration on the numbers of deaths due to cycling injuries, at both the national and the regional level.

Another possible data limitation in our geographical analysis concerns the available figures on the incidence of traffic injuries by mode of transport. There could be lower reporting levels (restricted to injuries of higher severity) in the poorer and more rural parts of the country. This may have led to an underestimation of the incidence figures and to an overestimation of the case fatality figures in these regions. Regional variation in case fatality has been a main finding of our study. We found lower case fatality rates in regions having more advanced medical care. This could, however, in part be based on artificially lower injury severity levels in those regions. In view of the fact that no subsequent adjustment for injury severity could be made, our results on the role of medical care in reducing the regional level of traffic accident mortality should be interpreted with care.

This shows that, as in other ecological studies,[34] registration artefacts cannot be competely excluded. And what other possible sources of bias could have affected our main results? In explaining regional variation in mortality, the influence of health-related "selection" must always be considered.

For example, an inverse relation between the prosperity of a region and the mortality due to ischemic heart disease could be based on migration of healthier individuals into the more prosperous regions. It is not very likely that a similar mechanism would operate in the case of traffic accidents, which highly affect young and healthy individuals. Another general source of bias in ecological studies concerns the existence of "time lags" between exposure and effect. This kind of bias can also be excluded in our study. This does not, however, apply to the problem of "omitted variables". For example, we were not able to include characteristics of road behaviour and road vehicles in our study, which means that the observed influences of infrastructural variables and medical care must be interpreted with care (see chapter 3.1).

Despite the aforementioned limitations, ecological analysis appeared to be an an adequate design to identify determinants of injury mortality. Traffic accidents are a "disease" with many determinants operating at the "ecological level".

With respect to these determinants there is no bias based on the "ecological fallacy", which states that aggregate level relationships are not necessarily identical to individual level relationships.[35] Our study focused on aggregate level determinants, in particular in the specific analysis studying the influence of infrastructural characteristics and medical care. It must be realized that our analysis on the influence of socio-demographic variables must be interpreted in "aggregate" terms as well. Our finding that the most prosperous regions have the lowest levels of traffic accident mortality may not lead to the conclusion that these variables are also inversely related at the individual level. The prosperity level of a region may exert its influence through determinants at the aggregate level (e.g infrastructure) which benefit all individuals of the population independent of their income. The study of individual level determinants needs other designs. This will be further addressed in chapter 5.4.2.

Economic development and traffic accident mortality in the industrialized world, 1962-1990

We examined the relation between prosperity and traffic accident mortality and its underlying parameters (i.e traffic mobility and fatal injury rate) in a long-term perspective, using data from several decades.

Focusing on longitudinal developments has been a major strength of our analysis.

Cross-sectional studies into the association between prosperity and traffic accident mortality had been showing varying results, dependent on the countries or regions included in the analyses.[15-20]

We found that this was due to a non-linear longitudinal relation between prosperity and traffic accident mortality. The availability of data on motor vehicle ownership in industrialized countries since the early 1960s enabled us to establish the underlying developments in exposure and fatal injury rate. We found that at a certain level of prosperity the growth rate of motor vehicle ownership levels off, whereas the fatal injury rate continues to decline at a similar rate as in an earlier phase of economic development.

Our results are plausible in the light of observations with respect to other public health problems, and cardiovascular diseases in particular.[36-39] They are plausible in the light of general long-term developments in public health. Increasing wealth leads to the introduction and large scale use of new forms of exposure (e.g. tobacco, motor vehicles), but simultaneously facilitates adaptations.

It should be kept in mind that our analysis of international variations was subject to various limitations.

A possible weakness of the analysis of longitudinal relationships concerns the exposure data that were used. In order to obtain an (almost) complete set of exposure data from 21 countries since the early 1960s, we had to use figures on motor vehicle ownership. Therefore, it cannot be ruled out that one of our key findings -mobility growth levelling off after reaching a certain level of prosperity- may be based on a registration artefact. This could be the case if a lower growth rate of motor vehicle ownership was compensated by a faster growth rate of the number of passenger kilometres per motor vehicle. In the Netherlands, however, we found no evidence of such a development. Since the 1970s the growth rate of passenger kilometres in the population has levelled off as well.[40] A similar development has also been found in several other industrialized countries.[41]

Our study of cross-sectional associations at different points of time is limited because of the low number of countries included. The current inverse association between prosperity and traffic accident mortality is largely based on the unfavourable position of a few countries in Southern Europe, which are the poorest of the industrialized world. The majority of countries included in our analysis has reached a more or less equal level of prosperity. These countries still exhibit a large degree of variation in traffic accident mortality, which indicates the importance of other determinants than prosperity.

On the other hand, a study of cross-sectional associations in a larger sample (expanded by 11 middle-income countries from Eastern Europe and Latin America) produced results similar to those reported in this thesis.[42] This strengthens our findings, which are further supported by a number of additional analyses into the relation between prosperity and mortality due to nontraffic accidents (one study restricted to the industrialized world, and one study expanded by middle-income countries). These additional analyses did not show any significant association between prosperity and mortality.[42]

Another limitation concerns the fact that we could not establish the factors intermediating (or confounding) the observed inverse relation between prosperity and the fatal injury rate. This would have required additional data (e.g.on the incidence and severity of traffic injuries, on socio-cultural factors, on the traffic infrastructure, on the medical care for injury victims). It was therefore not possible to perform an analysis similar to our study into regional mortality differences within the Netherlands (see chapter 3.1). Such a detailed study into determinants of international variation in traffic accident mortality (including high-income and middle-income countries) could provide information on the possible adaptations facilitated by prosperity. Our study is not very specific at this point.

5.2.3 FORECASTING AND MONITORING OF INJURIES

Delphi study

Our new tool for the forecasting and monitoring of injuries included the results of a traditional approach to collect expert opinion: the Delphi method. We performed a Delphi study among 80 Dutch experts (see chapter 4.1). The Delphi method is not beyond criticism. There has always been an intensive debate on the methodology. Major publications from the 1970s have either scrutinized the nature of the approach,[43,44] while others have defended the method, arguing that the criticism only makes sense where it concerns the poor conduction of Delphi projects.[45] A major publication of more recent date views the Delphi method -if fairly conducted- as a valuable tool for informed decision making in social policy and public health.[46] Major general problems in performing Delphi studies concern the selection of panel members, the sample size, the design of the procedure and the structure of the questionnaires.[47] Our solutions to these problems have been described in chapter 4.1.

Our Delphi study was performed in 1986 at a time when the epidemiology of injuries had been developing in favourable direction for about 15 years. As we were able to monitor the subsequent actual developments we could assess the validity of the results obtained. This paragraph examines whether or not our Delphi study produced expectations which approximated actual trends. And if not, whether this could be due to limitations imposed by the conduction of our study.

In general, the Delphi panels anticipated somewhat less favourable trends than in the past. Developments along these lines did indeed emerge later (see chapter 4.1). But how realistic were the specific detailed estimates of the Delphi panels?

Table 5.2.1 shows expected epidemiological developments compared with actual observed trends for traffic, occupational and home and leisure injuries. Information on parameters is provided only where data on actual trends are available.

Table 5.2.1

Comparison of Delphi estimates (1985-2000) with actual observations (1985-1994)

	Exposure Reference	Observed	Injury risk Reference	Observed
Traffic				
- passenger car	+	+/0	-	0/-
- moped	0/-	-/--	+/0	+/0
- bicycle	+/0	0	0/-	0/-
- pedestrian	0	0	0/-	-
- other traffic	0	++/+	0/-	0/-
Occupation				
- manufacturing	0/-[1]	+/0	0/-	0/-
- construction	0/-[1]	+/0	0/-	0/-
- service sector	+/0[1]	++/+	0	0/-
Home and leisure				
- DIY-activities	+	0	+	--/-
- sports	+/0	0	+/0	-

1) Estimates of Central Planning Bureau

A general overview gives the impression that the panel on traffic safety has produced results that resemble actual developments. This is particularly true for the expectations regarding the injury risks. The anticipated exposure developments deviate more strongly from the actual trends. The experts, for example, did not foresee the spectacular rise in exposure in the subcategory 'other traffic', which reflects the fastly growing popularity of the motor cycle since the second half of the 1980s. Another interesting example is related to the growth of passenger car traffic. Experts did obviously overestimate the annual growth rate of the number of passenger car kilometres in the population (also see figure 4.3.2). They probably did not take into account that the association between prosperity growth and mobility increase has become weaker since the second half of the 1970s (see the results of our analysis of chapter 3.2).

The panel on occupational safety expressed expectations on the development of the injury risks that are close to actual observations, although they were too pessimistic about trends in the service sector. This panel was not required to forecast exposure developments because estimates of the Dutch Central Planning Bureau were already available.

The experts on home and leisure safety produced expectations that did not coincide with actual observations at all. They were too pessimistic about both exposure developments and trends in injury risks with respect to DIY-activities and sports.

In the light of the above, the impressions concerning the accuracy of the detailed findings from the Delphi study present a mixed picture. In principle, semi-quantitative information of acceptable quality can be generated by experts, as illustrated by the results on injury risks in the traffic and occupational sector.

The outcome in the area of home and leisure injuries might indicate that this part of the Delphi study was less well conducted than the other parts. This could be a result of the size and the composition of the panel.

Due to the heterogeneous nature of this field the panel (17 repondents) in fact consisted of small subsamples of accident-specific experts (e.g. domestic accidents, sports accidents, poisoning). For specific safety issues, the number of experts was probably too small to produce valid results . The field of sports injuries, for example, would have deserved its own panel. Home and leisure safety is probably too heterogeneous to be served by one panel of 15-20 experts. Adequate panel selection therefore probably ranks as one of the most important decisions to be made by Delphi researchers.

If this condition is met and a well-constructed questionnaire is used, policy makers can be provided with "informed judgements" on possible future developments in the field of injuries.

The question then remains whether this information could be obtained in other ways. For specific issues the answer is probably "yes". Anticipating on exposure developments in traffic, for example, could be based on quantitative analyses of historical data.

Nevertheless, the Delphi study produced some information of particular value. With the exception of the field of home and leisure safety, the Delphi experts have foreseen slower rates of decline of the injury risks than in the period 1970-1985. This was not a simple extrapolation of observations from previous years. The period immediately preceding our Delphi study (i.e the end of the 70s and beginning of the 80s) was characterized by economic stagnation. During this period many injury risks in traffic and at work fell sharply. When the Delphi questionnaires were filled out (second half of 1986) the most recent epidemiological information reflected the favourable developments of those years. What knowledge then did bring the experts to express somewhat less optimistic views for the future?

The most likely general explanation is that they have reasoned that an important part of the decline in injury risks between 1970 and 1985 had to be attributed to public health policy. Our method explicitly asked them to express their anticipations in the absence of new policy initiatives.

This shows that the Delphi method is probably of particular help in generating information of the 'what if' type. It enabled us to calculate the expected burden of injuries under the assumption that no major new policy measures would be implemented.

Future health scenarios

The results of the Delphi study were incorporated into a new quantitative approach (see chapter 4.2). By including Delphi expectations on many separate variables in one comprehensive computer model the 'net effects' on the burden of injuries in the population could be calculated. By applying the scenario method a wide range of possible trends in the epidemiology of injuries, with and without government intervention, could be presented to policy makers.

The quantitave estimates of the epidemiology of injuries in different scenarios are derived from the expectations of the Delphi panels on separate variables. Therefore the quality of the estimates primarily depends on the quality of the Delphi results.

This indicates that the calculations on home and leisure injuries could be greatly improved. Separate panels on sports injuries and domestic injuries respectively should be able to produce more accurate estimates.

Empirical knowledge on developments in these areas over the last 15 years would certainly lead to better estimates than acquired in our study. The calculations on traffic injuries could be improved as well. Table 5.2.1 showed that in the field of traffic safety the validity of the estimates on exposure was lower than that of the estimates on injury risks. This means that the incorporation of exposure estimates from traffic mobility models based on the most recent scientific knowledge (such as the results of our analyses into the relation between prosperity growth and mobility) would probably lead to a further improvement of the scenario calculations. Moreover, new estimates of employment developments broken down according to branch of industry could improve the estimates in the field of occupational safety. The relevant occupational exposure estimates used in the scenario calculations were far too low. These were not derived from the Delphi study but were taken from publications of the Dutch Central Planning Bureau. Since the scenario study, however, the dynamics of the labour market in the Netherlands have changed, leading to a much higher employment growth rate than in the past.

We conclude that the scenario calculations could be improved in a number of ways. A first step would be to improve the compositions of the panels. Secondly, the use of estimates from exposure models, based on the the most recent scientific information, would be helpful. Exposure is a key variable behind developments in the societal burden of injuries. The availability of valid exposure models therefore merits attention.

The above shows that the Delphi method has produced indications of future developments that, at a general level, resemble actual trends. At a more detailed level, however, many differences with actual trends could be observed. Hence, the results obtained with our scenario calculations should not be interpreted as "predictions". It should moreover be borne in mind that they were never presented as such. The results present the broad effects of possible 'what if' scenarios. They are useful for supplying answers to general policy questions. How will the burden of injuries develop without new major investments in injury prevention or trauma care? What would happen if the economy grew very rapidly? Will we need extra efforts to reach a further substantial reduction in the number of injury victims?

Our study is an example of exploratory future research: scanning the future with the help of a causal theoretical model, but not using formal historical data in the calculations.[48]

We have explored possible future developments with the help of the central conceptual framework of this thesis (see chapter 1). And we have used an extensive set of detailed Delphi estimates in our calculations of the future burden of injuries.

Other scenario projects in the field of health care in the Netherlands have used somewhat different approaches. A scenario study on cardiovascular diseases used a simulation model for the in-depth analysis of historical data, which were subsequently extrapolated into the future.[49] The projects on cancer,[50] mental health[51] and chronic diseases[52] included a Delphi study of which, however, only a small number of predictions were incorporated in the quantitative scenario calculations. Developments in the burden of those diseases are predominantly influenced by demographic changes. The ageing of the population is the major determinant of increases in public health damage. Nevertheless, for specific diseases larger quantitative increases were calculated than accounted for by a growing number of elderly people. This regards, for example, the calculations on diabetes mellitus, which included an increasing age-specific incidence as a model parameter.[53] This specific assumption was derived from a Delphi study. The use of an extensive set of detailed Delphi estimates to make calculations on the future public health impact of one comprehensive "disease", however, is characteristic for our study.

Monitoring and surveillance

Another characteristic of our study regards the following. The results of our scenario calculations were subsequently used as a framework in injury surveillance (see chapter 4.3). Surveillance is one of the major activities in public health.[54] A main element of all public health surveilllance systems is the detection of changes in disease frequency, which might be described as trend monitoring.[55] Surveillance systems aim to detect trend interruptions or trend reversals as early as possible. This refers in particular to the early identification of unfavourable developments. To this end, several statistical approaches have been developed in the field of infectious diseases.[56]

These techniques have in common that they try to calculate a reference value, based on historical observations and distribution assumptions, which can be compared with observed values of case counts or rates. This comparison is made in order to assess whether there is an excessive number of cases in a certain period or not. If so, this should signal an alarm to health policy makers. Our approach included producing a reference value for comparison with observed values of case counts or rates: the results of the 'most likely', or 'reference' scenario.

Table 5.2.2

Present status of the policy measures proposed in the scenario report (1988)

Proposed measure	Government has expressed intention to implement measure	Implementation of measure already under way
Traffic		
- implementation of road safety education policy plan	+	-
- implementation of road user observability policy plan	-	-
- further separation/categorization of road-users	-	-
- black spot elimination/further involvement of local government	+	+
- reducing speed limits in built-up areas	-	-
- encouraging introduction of safety-promoting technology	-	-
- alcohol legislation aimed at limited distribution and consumption	+	-
Occupational		
- compulsory annual occupational safety plan	+	+
- compulsory industrial safety units	+	+
- extension of Health and Safety at Work Act to entire working population	+	+
- extension of capacity + powers of factory inspectorate	-	-
- introduction of Safety Decree for residual groups	+	+
- Works Council safety powers	-	-
- SMB safety advisory/information bureau	+	+
- requirement to report breakdowns and near-accidents	-	-
- compulsory risk analyses	+	+
- statutory regulation of risk liability	-	-
Home and leisure		
- national safety education policy plan	-	-
- primary-school safety education	+	-
- safety standards for products commonly involved in accidents	+	-
- statutory regulation of product recall	-	-
- statutory regulation of product liability	+	+
- expansion of responsibilities + capacity of Food Inspection Department	+	+
- safety hallmark/certification	+	+
- improvement of product information	+	+
- legal requirement for childproof drug packaging	+	-
- inclusion of overdose toxicity as criteria for drug registration	-	-
- adaption of sporting regulations to safety requirements	-	-
- improved instruction on prevention of sports injuries	+	+

Table 5.2.2 - Continued

Present status of the policy measures proposed in the scenario report (1988)		
Proposed measure	Government has expressed intention to implement measure	Implementation of measure already under way
Medical care		
- national emergency number	+	+
- trauma-trained nurse in each ambulance	+	+
- treatment protocols for ambulance staff	+	+
- concentration of traumatology facilities within hospitals	+	-
- trauma coordinator in hospitals	+	-
- regionalization of trauma care	+	-
- one rehabilitation physician per 500 beds	-	-

We emphasize that this reference value is not based on statistical procedures, but on expert opinions on the most likely developments. An advantage of this procedure is that the reference value is not the mere result of a mathematical exercise, but that it is based on broadly accepted ideas on developments in its underlying factors. A disadvantage is that the method depends highly on available expertise on detailed topics. Our results on home and leisure safety illustrate that this kind of expertise is probably not always included in a Delphi panel.

The use of a reference scenario in trend monitoring aims to facilitate the early detection of trend interruptions. This is an important added value for health policy making. Although we have gained indications that our approach indeed works as an 'early warning system', there are still some limitations at this point. Apart from raising 'true positive signs', the method is capable of producing 'false alarms'. In addition, the early detection of unfavourable developments is only facilitated where they were already expected by experts. Moreover, the method depends strongly on high quality surveillance data without too many major changes in registration procedures and criteria. This means that the method must be applied with great care. If this condition is met, the method can serve as a valuable new health policy instrument, as we concluded from our evaluation over a period of about ten years (see chapter 4.3).

But did our approach have any effect on health policy so far? This is an important but difficult question.

Table 5.2.2 shows that the Delphi study generated many ideas on policy interventions which were proposed to the government in 1988.[57] The table also indicates whether the government has, in the meantime, expressed its intention to implement the measure, and whether or not implementation of a measure is already under way.

Clearly, the government did express its intention to introduce a large number of the proposed measures. But the number of measures actually introduced remains limited. In the area of road safety the influence of our system has been very small. Its impact on the field of occupational safety appears greater, yet most of the proposed measures in this area were already under way when we started our project. In the field of home and leisure safety, some measures have been implemented. This may have been stimulated by the scenario project. The same applies to the field of trauma care. Long existing ideas from professional organizations are gradually being implemented. The scenario project has repeatedly offered support for improvement of trauma care[42,57-60] as recently decided to by the government.[61]

This decision is primarily due to the efforts of professional organizations. Yet the scenario calculations may have provided relevant background information for planning and decision making.

5.3

Injuries and the epidemiologic transition theory

The epidemiologic transition theory, as first formulated by Omran in 1971,[62] provides a description and explanation of changing patterns of mortality in populations. The original theory assumes a uniform decline of infectious diseases since the nineteenth century combined with a uniform increase of non-infectious diseases and injuries. Growing prosperity is often seen as the major factor behind these broad changes,[63] that would develop according to the following three phases: the "age of pestilence and famine", the "age of receding pandemics", and the "age of degenerative and man-made diseases".[64] Based on recent developments the possible existence of a fourth stage, the "age of delayed degenerative diseases", has been added to the literature.[65]

It has been shown, however, that the conventional interpretation of the epidemiologic transition needs modification. Detailed analyses of specific causes of death have clearly illustrated the great diversity within the broad alterations often indicated as "the decline of infectious diseases" and "the rise of degenerative and man-made diseases".[66] Moreover, since 1970 the mortality of non-infectious diseases and injuries has declined in many industrialized countries. And in explaining changes in specific causes of death other factors than prosperity have shown their importance, including cultural determinants, preventive measures and improvements of medical care.[67]

The explanation of changing mortality patterns needs more detailed analyses than originally made within the framework of the epidemiologic transition theory. The studies reported in this thesis offer such detailed information on long-term developments in the heterogeneous field of injuries. They are thus able to shed some light on our knowledge of injuries as a component of the epidemiologic transition, a subject which has so far not been studied extensively.

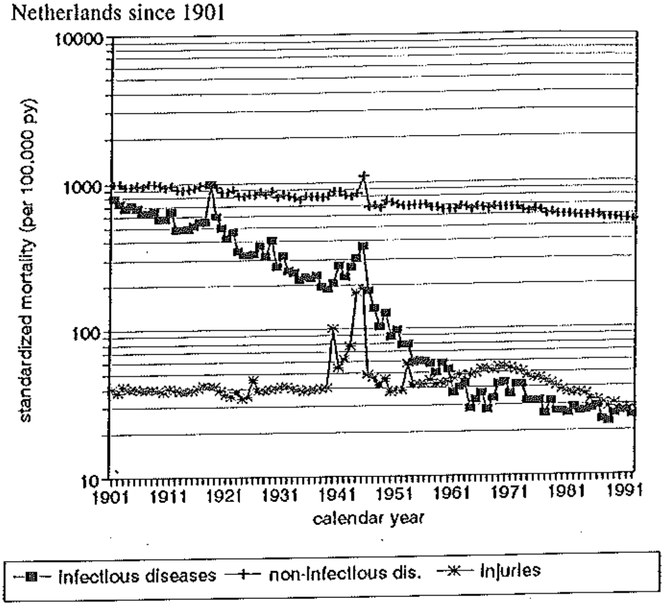
In this paragraph our findings are placed in an historical perspective. We describe changes in injury mortality and its major subclasses in the Netherlands since the end of the nineteenth century (5.3.1). Subsequently, we seek explanations for those changes (5.3.2) and address the need of forecasting possible future developments (5.3.3).

5.3.1 DESCRIBING HISTORICAL DEVELOPMENTS IN THE FIELD OF INJURIES

Figure 5.3.1 demonstrates that since the beginning of this century a cause of death-pattern with a high contribution of infectious diseases (with high mortality) has been replaced by a pattern dominated by non-infectious diseases (with lower mortality). The Netherlands is an example of an industrialized country where the epidemiologic transition has been completed. But what happened to injury mortality during this development? It appears that injury mortality as a whole did not rise since the beginning of this century, with the exception of a short period between 1950 and 1970. From our analysis of chapter 2.1 we know that this reflects the peak of the epidemic in accident mortality observed in the Netherlands after world war II. On the whole, however, injury mortality has been rather stable.

Figure 5.3.1

Trends in mortality due to infectious diseases, non-infectious diseases and injuries in the Netherlands since 1901



This means that no uniform increase of injuries occurred at all during the epidemiologic transition. As already suggested, a more detailed description of historical developments in this heterogeneous field is necessary.

Table 5.3.1 shows that, although injury mortality has generally been rather stable, the relative proportions of several subclasses of injuries have changed enormously over time.

At the beginning of this century accidental drowning was the most important specific cause of death among all external causes, where nowadays it has almost disappeared. Accidental drowning has shown a spectacular decline during the epidemiologic transition. Previous studies indicate that in the nineteenth century accidental drowning was responsible for over 50% of the mortality from injuries in the Netherlands, amounting to 25 deaths per 100.000 person-years.[63] This latter figure is on par with the figure for traffic accident mortality at its peak level around 1970 (see table 5.3.1).

Accidental drowning has so far been neglected as a rapidly declining cause of death during the epidemiologic transition. As so many infectious diseases have, it has almost disappeared as a cause of death in the Netherlands.

Table 5.3.1

Mortality due to injuries and its major subclasses in the Netherlands, 1910-1995 (crude mortality rates per 100.000 person-years)

	All external causes	Traffic accidents	Accidental fall	Accidental drowning	Other nontraffic accidents	Suicide	Homicide
1910	42.6	2.5	3.4	14.4	15.9	6.1	0.3
30	37.5	7.5	5.0	7.9	8.7	8.1	0.3
50	35.9	11.8	6.4	5.1	6.7	5.5	0.4
70	58.2	25.6	17.0	2.3	4.7	8.1	0.5
85	38.4	10.5	10.2	0.8	3.6	12.4	0.9
95	35.0	8.7	10.2	0.7	4.1	10.2	1.1

Source: Central Bureau of Statistics

5.3

Another subclass showing a decline during the epidemiologic transition is that of other nontraffic accidents. This is a heterogeneous category with occupational accidents as one of the components. From historical publications it can be inferred that occupational accident mortality has been largely reduced in the Netherlands since the nineteenth century.[69] Another main component is the subclass of accidents caused by fires and flames. Historical data from England and Wales have shown that accidental burns, being a major external cause of death during the nineteenth century,[70] sharply declined between 1848 (14 deaths per 100.000 person-years) and 1947 (2 deaths per 100.000 person-years).[71] A similar development may have taken place in the Netherlands as well.

Table 5.3.1 shows that different subclasses have replaced accidental drowning and "other nontraffic accidents" as major external causes of death.

Traffic accidents are known in the literature as a main exponent of the "age of degenerative and man-made diseases".[72] This is confirmed by our results. Mortality from traffic accidents has risen sharply during this century, especially up to 1970. Accidents of this kind were the most important external cause of death from the 1950s until the early 1980s.

But are traffic accidents the only exponent of the "degenerative and man-made diseases" or can we identify other injury subclasses as such as well?

Table 5.3.1 shows that mortality due to accidental fall has followed a pattern almost identical to that of traffic accident mortality over the last century. Mortality due to accidental fall has also sharply risen until 1970.

In the years from the beginnning of this century until 1970, traffic accidents and accidental fall replaced accidental drowning and "other non-traffic accidents" as major external causes of death, while ischemic heart disease and cancer took over from infectious diseases as main source of mortality in the population. When Omran formulated his original theory, a specific transition had already taken place within the injury field.

What happened in this field after 1970? As was the case for ischemic heart disease,[73] traffic accident mortality and mortality due to accidental fall showed a spectacular decline at the end of the epidemiologic transition. This decline, however, has recently levelled off for both external causes of death, and accidental fall in particular. This is based on the fact that the incidence of traffic injuries has more or less stabilized at the level of 1985, whereas the incidence of accidental fall has risen (see chapter 2). Therefore, since the second half of the 1980s accidental fall has contributed more strongly to injury mortality than traffic accidents.

Currently, accidental fall is the most important external cause of death, accounting for almost one-third of injury mortality.

Table 5.3.1 makes it clear that accidental fall shares this position with suicide. And this brings us to a final striking development in the field of injuries: during the past century intentional injuries, including suicide and homicide, have grown in importance. Especially since 1970, the share of intentional injuries (which are really "man-made") has risen. Since that time the number of deaths from all types of accident has declined, while deaths from intentional injuries have continued to rise until at least the middle of the 1980s . Fortunately, the growing number of deaths from suicide has recently shown signs of levelling off. Homicide, however, is still on the increase.

These trends render suicide currently a more important cause of death than traffic accidents. And homicide causes more victims than accidental drowning, which happened to be the major external cause of death at the beginning of this century.

5.3.2 EXPLAINING HISTORICAL DEVELOPMENTS IN THE FIELD OF INJURIES

In the previous paragraph we described dynamic developments in the field of injuries during the epidemiologic transition. Although injury mortality as a whole has been rather stable, with the exception of an "epidemic" between 1950 and 1970, there have been major shifts between subclasses.

Accidental drowning and other nontraffic accidents showed a decline during the epidemiologic transition, resembling that of infectious diseases. Traffic accidents and accidental fall are characterized by rising numbers of deaths until 1970, followed by a trend reversal afterwards similar to that seen for ischemic heart disease. Finally, mortality due to intentional injuries was shown to have grown in importance, in particular since 1970.

This paragraph will seek an explanation for the major "transitions" that we observed. We found rises and declines in specific causes of death during different periods of time. Rising mortality figures could be due to the emergence and growth of new types of exposure during a specific period of economic and socio-cultural development in the Netherlands. Declines could be the result of adaptation mechanisms during a subsequent phase.

5.3

In this paragraph we will discuss the possible role of economic and socio-cultural determinants and of adaptation mechanisms (including preventive public health measures and improvements of medical care) in relation to the dynamic developments in injury mortality since the nineteenth century. Where similarities with other major diseases were found, the possibility of common determinants will be reviewed.

Transition 1: trends since the nineteenth century until 1970

The sharp decline in accidental drowning and other nontraffic accidents

At the beginning of this century the mortality due to drowning and other nontraffic accidents was much higher than nowadays. Probably, accidental drowning was previously an important external cause of death in the Netherlands.[68] In the nineteenth century its level was equal to that of traffic accident mortality at its peak, around 1970. A high exposure to open water seems the prominent background factor. It is likely that, similar to a description from London 1831-1883, "Victims fell into the water from boats, bridges, the river banks, and even from houses along the shore".[70] But mortality due to drowning sharply declined, as did the trend in infectious diseases. Which general factors could have contributed to this development and were they similar to the major determinants of the decline in infectious disease mortality?

Rising living standards are considered to be a major factor behind the decline in infectious disease mortality.[63,67,74,75] They have a direct effect through material conditions, such as better nutrition and improved housing conditions. They achieve indirect influence by stimulating cultural modernization, including a higher education attainment of women and lower fertility rates. And they allow the implementation of preventive public health measures and of new medical technologies.

Compared with infectious diseases, similar direct effects due to rising living standards (better nutrition and improved housing) did not affect the trends in accidental drowning. On the other hand, indirect effects of growing prosperity have probably been more important. Cultural modernization, as stimulated by rising living standards and vice versa, has probably been a major determinant. Accidental drowning is a cause of death which to a large degree affects children. The declining fertility rates since the beginning of this century have led to smaller family sizes and improved parental supervision,[76] which is one of the important factors in protecting children from drowning.[77]

In addition, growing urbanization seems important,[76] as drowning rates are much higher in rural than in urban areas.[78,79] Important preventive public health measures were taken as well. First, the activities of the Foundation for the Rescue of Drowning Persons (initiated in 1767) and the Royal Union for the Rescue of Drowning Persons (founded in 1917) are worthy of mention in this respect. These organizations have saved the lives of near-drowning persons. But one of the most important "adaptations", that certainly helped to reduce accidental drowning to its present level, is an enormous increase in swimming abilities in the population over the last century. This is reflected in current figures on swimming abilities by age in the Dutch population. These figures show that 99% of all twelve year old children can swim. This percentage shrinks, in particular above the age of 35 years, to only 30% among persons older than 80 years.[80] The introduction of swimmming education at primary schools[81] played an important role in stimulating swimming skills.

Rising living standards probably had effects on other nontraffic accidents too, and on accidents caused by fire and flames in particular. Improved housing conditions, including a better quality of building materials and less crowding, probably helped to reduce the number of victims of accidental burns. And the implementation of preventive public health measures has probably been important as well. Around the turn of the century, the "building act" was introduced in the Netherlands to regulate housing conditions.[82] Preventive public health measures have also helped to reduce the burden of occupational injuries. During the industrial revolution new hazards to society were introduced. In 1868, William Farr, one of the founders of modern epidemiology, stated: "still mechanical force, steam and chemical agency are undoubtedly new elements of danger to mankind".[83] Adaptation to these new dangers came from legislative efforts, that started more than a century ago. First, measures were taken to reduce the numbers of hours at work of children (1874) and adults (1889), followed by the "Factory Safety Act" (1901) that regulated working conditions. In addition to these public health measures, the modernization of labour has been important. An important element of this change concerns the shift from high-risk work in agriculture and manufacturing towards low-risk work in the service sector that took place during this century.[42,84]

It may be concluded from the above that the disappearance of accidental drowning and other nontraffic accidents as major external causes of death can probably be explained by similar general factors as the decline in infectious diseases: growing prosperity, cultural modernization, and the implementation of preventive public health measures.

But what about the influence of improvements of medical care? During the first half of this century the safety of anaesthesia increased, surgical techniques improved, and blood transfusions were introduced.[71] This indicates that medical care could have contributed to the observed mortality reductions during this period.

This contribution, however, has probably not been large. The major external causes of death, such as drowning and accidental burns, can have benefited only to a limited extent from the new medical technologies during the first half of this century.

The rising mortality due to traffic accidents and accidental fall

At the beginnning of this century, traffic accident mortality was low (see table 5.3.1). A new hazard to society was then introduced: the motor vehicle. Historical data show that in England/Wales the first deaths due to this new hazard were registered in 1896.[83] In the Netherlands, the victims of motor vehicle exposure can be identified from 1910 onwards, with sharply increasing rates until 1970.[72] This rise is certainly related to economic development. The rising living standards of the Dutch population allowed a steep increase in the use of motor vehicles. In particular, the "mass motorization" of the Dutch population between 1950 and 1970 made many victims. This mass motorization was induced by a period unmatched in terms of economic growth during this century.

From 1910 until 1970, growing prosperity led to an increasing incidence and mortality of traffic injuries, intermediated by exposure growth (see chapter 2 and 3). This is similar to the development in ischemic heart disease. Until 1970, mortality from ischemic heart disease sharply rose under the influence of growing prosperity. This was probably intermediated by an increased exposure to some of the major risk factors in this area, such as unhealthy nutritional habits and tobacco smoking.[85]

A similar observation could also be made with respect to accidental fall. This was a small external cause of death at the beginning of this century, which also increased rapidly in importance up to the year 1970. Was this development also induced by growing prosperity?

It must be recognized that the vast majority of deaths due to accidental fall concerns fractures of the lower extremity.[86] This reflects the problem of hip fractures among the elderly. The literature reveals that in many industrialized countries, including the Netherlands, a secular trend in the incidence of hip fractures is met.

During this century the number of hip fractures in western populations has risen sharply, even after adjusting for the ageing of these populations.[87-91] A major determinant of this increase is the growing prevalence of osteoporosis, which leads to higher fracture risks in case of an accidental fall.[92-94] The growing prevalence of osteoporosis is probably related to a reduction in physical activity, which was -at least partly- induced by the increased use of motor vehicles referred to above. Moreover, changes in nutritional habits and increased smoking are determinants of osteoporosis as well.[95-96] This means that growing prosperity could have influenced mortality from accidental falll, in part intermediated by similar determinants to those found for traffic accidents and ischemic heart disease.

Transition 2: trends since 1970

The declining mortality due to traffic accidents and accidental fall

Around 1970, mortality due to traffic accidents started to decline, closely following the trend reversal for ischemic heart disease. Did the decline in both public health problems have similar general determinants?

Let us first summarize some major findings with regard to ischemic heart disease. There is a consensus of opinion on the fact that a reduced incidence has greatly contributed to the declining mortality in this area. This is often ascribed to the combined effect of several "adaptations" to the epidemic of cardiovascular diseases, including preventive public health measures (e.g. health promotion activities aiming at better nutrition and reduced smoking) and improvements in medical care (e.g. earlier diagnosis and treatment of hypertension).[36,38] It has long been debated whether a reduction of the case fatality (caused by improvements of medical care) has also contributed to this decline.[67] Recent findings, however, demonstrate the importance of a declining case fatality.[37,39]

Apart from preventive public health measures and improved medical care, autonomous trends in the prevalence of risk factors have probably been important too, although their mechanisms have not yet been clarified. A striking observation concerns the reversal which was seen around 1970, in which ischemic heart disease mortality went from being a "manager's disease" to a "disease of the common people".[97] This suggests that rising living standards, which previously had induced increases in the mortality due to ischemic heart disease, had finally become protective.

The decline in mortality due to traffic accidents seems to be the result of "adaptation mechanisms" similar to those responsible for the decline in ischemic heart disease.

5.3

After 1970, the incidence of traffic accidents was greatly reduced as well. Preventive public health measures have certainly contributed to this development (e.g. infrastructural improvements, seat belt laws, helmet laws, speed limits, alcohol legislation and safety promotion campaigns). The effects of these measures, however, must not be overestimated (see chapter 2 and 3).

We found a major influence of autonomous factors on the reduced incidence of traffic injuries: the increasing use of passenger cars levelled off, whereas the use of mopeds declined enormously after 1970.

Similar to ischemic heart disease, the case fatality of traffic injuries has also been reduced. To some extent, the same determinants as those responsible for the declining incidence are involved. For example, helmet laws and the declining popularity of mopeds have led to a more than proportionate reduction of intracranial injuries. This has led to a lower mean injury severity. On the other hand, we found indications that improved medical care has contributed to a reduced case fatality (see chapter 2 and 3).

As was the case for ischemic heart disease, we found that in the end rising living standards become protective against traffic accidents. It seems as if in later phases of the epidemiologic transition, prosperity reaches a level where the balance between negative effects (mobility growth) and positive effects (adaptations, including preventive public health measures and improvements of medical care) weighs in favour of the latter.

Strikingly, as was the case for ischemic heart disease and traffic accidents, mortality from accidental fall has also shrunk since 1970. Were common determinants (such as for the rises we found before 1970) accountable?

This, however, is not very likely. Contrary to the incidence of ischemic heart disease and traffic accidents, the incidence of accidental fall (and resulting hip fractures) has continued to rise since 1970 (see chapter 2). Preventive public health measures aiming at a reduction of the incidence of ischemic heart disease (more healthy nutrition and less smoking) have not yet affected the incidence of hip fractures. And autonomous developments that helped to reduce the incidence of traffic accidents (mobility growth leveling off) have, as yet, failed to have an effect too. One explanation is the following. Contrary to ischemic heart disease and traffic accidents, which are dominated by males, the vast majority of hip fractures is sustained by women. It must be noticed that women knew rather unfavourable developments in common determinants (e.g increased smoking) in the most recent period.

It should be recognized that accidental fall is in fact still characterized by an increasing amount of public health damage resulting in enormous societal costs. The mortality reduction since 1970 gives the appearance of a declining number of victims. Yet, contrary to ischemic heart disease and traffic accidents, this mortality reduction is completely due to a reduction in the case fatality. In the case of accidental fall the "adaptation" is restricted to improved medical care (see chapter 2).

In spite of fewer deceased persons, we are dealing with a growing public health problem.

The rising importance of intentional injuries

This thesis has focused on accidental injuries. In reviewing historical developments, however, some attention must be devoted to intentional injuries. At the beginning of this century, intentional injuries accounted for about 15% of all deaths due to external causes, most of them being suicides. This situation still existed around 1970. Since then, however, their importance has sharply risen. Currently, almost one third of injury mortality is the result of an intentional event, for the most part suicides, although the share of homicide is climbing.

Are these developments alarming? From an historical perspective there would appear to be little reason for alarm. Suicide levels have fluctuated throughout history.[98-99] At present they are somewhat higher than at the beginning of this century, but this could in part be explained by a greater openness around suicide leading to a more complete registration of this phenomenon.

The growing share of suicides as a cause of death, on the other hand, should make them a public health priority. The human pain and sufferings of relatives and friends of suicide victims is extensive. The prevention of suicide[100] needs more attention, as already been recognized at the beginning of this century.[101]

Homicide is still a minor external cause of death, despite a steady rise since the beginnning of this century. According to historical analyses, homicide and assault reached far higher levels in western societies in the past, as for example from the seventeenth to the nineteenth century.[102] In the Netherlands, examples from nineteenth century cultures may be cited where armed violence is viewed as an acceptable conduct.[103] In the past, the tolerance of individual violent behaviour was probably much higher than in contemporary society. An important theory offers the following explanation for this phenomenon.

During the process of civilization violence became the monopoly of the government. Increasing mutual dependency between citizens could have led to a more effective internalized and external control of aggressive impulses.[104]

Nevertheless, the rising share of intentional events in injury mortality in the Netherlands causes concern. The rapid increase in homicide and assault since the early 1970s is a reversal in a historical trend towards less violent behaviour in civilized societies.

Since that time not only has the number of homicides increased sharply, but the incidence of hospital admissions[105] and emergency department visits[106] due to interpersonal violence grew as well. Moreover, there are signs of recent increases in injury severity caused by the more frequent use of weapons.[107]

Currently, about 200 people are killed each year in the Netherlands. This is the tip of the iceberg of an unacceptable and increasing public health problem. Can we identify determinants of this increase?

There are many theories about the major causes of interpersonal violence.[108] Major determinants could be structural (e.g. poverty and lack of opportunities), cultural (e.g. the media glorification of violence, and the disruption of social support mechanisms) or interactionist (e.g. the use of alcohol and drugs and the possession of weapons). It is unlikely that any of these factors alone could be held responsible for the observed increase in interpersonal violence. Moreover, it is unlikely that there has been a general increase in all those factors in the population. However, our contemporary society could be characterized by a growing number of people, where combinations of the aforementioned structural, cultural and interactionist factors are concentrated. We must certainly consider the possibility that subcultures have arisen in our society, for whom the threshold for violent behaviour is low, as it was in the general population during earlier phases of the epidemiologic transition.

5.3.3 FORECASTING FUTURE DEVELOPMENTS IN THE FIELD OF INJURIES

Historical developments in the field of injuries have shown the dynamic nature of this area. The field consists of a collection of highly divergent subclasses of injuries. All these subclasses strike their own balance between favourable and unfavourable factors, and are characterized by continuous changes in these balances.

5.3

The main lessons from the past seem as follows. Specific injury subclasses grow in importance during a specific phase of economic and socio-cultural development. During this phase, new hazards to mankind are introduced, followed by an increasing exposure of the whole population.

Subsequently, adaptations are made to the new hazards. These adaptations include preventive public health measures and new medical technologies. Forecasting future developments and early detection of unfavourable trends should help to accelerate the adaptations. In addition to anticipating on trends in longer existing injury risks (see chapter 4), possible new hazards for the future should be identified.

One example of such a new hazard concerns air traffic. We could be at the beginning of a new era: the era of "globalizing". This new economic and socio-cultural development rapidly stimulates the expansion of air traffic. Although air traffic is considered one of the safest modes of transport, we have already been confronted with aeroplane crashes with Dutch casualties: Tenerife (1977), Faro (1992), Amsterdam (1992), Eindhoven (1996), Den Helder (1996). Air traffic could further increase in the future. Hence, a new transition within the field of traffic accidents cannot be exluded. This illustrates the need for adaptations, including safety regulations and an adequate organization of "disaster medicine" embedded in regular trauma care.

Another example concerns the growing amount of leisure time in our society, which could be accompanied by increases in high-risk recreational activities. And if so, a growing incidence of injuries could be the result.

This stresses the need for continuous injury surveillance systems. Humans seem to be born with a passion for new challenges that call for new adaptations. Forecasting future developments and early detection of unfavourable trends, should help to accelerate these adaptations. This may lead to the prevention of unnecessary public health damage. The instrument we developed and evaluated may prove useful to this process.

5.4

Challenges for the future

The analyses reported in this thesis have offered a body of scientific and policy information.

The material shows that, although the amount of public health damage due to injuries has been reduced in the past, much work remains to be done. The dynamic nature of the field forces health policy makers continuously to (re)define priority areas, in which effective policy measures must be implemented. Injury surveillance and research have to provide continuous support for new initiatives in prevention and trauma care. Injuries are a continuous challenge for public health. This concluding paragraph will discuss the major issues for the near future.

5.4.1 MAJOR CHALLENGES IN INJURY SURVEILLANCE

Surveillance is one of the primary activities of public health.[54] In the field of injury control it has been recognized as a major tool supporting priority setting in prevention.[109] We performed several analyses within the framework of public health surveillance. We applied methods for trend analysis, cost assessment, geographical analysis and forecasting and monitoring. We were able to evaluate these methods, and in particular the forecasting and monitoring techniques that we developed. This yielded the conclusion that, in spite of some general and specific limitations, the applied methods may promote an (early) identification of priority areas in public health policy (see chapter 5.2).

It should not be forgotten, however, that all our applications were highly dependent on the availability and quality of routinely collected data from several sources. The limitations of the analyses reported are therefore mostly concerned with (possible) registration problems.

This means that improving the registration of injuries and their consequences is one of the main challenges for the future. In particular the following must be recommended in order to solve the major registration problems identified (see chapter 5.2):

- improving the registration of the incidence of injuries;
- registration of injury severity.

Improving the registration of the incidence of injuries

In comparison to other public health problems (e.g. cardiovascular diseases) the field of injuries is supplied by many data sources.

The availability of information on the incidence of injuries, next to mortality figures, is extremely important.

A major problem, however, stems from the lack of uniformity between the methods of registration of the incidence of traffic, occupational, and home and leisure injuries respectively. This obstructs a straightforward comparison of the size of several subproblems and their developments over time. This problem had already been identified during the first years of our surveillance activities.[57] Subsequent initiatives were taken towards establishing a national intersectoral reporting system for injury victims. This resulted in the Dutch Injury Surveillance System (LIS), launched on January 1, 1997. It is a uniform surveillance system of sixteen hospitals, sampling almost 15% of the injury victims treated at Accident & Emergency (A&E)-Departments in the Netherlands.[110] It includes traffic injuries, occupational injuries, home and leisure injuries and intentional injuries. For the first time, all subclasses are registered according to similar criteria in a sample that aims to be representative at the national level. Although the system does not provide information on the incidence of injuries in the population at large, it constitutes a major improvement in injury surveillance.

Nevertheless, further work on standardization remains necessary. The vast majority of hospitals in the Netherlands still uses other classifications and registration procedures to record A&E-patients than the Dutch Injury Surveillance System. Moreover, there are important patient categories not fully covered by the system, such as patients treated by the general practitioner and patients seen by ambulance attendants. In addition, refined medical information on hospitalized patients, as needed for the evaluation of trauma care, is not (yet) included.

Therefore, several recording systems on injury patients are operational or being implemented in the Netherlands, both at the national (e.g the national trauma registry of the Dutch Society of Traumatology) and the local level (e.g the trauma registries of the university hospitals and other hospitals with extensive trauma facilities).

A challenge for the future is to achieve a situation of compatibility between the major surveillance systems. This will present some difficulty, as the primary aims of the existing systems differ (e.g health care management, assessment of quality of care, setting priorities in prevention). A national committee, installed by the government, has recently defined the basic information needed for the assessment of the quality of care.[112] The inclusion of this basic information in all injury surveillance systems in the Netherlands would be a great improvement.

Moreover, the development of standard classifications is of primary importance. For this reason a National Committee on Standardization of Injury Recording was established. An important example of the work of this committee is the development of a Dutch Injury Classification.[113] This classification is derived from the ICD-10. It will include several levels of detail, adapted to the setting where it will be used (e.g. population survey, emergency department, general hospital, trauma centre). A major challenge for the future involves the large scale implementation of this classification in injury surveillance in the Netherlands. This would certainly further improve the assessment of the burden of injuries.

Injury severity

Injury severity is a major parameter in the central conceptual framework of this thesis. In addition to figures on the incidence of injuries, data on injury severity are very important for purposes of priority setting in prevention.[114] Moreover, for the evaluation of trauma care it is highly necessary to record injury severity, being one of the major factors affecting outcome.[115] So far, adequate data on injury severity have been scarce in the national registries in the Netherlands. Some of the analyses of this thesis have identified this as a major limitation. We found indications that improvements of trauma care have contributed to reduced case fatality rates by period (chapter 2.1) or region (chapter 3.1). These findings, however, must be interpreted with care because a (refined) adjustment for injury severity could not be made.

It is therefore vital to ensure that the national registries are supplemented with refined information on injury severity.

It should be emphasized that two different criteria can be used for assessing injury severity: the threat to life on the one hand and the expected functional outcome on the other. Severity scaling with threat to life as the criterion has long been practiced. The international standard systems (Abbreviated Injury Scale/AIS and Injury Severity Score/ISS) were developed in the 1970s[116-117] and further refined subsequently.[118-122] They are frequently used in trauma registries all over the world and have already been shown to be fair predictors of the case fatality rates of hospitalized patients in the Netherlands.[123-124] Their inclusion in surveillance systems is basic to the evaluation of trauma care.[125] Using these injury scales is, however, time-consuming, which limits their practicality. And the assignment of severity scores is unduly subjective and may be accompanied by wide observer variation.[126]

Recently attempts have been made to develop simplified techniques for injury severity grading based upon the International Classification of Diseases/ICD.[127] With the help of large hospital data bases using this classification, "expected case fatality rates" have been calculated for each separate ICD-code. Studies comparing ICD-derived severity scores (ICISS) with AIS-derived severity scores (ISS) have concluded that the first is at least as good as a predictor of survival in injured patients as the latter.[128-129]

In addition, it is important that a conversion programme is available in which each ICD-code has been assigned a separate AIS-code.[28-29] The validity of this programme has already been tested in the Netherlands among 1135 trauma patients treated at Groningen University Hospital. On the basis of this study it was concluded that the programme is a highly usable and valid method for the large-scale recording of severity scores.[130] Recently a new version of the programme was introduced.[131]

From the above it may be concluded that registration of injury severity can be based on either the AIS or the ICD-classification. If only ICD-codes are available two methods to assess injury severity can be applied. Either large hospital data sources can be used to calculate "expected case fatality rates" and ICISS scores for each separate ICD-code, or ICD-codes can afterwards be converted into AIS/ISS scores.

A complication, however, is that ICD-coding as a basis for severity scoring has not yet been tested for its latest revision: ICD-10. In the coming years this will probably be the standard for the registration of morbidity in the Netherlands, as it already is in the registration of mortality. The aforesaid Dutch Injury Classification is also based on the ICD-10. A challenge for the future is the development, application and evaluation of large scale severity scoring based on the ICD-10.

This includes the development of conversions between ICD-10 and AIS.
In addition, further work on severity scales that predict functional outcome is necessary.

There is international consensus that AIS and ISS are poor predictors of both temporary and permanent disabilities and handicaps.[114,132,133] Several efforts have therefore been made to develop tools to assess injury severity from the perspective of functional outcome. Important initiatives are the development of the Injury Impairment Scale[134] and the Functional Capacity Index.[132]

These instruments map AIS-descriptions into scores that reflect expected post-injury levels of function. The scores are based on judgements of groups of (clinical) experts. The extensive field testing of these new measures is recommended. This includes testing among "low energy" injuries, because the application of the measures has so far more or less been restricted to patient groupings with "high energy" accidents (e.g motor vehicle crashes). This thesis illustrates the high societal impact of "low energy" injuries (e.g. sports injuries, occupational injuries, hip fractures among the elderly). The standard severity scales (AIS and ISS) have too little discriminative power where these injuries, in particular, are concerned.

In addition to testing of instruments which are already available, other methods should be explored. The challenge is to develop ICD- or AIS-derived "expected functional outcomes" based on large empirical studies. It would appear worthwhile to develop separate measures for temporary and permanent disabilities, because many injuries finally lead to complete recovery after incapacitating the victim and his family for some time. This requires empirical research which will be further dealt with in chapter 5.4.2.

New directions in injury surveillance

The aforementioned improvements of the registrations should be accompanied by new directions. This thesis has shown the value of trend analysis, cost assessment and forecasting and monitoring for public health policy.

It is recommended that the analyses in this thesis be performed on a more regular basis, using the most recent injury surveillance data. So far we have focused on developing and evaluating methods for public health monitoring. These methods have produced results which frequently do not describe the most recent situation in the Netherlands. In fact, a more frequent application of the methods is needed to fulfill one of the most important purposes of public health surveillance: the "timely dissemination of information to those who need to know".[135]

Our methods should be embedded in the framework of existing surveillance systems. This would enable, for example, the continuous monitoring of costs, as has already been initiated.[136] This is an important step forward, because continuous information on the incidence of injuries will be supplemented by continuous information on the costs of injuries. Likewise, our new tool for forecasting and monitoring of injuries should be embedded in continuous monitoring activities. The development of future health scenarios for the period 2000-2015, based on data of the Dutch Injury Surveillance System and a new Delphi study, could provide a good framework for trend analyses. This could support the early identification of new priority areas in injury control.

5.4.2 MAJOR CHALLENGES IN INJURY RESEARCH

In order to reduce the future public health damage caused by injuries, epidemiological research in this area should be stimulated. There are still many gaps in the available scientific information. In the Netherlands, much work has already been done on the assessment of the burden of injuries, including the analyses reported in this thesis. Nevertheless, to support priority setting new ways must be explored. This thesis has shown, for example, that empirical findings on disabilities and handicaps as a result of injuries are hardly available.

New ways are also needed to make adequate choices on specific preventive measures and improvements in trauma care. Subgroups exposed to particular risks, both at the individual and the population level, should continuously be identified. In the Netherlands, the research into determinants of injuries at the individual level has so far been limited. The same applies to the research on the effectiveness and efficacy of injury prevention and trauma care.

This paragraph will discuss challenges in injury research, focusing on the information gaps that we mentioned.

Disabilities and handicaps

An important issue relates to the development and application of methods for the measurement of the "quality of life" of injury victims. Internationally, most work has so far focused on the long-term consequences of "high energy accidents", resulting in major trauma.[137-141]

These were recently the subject of study in the Netherlands as well.[142-145] More information on the long-term consequences of less severe injuries is also urgently required. In the Netherlands, for example, it was recently found that the differences in functional outcome between patients with ankle fractures and patients with major trauma are much smaller than generally assumed.[146] Moreover, at the population level at least two-thirds of the disabilities and handicaps resulting from injuries are probably caused by injuries that did not even need hospitalization.[147-149]

This means that studies are needed on the functional outcome of both "high energy" and "low energy" injuries. In addition to the long-term consequences, temporary disabilities should be studied as well.

Generic health status measures (e.g. the Nottingham Health Profile, the EuroQuol and the Short Form-36) as developed in quality-of-life-research[150] should be tested in distinct injury patient populations. Some interesting studies have already reported an acceptable performance of these instruments, in particular in relation to the more severe injuries.[151-153]

Important in this very heterogeneous field is to specify the feasibility, reliability and validity of generic health status measures for different patient groupings by age (e.g. children, adults and the elderly), type of injury, and level of injury severity. In addition, specific measures for injury patients should be developed, because the combination of generic and disease-specific measures yields the best results in health status measurement.[150]

The measurement of temporary and permanent functional losses in distinct patient groupings is sorely needed in injury research. This could be followed by another important step. When adequate data on the incidence and prevalence of disabilities by type of injury are available the calculations of the "human costs" can be improved. So far, the most comprehensive effort in this area was the assessment of the global burden of disease and injury.[154] This assessment, however, relied strongly on expert opinions on disability rates by type of injury, because of the almost complete lack of empirical data in this field. The measurement of functional losses due to injuries could therefore further improve the calculation of "disability-adjusted life-years".[32,155] Important information could thus be gained, on the burden of injuries as a result of disabilities, in addition to figures on the incidence, mortality and economic costs as reported in this thesis.

5.4

Determinants of injuries at the individual level

This thesis has examined the burden of injuries and its major determinants at the population level. It has confirmed that factors exerting an effect at the aggregate level may not be ignored in injury research. The prosperity level of a population, for example, influences the level of traffic accident mortality. And regional characteristics , such as the road infrastructure and the availability of advanced medical care , are major determinants of traffic accident mortality levels as well. This means that research into determinants of injuries at the population level should certainly be continued.

Obviously, however, research at the individual level is also vital. In order to develop effective prevention strategies, individuals with higher than average injury risks should be identified, and the underlying reasons should be clarified. The epidemiologic research into determinants of injuries at the individual level has so far been limited in the Netherlands. Standard methods of observational research, such as the case-control design and the cohort-study, have hardly been used. Nevertheless, these are important instruments for effective injury control.[156] Moreover, the application of new methods to study acute causes of diseases and injuries, such as the case-crossover design, seems promising.[157-159]

An area meriting priority is the investigation of socio-economic differences in the incidence, severity and consequences of injuries. This research should focus on determinants that can be influenced by interventions. We found and analyzed socio-economic differences in injury mortality at the population level. In the Netherlands, hardly any attention has so far been paid to socio-economic differences in injuries at the individual level. A large survey among 25.000 households has shown the lower socio-economic groups to be disadvantaged where self-reported traffic, occupational and domestic injuries are concerned, but not for sports injuries.[27] Internationally, there are numerous indications that the lower socio-economic classes have higher injury rates than more wealthy groups, in particular among children.[160-164] But explanatory research in this area has been limited. The description and explanation of socio-economic health differences is one of the major issues in public health epidemiology today. In the Netherlands, a national programme on this issue has revealed large differences in morbidity.[165] The lower socio-economic groups are highly disadvantaged. Unhealthy living habits and unfavourable material conditions were identified as important (and interacting) specific determinants.[166]

Socio-economic differences in injuries in the Netherlands to be recorded in the aforementioned surveillance systems should be described and explained. The existence of these surveillance systems opens possibilities for case-control studies into the causes of socio-economic differences in the incidence of specific groups of injury patients. Attempts should be made to unravel the contribution of several controllable determinants in relation to these groups, including individual behaviour, exposure and protection, material conditions, and medical care.

Evaluation of preventive measures and trauma care

This thesis found general indications that prevention and trauma care have both contributed to a reduction in public health damage due to injuries in the Netherlands.

Moreover, it appeared that experts can generate many ideas on policy measures to be implemented, and have optimistic thoughts about their quantitative effects.

Existing scientific information on the effectiveness and efficacy of specific preventive measures is, however, scarce, both in the Netherlands and abroad. Although a few studies have evaluated (parts of) trauma care in the Netherlands,[167-169] the majority of quantitative information in this area is from abroad.

This thesis has shown that in order to reach a further reduction in public health damage new initiatives in prevention and trauma care are needed. Many of the measures to be implemented (e.g. new programmes of safety education, regionalization of trauma care) should be preceded and/or accompanied by quantitative effect studies estimating and/or measuring the resulting reduction in mortality and morbidity. This type of research has so far hardly been performed in relation to injury control in the Netherlands. The principles of "evidence based medicine"[170] should become the standard in this field.

5.4.3 MAJOR CHALLENGES IN INJURY PREVENTION AND TRAUMA CARE

Our analyses have identified many priority areas for public health policy. It has become clear that new initiatives are needed to reduce the amount of public health damage in the future. From the conceptual framework of this thesis it can be inferred that policy makers may influence several parameters.

Their interventions could focus on:
- exposure control;
- reductions of injury risk and injury severity;
- reductions of the severity-adjusted case fatalities and disability rates.

Inititiatives in exposure control

This thesis has confirmed the role of exposure as a major determinant of injuries at the population level. New and growing types of exposure tend to increase the amount of public health damage due to injuries. Exposure is a key variable in future health scenarios in this field.

Reducing the amount of exposure is probably a highly effective means of reducing the incidence of injuries and their consequences, including the "economic" and "human" costs.

Nevertheless, inititiatives in exposure control, in the sense of reducing or replacing a specific human activity, are hardly ever considered in injury prevention. At the time of our Delphi study the idea of exposure control was completely rejected as the experts did not consider it feasible at that time.

Why is there so much resistance to measures aimed at exposure control?

Probably because exposure to injury risks is based on the performance of general human activities, such as driving, cycling, flying, working, playing football, housekeeping, gardening and participating in citylife at night. Exposure to injury risks is related to both societal tasks and individual pleasures. Exposure to injury risks is part of human life. Measures to control exposure are often seen as measures to control human life.

What kind of exposure control measures could be implemented?

Two types of measures are conceivable: exposure reduction and exposure replacement. The first type of measure aims to reduce the participation rate in (hazardous) activities. The second, while similar, also provides an alternative. An example of the first type could be to abandon driving by young adults during weekend nights. A measure of the second type would include offering free public transport.

Exposure control measures affect individual freedom to such an extent that they should not be considered unless the amount of public health damage becomes unacceptable, and other measures are insufficient. If areas with an untolerable amount of public health damage are identified, creative solutions for exposure control should be taken into consideration.

If possible, exposure replacement should be preferred to exposure reduction. Consequently, one of our tasks for the near future is to define the unacceptable. This demands quantitative information of the kind presented in this thesis, although such a definition will probably be based to a large extent on ethical and political considerations. What is defined as an unacceptable burden of injuries will probably depend on the type of activity performed. Activities yielding high risks of injuries to other people seem the best candidates for exposure control.

Reducing injury risk and injury severity

Although specific exposure control measures might help to reduce the burden of injuries, prevention will always be primarily based on strategies affecting the injury risks and injury severity.

New prevention strategies should first of all be implemented in priority areas. From the analyses of this thesis at least two major priority areas could be derived: injuries to cyclists and domestic accidents among the elderly. In this paragraph these two examples are used to illustrate new ways to reduce the injury risk and/or injury severity.

In assessing the burden of injuries in the Netherlands injuries to cyclists surfaced as an important subproblem. Cyclists account for about one half of all traffic injuries in this country. This is reflected by high medical costs (see chapter 2.2) and a high share of traffic deaths (see chapter 3.1).

Interestingly enough, cycling injuries are increasingly recognized as an important public health problem in other countries.[171-172] Internationally, the discussion on reducing the risk and severity of cycling injuries focuses on one single measure: bicycle helmets.[173-176]

This is due to the very high frequency of head injuries among cyclists.[177] In the Netherlands, just under half of the hospitalized cycle-accident victims have suffered head injuries.[60] It is worth noting that among cyclists, head injuries are often the only life-threatening form of injury, wheras in other modes of transport they are frequently associated with other -often multiple-injuries of similar or even greater severity.[178] This is probably due to the fact that many head injuries are sustained in single accidents, without involvement of a motor vehicle.

The wearing of bicycle helmets has already been made compulsory in several parts of Australia, New-Zealand and the USA.[179] However, most bicycle helmet laws are restricted to children.

Research findings have indeed shown the effectivenes of bicycle safety helmets. Several case-control studies have shown that helmets cut down injuries to the brain and upper face by 60-90%.[180-183]

Nevertheless, there is much resistance to bicycle safety helmets, arguing that a change in the behaviour of motor vehicle occupants would be far more effective.[184] Arrestingly enough a broad majority of the experts consulted in our Delphi study in 1986 considered complusory wearing of bicycle helmets to be neither necessary nor desirable.

In the near future, we will have to take a well-informed decision on bicycle helmets in the Netherlands. The public health damage due to head injuries among cyclists should be adequately quantified. The effectiveness of bicycle helmets among several subgroups in this country (e.g. children and adults, single accidents and collisions with motor vehicles) should be established. And finally, the balance of positive and negative consequences of bicycle helmets should be weighed very carefully. The number of head injuries to cyclists is too large to reject helmets because of emotional resistance. Bicycle helmets are probably the most effective measure, available to reduce the severity of single bicycle accidents. On the other hand, measures to protect cyclists from a collision with a motor vehicle, should of course be continued. The reduction of risk and severity of cycling injuries is a priority area in injury control, with bicycle helmets as only one of the possible policy measures.

The reduction of risk and severity of domestic accidents among the elderly is another priority area in injury control. This holds in particular for the problem of accidental fall. This problem is rising (see chapter 2.1) and accounts for a very large proportion of all injury-related medical costs (see chapter 2.2).

There is a large body of knowledge on major determinants of accidental fall.[185-187] These include advanced age, female gender, living alone, poor health, existence of functional impairments (in particular with respect to mobility, sense of balance and vision), prior history of accidental fall and the use of (multiple) drugs. It is very important that the risk of accidental fall among those aged 75 and over rises linearly with the number of risk factors. Therefore it makes sense to influence each separate risk factor if possible. Offering periodic examinations to elderly people, which focus on the consumption of medical drugs and the existence of functional impairments, should be considered. In the Netherlands, it has been found that more than 10 % of the hospitalizations due to accidental fall are related to the use of medical drugs.[188]

Probably a large number of the injuries due to accidental fall might be prevented by measures, such as reducing the number of drugs and compensating functional impairments.

In addition, the severity of the injuries due to accidental fall can be reduced.

In particular, the problem of (hip) fractures can be influenced. Recently, methods have been developed to predict "fracture risks" based on measurements of bone density.[189] In addition, effective forms of drug treatment have become available to reduce these fracture risks.[190] This has opened the way for population screening. However, the public health benefits of this type of intervention will probably be limited, if only targeted at bone mineral density while ignoring other determinants.[191]

Although a large body of knowledge is available, there is still much uncertainty about the effectiveness and efficacy of prevention. It will be necessary to do additional research and to decide upon the most effective prevention strategy in this area.

Reduction of severity-adjusted case fatality and disability

Indications that adequate trauma care reduces public health damage due to injuries are given in this thesis. Interestingly, since the start of our surveillance activities, much progress has been made in this field. In 1988, it was reported that the policy of the Dutch government with respect to the medical care of injury victims had not yet taken clear shape.[57] The professional organizations in this field, however, already had specific ideas, which were worked up into a medical care scenario (see chapter 5.2). This probably triggered activities from the government and has supported the work of the professional organizations towards improvement of trauma care.

Over the last ten years great improvements have been achieved, such as the introduction of a national emergency number, the introduction of treatment protocols for ambulance attendants and medical specialists, and the highly improved training level of ambulance attendants. And recently the government decided to regionalize trauma care, which includes the designation of regional trauma centres and the establishment of regional facilities for ambulance help and transport.[61]

A major challenge for the future is to ensure that this new system of regionalized trauma care is adequately implemented. This should include concentration of specialist facilities within trauma hospitals, formalized working arrangements between hospitals and ambulance facilities in the same region, and development of a system of quality assurance based on registration activities from the time of the accident until complete recovery, permanent disabilty or death of the patient.

As with other public health measures, the further improvement of trauma care will greatly benefit from the availability of adequate surveillance systems. In combination with new prevention strategies, this should help to reduce the still unacceptable burden of injuries in the Netherlands.

REFERENCES

1. Lamm R, Chouieri EM, Kloeckner JH. Accidents in the US and Europe 1970-1980. Accid Anal Prev 1985;17:429-438.
2. Oppe S. The development of traffic and traffic safety in six developed countries. Accid Anal Prev 1991;23:401-412.
3. Oskam J, Kingma J, Klasen HJ. The Groningen Trauma Study. Injury patterns in a Dutch trauma centre. Eur J Emerg Med 1994;1:167-172.
4. Saari J. Long-term development of occupational accidents in Finland. Scand J Work Environ Health 1982;8:85-93.
5. Robinson JC. The rising long-term trend in occupational injury rates. Am J Public Health 1988;78:276-281.
6. Schoots W. Trends in privé-ongevallen 1986-1995. (Trends in home and leisure injuries 1986-1995, in Dutch). Amsterdam: Consumer Safety Institute; 1997.
7. Kopjar B. Costs of health care for unintentional injury in Stavanger, Norway. Eur J Publ Health 1997;7:321-327.
8. MacKenzie EJ, Morris J Jr et al. Acute hospital costs of trauma in the United States: implications for regionalized systems of care. J Trauma 1990;30(9):1096-1101.
9. Phillips DE, Langley JD et al. Injury: the medical and related costs in New Zealand 1990. N Z Med J 1993;106(957):215-217.
10. Sjögren H, Björnstig U. Unintentional injuries among elderly people: incidence, causes, severity, and costs. Accid Anal Prev 1989;21(3):233-242.
11. Max W, Rice DP, MacKenzie EJ. The lifetime cost of injury. Inquiry 1990;27:332-343.
12. Hartunian NS, Smart CN, Thompson MS. The incidence and economic costs of cancer, motor vehicle injuries, coronary heart disease, and stroke: a comparative analysis. Am J Public Health 1980;70:1249-1260.
13. COST 313. Socio-economic cost of road accidents. Final report of the action. Luxembourg: Commission of the European Communities; 1994.
14. Muizelaar J, Matthijssen MPM et al. Kosten van verkeersonveiligheid in Nederland 1993. (Costs of traffic unsafety in the Netherlands 1993, in Dutch). Leidschendam: SWOV; 1996.
15. Baker SP, Whitfield RA, O'Neill B. Geographic variation in mortality from motor vehicle crashes. N Engl J Med 1987;316:1384-1387.
16. Anonymous. Regional variation in mortality from motor vehicle accidents. Metrop Stat Bull 1987;68:27-31.
17. Balarajan R, McDowall ME. Regional socioeconomic differences in mortality among men in Great Britain today. Public Health 1988;102:33-43.
18. Avery JG, Vaudin JN, Fletcher JL et al. Geographical and social variations in mortality due to childhood accidents in England and Wales 1975-1984. Public Health 1990;104:171-182.
19. Söderlund N, Zwi AB. Traffic-related mortality in industrialized and less developed countries. Bull WHO 1995;73:175-182.

20. Wintemute GJ. Is motor vehicle-related mortality a disease of development? Accid Anal Prev 1986;17:223-237.
21. SWOV. SWOV voorspelt ca. 1200 verkeersdoden in 1990. (SWOV predicts approx. 1200 road traffic deaths in 1990, in Dutch). Leidschendam: SWOV-magazine; 1986.
22. Oppe S. Macroscopic models for traffic and traffic safety. Accid Anal Prev 1989;21:225-232.
23. Adams JGU. Smeed's law: some further thoughts. Traff Engng Control 1987; 28:70-73.
24. Broughton J. Predictive models of road accident fatalities. Traff Engng Control 1988;29;296-300.
25. Brühning E. Zum Rückgang der getöteten-zahlen in Strassenverkehr. (Towards a declining number of road accident fatalities, in German). Zeitschrift für Verkehrssicherheit 1986;32(4):154-163 .
26. Yates DW. Scoring systems for trauma. Br Med J 1990;301:1090-1094.
27. Mulder S, Bloemhoff A, Harris S. Ongevallen in Nederland: opnieuw gemeten 1992/1993. (Injuries in the Netherlands: new estimates 1992/1993, in Dutch). Amsterdam: Consumer Safety Institute; 1995.
28. MacKenzie EJ, Steinwachs DM, Shankar B. Classifying trauma severity based on hospital discharge diagnoses. Validation of an ICD-9CM to AIS-85 conversion table. Medical Care 1989;27:412-422.
29. Kingma J, Ten Vergert EM, Werkman HA. A Turbo Pascal program to convert ICD-9CM coded injury diagnoses into injury severity scores: ICDTOAIS. Perceptual and Motor Skills 1994;78:915-936.
30. Koopmanschap MA, Rutten FFH, van Ineveld BM et al. The friction cost method for measuring indirect costs of disease. J of Health Economics 1995;14:171-189.
31. Polder JJ, Meerding WJ, Koopmanschap MA. Kosten van Ziekten in Nederland 1994. (Costs of diseases and injuries in the Netherlands 1994, in Dutch). Rotterdam: Erasmus University, Department of Public Health; 1997.
32. Murray CJL. Quantifying the burden of disease. The technical basis for disability-adjusted life years. Bull WHO 1994;72:429-445.
33. Hutchinson TP. Road Accident Statistics. Adelaide: Rumsby Scientific Publishers; 1987.
34. Mackenbach JP. Mortality and medical care (thesis). Rotterdam: Erasmus University; 1988.
35. Susser M. The logic in ecological. Am J Public Health 1994;84: 825-835.
36. Sytkowski P, Kannel W, D'Agostinho R. Changes in risk factors and the decline in mortality from cardiovascular disease. N Engl J Med 1990;322:1635-1641.
37. McGovern PG, Pankow JS, Shahar E et al. Recent trends in acute coronary heart disease-mortality, morbidity, medical care, and risk factors. The Minnesota Heart Survey Investigators. N Engl J Med 1996;334:884-890.
38. Goldman L, Cook E. The decline in Ischemic Heart Disease mortality rates. Ann Intern Med 1984;101:825-836.

39. Bonneux L, Looman CW, Barendregt JJ, van der Maas PJ. Regression analysis of recent changes in cardiovascular mortality and morbidity in the Netherlands. Br Med J 1997;314:789-792.

40. van Beeck EF, Mackenbach JP, Van Oortmarssen GJ et al. Scenarios for the future development of accident mortality in the Netherlands. Health Policy 1989;11:1-17.

41. Koornstra MJ. Development of road safety in some European countries and USA. Leidschendam: SWOV; 1988.

42. van Beeck EF, Mackenbach JP. Ongevallen signaleringsrapport 1995. (Accidents Monitoring Report 1995, in Dutch). Zoetermeer: Foundation on Future Health Scenarios; 1995.

43. Sackman H. Delphi critique: expert opinion, forecasting and group process. Lexington: Heath;1974.

44. Sackman H. Summary evaluation of Delphi. Policy Analysis 1975;20:694-718.

45. Goldschmidt P. Scientific inquiry or political critique? Remarks on Delphi assessment, expert opinion, forecasting and group process by H. Sackman. Technological Forecasting and Social Change 1975;7:195-213.

46. Ziglio E. The Delphi method and its contribution to decision making. In: Adler M, Ziglio E (eds). Gazing into the oracle. The Delphi method and its application to social policy and public health. London: Jessica Kingsley Publishers; 1996.

47. van Beeck EF, Mackenbach JP, Habbema JDF, Van der Maas PJ. Delphi-study "Accidents and traumatology in the future". In: Lapré RM, Mackenbach JP (eds). Accidents in the year 2000; accident and traumatology scenarios 1985-2000. Dordrecht: Kluwer; 1989.

48. Dewulf G. Limits to forecasting. Towards a theory of forecast errors (thesis). Amsterdam: Thesis Publishers; 1991.

49. Dunning AJ, Wils WIM (eds). The heart of the future: the future of the heart. Dordrecht: Kluwer Academic Publishers; 1987.

50. Cleton FJ, Coebergh JWW (eds). Cancer in the Netherlands. Dordrecht: Kluwer Academic Publishers; 1988.

51. Idenburg P, Ketting E, Bijl RV et al. Caring for mental health. Future scenarios on mental health and mental health care 1990-2010. Dordrecht: Kluwer Academic Publishers; 1991.

52. Casparie AF, Verkleij H (eds). Chronic diseases in the year 2005. Dordrecht: Kluwer Academic Publishers; 1991.

53. Ruwaard D. Diabetes mellitus; from epidemiology to health policy (thesis). Utrecht: Elinkwijk Publishers; 1996.

54. Berkelman RL, Buehler JW. Surveillance. In: Holland W, Detel R, Knox G (eds). Oxford Textbook of Public Health. Second edition, volume 2. Oxford/New York: Oxford University Press; 1991.

55. van Beeck EF. Trend monitoring as an instrument for priority setting. In: Rogmans WHJ, Mulder S (eds). Priority setting in accident prevention. Amsterdam: European Consumer Safety Association; 1995.

56. Stroup DF, Williamson GD, Herndon JL. Detection of abberations in the occurrence of notifiable diseases surveillance data. Stat Med 1989;8:323-329.
57. Lapré RM, Mackenbach JP (eds). Ongevallen in het jaar 2000. Scenario's over ongevallen en traumatologie 1985-2000. (Accidents in the year 2000. Accident and traumatology scenarios 1985-2000, in Dutch). Utrecht: Bohn, Scheltema & Holkema; 1988.
58. van Beeck EF, Mackenbach JP. Ongevallen signaleringsrapport 1989.(Accidents Monitoring Report 1989, in Dutch). Rijswijk: Steering Committee on Future Health Scenarios; 1989.
59. van Beeck EF, Mackenbach JP. Ongevallen signaleringsrapport 2; trends in enkele geïndustrialiseerde landen 1970-1987. (Accidents Monitoring Report 2; trends in selected industrialized countries 1970-1987, in Dutch). Rijswijk: Steering Committee on Future Health Scenarios; 1990.
60. van Beeck EF, Mackenbach JP. Accidents Monitoring Report 1992; developments since 1985. Rijswijk: Steering Committee on Future Health Scenarios; 1992.
61. Ministry of Public Health/Ministry of Internal Affairs. Met zorg verbonden (Improving the chain of medical care for injury victims, in Dutch). The Hague; 1997.
62. Omran AR. The epidemiologic transition: a theory of the epidemiology of population change. Millbank Memorial Fund Quarterly 1971;49:509-538.
63. McKeown T, Record RG. Reasons for the decline of mortality in England and Wales during the nineteenth century. Pop Stud 1962;16:94-122.
64. Mackenbach JP. The epidemiologic transition theory. J Epidemiol Community Health 1994:48:329-332.
65. Olshansky SJ, Ault AB. The fourth stage of epidemiologic transition: the age of delayed degenerative diseases. Milb Quart 1986;64:355-391.
66. Wolleswinkel-van den Bosch JH, Looman CWN, Van Poppel FWA, Mackenbach JP. Cause-specific mortality trends in the Netherlands, 1875-1992: a formal analysis of the epidemiologic transition. Int J Epid 1997;26:772-781.
67. Mackenbach JP. De veren van Icarus; over de achtergronden van twee eeuwen epidemiologische transities in Nederland. (The feathers of Icarus; about the backgrounds of two centuries of epidemiologic transitions in the Netherlands, in Dutch). Utrecht: Bunge; 1992.
68. Veen H. Een beschouwing over het vraagstuk der verdrinking. (A contemplation on accidental drowning, thesis, in Dutch). Amsterdam: Noord-Hollandsche Uitgevers Maatschappij; 1945.
69. Heijermans L. Handleiding tot de kennis der beroepsziekten. (Introduction to occupational diseases, in Dutch). Rotterdam: WL & J Brusse's Uitgevers-Maatschappij; 1926.
70. Forbes TR. Coroners' inquisitions from London parishes of the Duchy of Lancaster: the Strand, Clapham, Enfield, and Edmonton, 1831-1883. J Hist All Sciences 1988;43:191-203.
71. Logan WPD. Mortality in England and Wales from 1848 to 1947; a survey of the changing causes of death during the past hundred years. Pop Studies 1950;4:132-178.
72. Wolleswinkel-van den Bosch, Van Poppel FWA, Mackenbach JP. Reclassifying causes of death to study the epidemiological transition in the Netherlands, 1875-1992. Eur J Pop 1996;12:327-361.

73. Uemura K, Pisa Z. Trends in cardiovascular disease mortality in industrialized countries since 1950. World Health Stat Quart 1988;41:155-178.

74. Frenk J, Bobadilla JL, Stern C et al. Elements for a theory of the health transition. Health Transition Review 1991:1:21-38.

75. Murray CJL, Chen LC. In search for a contemporary theory for understanding mortality change. Soc Sci Med 1993;36(2):143-155.

76. De Jonge GA. Preventie van verdrinking van kinderen (Prevention of drowning among children, in Dutch). Leiden: Spruyt, Van Mantgem & De Does; 1982.

77. Carey VF. Childhood drowning: who is responsible? Br Med J 1993;307:1086-1087.

78. Waller AE, Baker SP, Szocka A. Childhood injury deaths: national analysis and geographic variation. Am J Public Health 1989;79:310-315.

78. Waller AE, Baker SP, Szocka A. Childhood injury deaths: national analysis and geographic variation. Am J Public Health 1989;79:310-315.

79. Baker SP, O'Neill B, Ginsburg MJ, Li G. The Injury Fact Book; second edition. New York: Oxford University Press; 1992.

80. Verweij GCG. Zwemvaardigheid in Nederland nader onderzocht. (Swimming ability in the Netherlands further investigated, in Dutch). Mndber Gezondheid (CBS) 1992;10;4-17.

81. Spee-van der Wekke J, Meulmeester JF, Hemgreen WP. Zwemvaardigheid (Swimming abilities, in Dutch). In: Peilingen in de jeugdgezondheidszorg. Leiden: TNO-PG; 1994.

82. Querido MD. The development of socio-medical care in the Netherlands. London: Routledge& Kegan Paul Ltd; 1968.

83. Greenwood M, Martin WJ, Russel WT. Deaths by violence,1837-1937. J R Stat Soc 1941;104:146- 171.

84. van Beeck EF, Mackenbach JP. Trends in de sterfte ten gevolge van ongevallen in Nederland sinds 1950. (Trends in injury mortality in the Netherlands since 1950, in Dutch). Tijdschr voor Soc Gezondhz 1988;66:89-95.

85. The Pooling Project Research Group. Relationship of blood pressure, serum cholesterol, smoking habit, relative weight and ECG-abnormalities to incidence of major coronary events: final report of the pooling project. J Chronic Dis 1978;31:201-306.

86. Hoogenboezem J. Sterfte ten gevolge van uitwendige oorzaken van letsel en vergiftiging, 1970-1995. (Mortality from external causes of injury and poisoning, in Dutch). Mndber Gezondheid (CBS) 1997;4:30-47.

87. Boereboom FT, de Groot RR, Raymakers JA, Duursma SA. The incidence of hip fractures in the Netherlands. Neth J Med 1991;38:51-58.

88. Melton III LJ. Epidemiology of hip fractures: implications of the exponential increase with age. Bone 1996;18:121S-125S.

89. Boyce WJ, Vessey MP. Rising incidence of fracture of the proximal femur. Lancet 1985;i:150-151.

90. Johnell O, Nilsson B, Obrant K, Sernbo I. Age and sex patterns of hip fracture changes in 30 years. Acta Orthop Scand 1984;55(3):290-292.

91. Nilsson R, Löfman O, Berglund K et al. Increased hip-fracture incidence in the county of Ostergötland, Sweden, 1940-1986, with forecasts up to the year 2000: an epidemiological study. Int J Epid 1991;20:1018-1024.
92. Cummings SR, Kelsey JI, Nevitt MC, O'Dowd KJ. Epidemiology of osteoporosis and osteoporotic fractures. Epidem Rev 1985;7:178-208.
93. Anonymous. Consensus development conference: diagnosis, prophylaxis and treatment of osteoporosis. Am J Med 1993;94:646-650.
94. Melton III LJ, Wahner HW, Richelson LS et al. Osteoporosis and the risk of hip fracture. Am J Epid 1986;124:254-261.
95. Hu JF, Zhao XH, Chen JS et al. Bone density and lifestyle characteristics in premenopausal and postmenopausal women. Osteoporosis Int 1994;4:288-297.
96. Ngyen TV, Kelly PJ, Sambrook PN et al. Lifestyle factors and bone density in the elderly: implications for osteoporosis prevention. J Bone Min Res 1994;9:1339-1346.
97. Rose G, Marmot MG. Social class and coronary heart disease. Br Heart J 1981;45:13-19.
98. Moritz BJM, Diekstra RFW. Suïcidaal gedrag in het jaar 2000. (Suicidal behaviour in the year 2000, in Dutch). In: Lapré RM, Mackenbach JP (eds). Ongevallen in het jaar 2000; deel 2 Achtergrondstudies en wetenschappelijke verantwoording. Utrecht: Bohn, Scheltema & Holkema; 1988.
99. CBS. Vijfentwintig jaar zelfdoding in statistieken 1970-1994 (Twenty-five years of suicide statistics 1970-1994, in Dutch). Voorburg: CBS; 1995.
100. Jenkins R, Griffiths S, Wylie I et al (eds). The prevention of suicide. London: HMSO;1994.
101. Selkin J. The legacy of Emile Durkheim. Suicide and Life-Threatening Behaviour 1983;13:(1):3-14.
102. Franke H. Geweldscriminaliteit in Nederland (Violence in the Netherlands, in Dutch). In: Franke H, Wilterdink N, Brinkgreve C (eds). Alledaags en ongewoon geweld. Groningen: Wolters-Noordhoff; 1991.
103. Van den Brink G. Geweldpleging in het Zuidoosten van Brabant 1811-1875. (Violence in the south- east of Brabant 1811-1875, in Dutch). In: Franke H, Wilterdink N, Brinkgreve C (eds). Alledaags en ongewoon geweld. Groningen: Wolters-Noordhoff; 1991.
104. Elias N. Het civilisatieproces (The process of civilization, in Dutch). Utrecht; 1939.
105. De Campos Cardoso A. Slachtoffers van moord en door anderen opzettelijk toegebracht letsel. (Victims of homicide and assault, in Dutch). Mndber Gezondheid (CBS) 1986;6:4-15.
106. Kingma J, Eijken AWM, Lalkens A, Klasen HJ. Geweld: een retrospectieve studie naar herhaald slachtofferschap in de periode 1971-1993 (Violence: a retrospective study into repeated victimization in the period 1971-1993, in Dutch). Groningen: University Hospital;1995.
107. Oskam J, Kingma J, Klasen HJ. Het gebruik van voorwerpen en wapens bij geweldsletsels. (The use of objects and weapons in relation to injuries resulting from violence, in Dutch). Tijdschrift voor Criminologie 1994;36:120-128.

108. Rosenberg M, Mercy JA. Assaultive violence. In: Rosenberg M, Fenley MA (eds). Violence in America. A public health approach. New York: Oxford University Press; 1991.

109. Rogmans WHJ, Mulder S (eds). Priority setting in accident prevention. Amsterdam: European Consumer Safety Association; 1995.

110. Consument en Veiligheid. Werkboek Letsel Informatie Systeem (LIS) (Manual Dutch Injury Surveillance System, in Dutch). Amsterdam: Consumer Safety Institute; 1997.

111. Nederlandse Vereniging voor Traumatologie. Traumazorg; onze zorg! (Trauma care; our responsibility; towards improvement of trauma care in the Netherlands, in Dutch). Utrecht: NvT;1997.

112. Commissie Registratie en Informatie GHOR. Definitiestudie letselregistratie voor kwaliteitszorg (Definition study injury registration for quality assurance). Den Haag: GHOR;1998.

113. Commissie Standaardisatie voor Ongevallen. Nederlandse Letsel Classificatie (NLC), ontwerp. (Dutch Injury Classification, design, in Dutch). Amsterdam: Consumer Safety Institute; 1998.

114. Falck Larsen C. Indicators for severity of injuries. In: Rogmans WHJ, Mulder S (eds). Priority setting in accident prevention. Amsterdam: European Consumer Safety Association;1995.

115. Champion HR, Copes WS, Sacco WJ et al. The Major Trauma Outcome Study: establishing national norms for trauma care. J Trauma 1990;30:1356-1365.

116. Committee on Medical Aspects of Automotive Safety. Rating the severity of tissue damage. JAMA 1971;215:277-280.

117. Baker SP, O'Neill B, Haddon W Jr et al. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-196.

118. Champion HR, Sacco WJ, Lepper RL et al. An anatomic index of injury severity. J Trauma 1980;20:197-202.

119. Copes WS, Lawnick M, Champion HR et al. The injury severity score revisited. J Trauma 1988;28:67- 77.

120. American Association for Automotive Medicine. The Abbreviated Injury Scale (AIS)-1980 Revision. Des Plaines: AMA;1980.

121. American Association for Automotive Medicine. The Abbreviated Injury Scale (AIS)-1985 Revision. Des Plaines: AMA;1985.

122. Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale, 1990 Revision. Des Plaines: AAAM;1990.

123. Kingma J, Ten Duis HJ. De registratie van letsels en ongevallen Groningen, jaarverslag 1995. (Trauma registry University Hospital Groningen, annual report 1995, in Dutch). Groningen: University Hospital;1996.

124. Janssens M, Hammacher ER. Registratie Correspondentie Systeem CAOEH, jaarverslag 1996 (Trauma registry University Hospital Utrecht, annual report 1996, in Dutch). Utrecht: University Hospital;1997.

125. Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. J Trauma 1987;27:370-378.

126. Zoltie N, de Dombal FT. The hit and miss of ISS and TRISS. Br Med J 1993;307:906-909.

127. Rutledge R, Fakhry S, Baker C, Oller D. Injury severity grading in trauma patients: a simplified technique based upon ICD-9 coding. J Trauma 1993;35:497-507.

128. Osler T, Rutledge R, Deis J, Bedrick E. ICISS: an International Classification of Disease-9 based Injury Severity Score. J Trauma 1996;41:380-388.

129. Rutledge R, Hoyt DB, Eastman B et al. Comparison of the Injury Severity Score and ICD-9 diagnosis codes as predictors of outcome in injury: analysis of 44,032 patients. J Trauma 1997;42:477-489.

130. Ten Vergert EM, Werkman HA, Ten Duis HJ. Klinimetrie: een gecomputeriseerde conversie van ICD- 9-CM rubrieken naar AIS- en ISS-scores (Clinimetrics: a computerized conversion of ICD-9-CM diagnoses into AIS- and ISS-scores, in Dutch). Traumatology Review 1991;1:107-111 .

131. Center for Injury Research and Policy/ Tri-Analytics. Introducing the new ICDMAP-90. Maryland; 1997.

132. MacKenzie EJ, Damiano A, Miller T et al. The development of the Functional Capacity Index. J Trauma 1996;41:799-807.

133. MacKenzie EJ. Possibilities and problems with severity scaling for evaluation and research. In: Rogmans WHJ, Mulder S (eds). Measuring the severity and costs of accidental injuries. Amsterdam: European Consumer Safety Association; 1998.

134. Waller JA, Skelly JM, Davis JH. The Injury Impairment Scale as a measure of disability. J Trauma 1995;39:949-954.

135. Thacker SB, Berkelman RL. Public health surveillance in the United States. Epidem Rev 1988;10:164-190.

136. van Beeck EF, den Hertog P, Meerding WJ et al. Een model ter berekening van de directe medische kosten van letsels.(A model for the calculation of direct medical costs of injuries, in Dutch). Amsterdam; Consumer Safety Institute; 1996.

137. MacKenzie EJ, Siegel JH, Shapiro S et al. Functional recovery and medical costs of trauma: an analysis by type and severity of injury. J Trauma 1988;28:281-297.

138. MacKenzie EJ, Burgess AR, McAndrew MP et al. Patient-oriented functional outcome after unilateral lower extremity fracture. J Orthop Trauma 1993;7:393-401.

139. Smit E, Leeflang M, Lankhorst GJ. Polytrauma patients and functional outcome: a literature review. J Rehabil Sci 1992;5:48-51.

140. Anke GW, Stanghelle JK, Finset A et al. Long-term prevalence of impairments and disabilities after multiple trauma. J Trauma 1997;42:54-61.

141. Vasquez Mata G, Rivera Fernandez R, Perez Aragon A et al. Analysis of quality of life in polytraumatized patients two years after discharge from an intensive care unit. J Trauma 1996;41:326-332.

142. Van der Sluis CK, Ten Duis HJ, Geertzen JHB. Multiple injuries: an overview of the outcome. J Trauma 1995;38:681-686.

143. Van der Sluis CK, Klasen HJ, Eisma WH, Ten Duis HJ. Major trauma in young and old: what is the difference? J Trauma 1996;40:78-82.

144. Van der Sluis CK, Eisma WH, Groothoff JW, Ten Duis HJ. Long-term physical, psychological and social consequences of severe injuries. Injury (in press).

145. Van der Sluis CK, Kingma J, Eisma WH, Ten Duis HJ. Pediatric polytrauma: short-term and long-term outcomes. J Trauma 1997;43:501-506.

146. Van der Sluis CK. Long-term physical, psychological and social consequences of a fracture of the ankle. Injury (in press).

147. Passies G. Langdurige gevolgen van ongevalsletsels bij fietsers. (Long-term consequences of injuries to cyclists, in Dutch). Groningen: University Hospital; 1990.

148. Payne SR, Waller JA. Trauma registries and trauma center biases in injury research. J Trauma 1989;29:424-429

149. Waller JA, Skelly JM, Davis JH. Emergency department care and hospitalization as predictors of disability. J Trauma 1995;39(4):632-634.

150. Essink-Bot ML, Krabbe PFM, Bonsel GJ, Aaronson NK. An empirical comparison of four generic health status measures; the Nottingham Health Profile, the Medical Outcomes Study 36-Item Short- Form Health Survey, the COOP/WONCA Charts, and the EuroQol Instrument. Med Care 1997;35:523-535.

151. Temkin NR, Dikmen S, Machamer J, McLean A. General versus disease-specific measures; further work on the Sickness Impact Profile for head injury. Med Care 1989;27:S45-S53.

152. Elvik R. The validity of using health state indexes in measuring the consequences of traffic injury for public health. Soc Sci Med 1995;40:1385-1398.

153. Kopjar B. Occurrence and consequences of unintentional injuries (thesis). Oslo: University Oslo; 1996.

154. Murray CJL, Lopez AD. Regional patterns of disability-free life expectancy and disability-adjusted life expectancy: Global Burden of Disease Study. Lancet 1997;349:1437-1352.

155. Barendregt JJ, Bonneux L, Van der Maas PJ. DALYs the age-weights on balance. Bull WHO 1996;74(4):439-443.

156. Robertson LS. Analytic epidemiology. In: Robertson LS. Injury Epidemiology. New York: Oxford University Press; 1992.

157. MacClure M. The case-crossover design: a method for studying transient effects on the risk of acute events. Am J Epidemiol 1991;133:144-153.

158. Mittleman MA, Maldonado G, Gerberich SG et al. Alternative approaches to analytical designs in occupational injury epidemiology. Am J Ind Med 1997;32:129-141.

159. Redelmeier DA, Tibshirani RJ. Association between cellular-telephone calls and motor vehicle collisions. N Engl J Med 1997;326:453-458.

160. Singh GK, Yu SM. US childhood mortality, 1950-1993: trends and socioeconomic differentials. Am J Public Health 1996;86:506-512.

161. Anderson R, Dearwater SR, Olsen T et al. The role of socioeconomic status and injury morbidity risk in adolescents. Arch Ped Adolesc Med 1994;148:245-249.
162. Roberts I, Power C. Does the decline in child mortality vary by social class? Br Med J 1996;313:784- 786.
163. Jolly DL, Moller JN, Volkmer RE. The socio-economic context of child injury mortality in Australia. J Paediatr Child Health 1993;29:438-444.
164. Dougherty G, Pless IB, Wilkins R. Social class and the occurrence of traffic injuries and deaths in urban children. Can J Publ Health 1990;81:204-209.
165. Mackenbach JP. Socio-economic inequalities in health in the Netherlands: impact of a five year research programma. Br Med J 1994;309:1487-1491.
166. Stronks K. Socio-economic inequalities in health: individual choice or social circumstances? (thesis). Wageningen: Ponsen & Looijen; 1997.
167. Draaisma JMTh. Evaluation of trauma care (thesis). Meppel: Krips Repro; 1987.
168. De Man FH. Gezien de spoedeisendheid van het geval. Beoordeling van kwaliteit en effectiviteit van spoedeisende medische hulpverlening. (Assessment of the quality and effectiveness of emergency medical care, in Dutch, thesis). Groningen: Van Denderen; 1992.
169. Tyink JAW. Evaluatie van de preklinische spoedeisende hulpverlening in Nederland. (Evaluation of prehospital trauma care in the Netherlands, thesis). Amsterdam: Free University; 1992.
170. Cochrane AL. Effectiveness and efficiency: random reflections on health services. London: Nuffield Provincial Hospitals Trust; 1972.
171. Rivara FP, Thompson DC, Thompson RS. Epidemiology of bicycle injuries and risk factors for serious injury. Injury Prevention 1997;3:110-114.
172. Gilbert K, McCarthy M. Deaths of cyclists in London 1985-92: the hazards of road traffic. Br Med J 1994;308:1534-1536.
173. Callahan D. Legislating safety; how far should we go? N Engl J Med 1989;320:1412-1413.
174. Trippe HR. Helmets for pedal cyclists; they reduce the numbers of head injuries. Br Med J 1992;305:843-844.
175. Evans L. Cycle helmets and the law; even when the science is clear policy decisions may still be difficult. Br Med J 1994:308:1521-1522.
176. Davis RM, Pless B. Evidence shows that cyclists should wear helmets. Br Med J 1996;313:629.
177. Kraus JF, Fife D, Conroy C. Incidence, severity and outcomes of brain injuries involving bicycles. Am J Public Health 1987;77:76-78.
178. Waters EA. Should pedal cyclists wear helmets? A comparison of head injuries sustained by pedal cyclists and motor cyclists in road traffic accidents. Injury 1986;17:372-375.
179. Maimaris C, Summers CL, Browning C, Palmer CR. Injury patterns attending an accident and emergency department: a comparison of helmet wearers and non-wearers. Br Med J 1994;308:1537- 1540.

180. Thompson RS, Rivara FP, Thompson DC. A case-control study of the effectiveness of bicycle safety helmets. N Engl J Med 1989;320:1361-1367.
181. Thompson DC, Rivara FP, Thompson RS. Effectiveness of bicycle safety helmets in preventing head injuries; a case-control study. JAMA 1996;276:1968-1973.
182. Thompson DC, Nunn ME, Thompson RS, Rivara FP. Effectiveness of bicycle safety helmets in preventing serious facial injury. JAMA 1996;276:1974-1975.
183. Sibert JR. Controversy. Children and cycle helmets: the case for. Child: care, health and development 1996;22:99-103.
184. McCarthy M. Controversy. Children and cycle helmets: the case against. Child: care, health and development 1996;22:105-111.
185. Kellog international working group on the prevention of falls by the elderly. The prevention of falls in later life. Dan Med Bull 1987;34:S1-S24.
186. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med 1988;319:1701-1707.
187. Graafmans WC, Ooms ME, Hofstee HMA et al. Falls in the elderly: a prospective study on risk factors and risk profiles. Am J Epidemiol 1996;143:1129-1136.
188. Herings RMC. Geneesmiddelen als determinant van ongevallen. (Medical drugs as determinant of accidental injuries, in Dutch). Utrecht: Faculty of Pharmacy; 1994.
189. Kanis JA, and the WHO study group. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. Osteoporosis Int 1994;4:368-381.
190. Anonymous. New treatments for osteoporosis. Lancet 1990;335:1065-1066.
191. Reichgelt B, Bonneux L, van den Bosch JMH et al. Veroudering als oorzaak van heupfracturen; een theoretisch rekenmodel (Senescence as a cause of hip fractures, in Dutch). Ned Tijdschr Geneeskd 140;25:1312-1317.

Summary

CHAPTER 1

Injuries are a persistent and dynamic public health problem caused by a variety of widely different events. The field is characterized by the continuous introduction of new hazards to societies and by the exposure of new generations, time and again, to longer existing risks. This calls for accurate public health surveillance systems to be used as a basis for research and policy.

This thesis explores long-term developments in the burden of injuries and its underlying factors in the Netherlands. It mainly focuses on unintentional injuries as caused by three major types of accidents: traffic accidents, occupational accidents and home and leisure accidents. It presents a number of quantitative analyses that were performed within the framework of a public health surveillance system initiated in 1985.

These studies used a central conceptual framework, which considers (changes in) rates of mortality (the number of deaths per 100.000 person-years) to be the result of (changes in) the rates of the incidence of injuries (the number of injured people per 1000 person-years) and the case fatality (the number of deaths per 100 injured persons). The incidence of injuries is the result of the exposure (e.g. the number of passenger car kilometers per 1000 person-years) and the injury risk (the number of injured persons per unit of exposure). Differences in the case fatality are the result of differences in the injury severity (the distribution of injuries by type of injury) and differences in the severity-adjusted case fatality (the number of deaths per 100 injured persons adjusted for changes in the distribution of injuries). The exposure, injury risk, injury severity, and (severity-adjusted) case fatality are influenced by demographic, economic, socio-cultural and technological factors (all "autonomous" from the point of view of health

policy makers in the field of injury control), as well as by policy measures aimed at the prevention of injuries or the improvement of medical care for injury victims.

The studies presented in this thesis aimed to assess the frequency and societal burden of injuries in the past and present (chapter 2), to identify determinants of injury mortality (chapter 3), and to establish the value of new quantitative methods of forecasting and monitoring in this field (chapter 4).

CHAPTER 2

With the help of national registration data we analyzed trends in traffic injuries, occupational injuries, and home and leisure injuries in the Netherlands (chapter 2.1). We established the contribution of developments in the incidence and case fatality to mortality trends since 1950. We studied the influence of trends in exposure and injury risk on trends in the incidence of injuries, and we related case fatality trends to developments in injury severity. We found that the mortality due to unintentional injuries in the Netherlands is characterized by rapid changes. Between 1950 and 1970 it rose because of an increasing incidence of injuries. This was followed by a sharp decline based on a decreasing incidence combined with a rapidly falling case fatality. Since the second half of the 1980s, however, the declining mortality has levelled off due to rises in the incidence of injuries. We found that growing or new exposures tend to increase the injury incidence and mortality. This can be compensated by measures reducing the injury risk and injury severity (prevention) or severity-adjusted case fatality (trauma care). Since the second half of the 1980s this compensation has fallen short in the Netherlands. This has led to a growing burden of injuries for specific external causes.

With the help of available data on health care utilization, sickness absenteeism, long-term work disability, and mortality we assessed the direct medical costs and indirect costs of injuries in the Netherlands (chapter 2.2). We used two alternative approaches to estimate the indirect costs of injuries. We used the traditional Human Capital Approach, which estimates the potential production losses of all victims from the time of injury until the mean age of retirement. In addition, we applied the Friction Cost Method which attempts to measure the actual production lossess of all victims from the time of injury until the mean moment of replacement in the work process. We found that injuries are an important source of medical costs and economic production losses in the Netherlands.

Almost two-thirds of the medical costs are the result of accidents among females (mainly domestic accidents among the elderly). On the contrary, independent of the method used, more than 80% of the indirect costs are the result of injuries of males (mainly caused by a high frequency of traffic injuries, occupational injuries and sports injuries among young males). The application of the Friction Cost Method stresses the importance of injuries as a source of economic production losses in comparison to other diseases, showing that they belong to the main three causes of indirect costs to society. This shows that the economic burden of injuries is high.

CHAPTER 3

The results of two studies into determinants of injury mortality are presented in chapter 3.

We analyzed regional differences in traffic accident mortality in the Netherlands, establishing the contribution of regional differences in exposure (traffic mobility), injury risk and case fatality (chapter 3.1). We made separate analyses for motor vehicle occupants and cyclists respectively.

We investigated possible determinants of regional differences in mortality by mode of transport with the help of multiple linear regression analysis. Both the influence of sociodemographic factors and of factors probably more direct related to traffic deaths (road infrastructure, medical care for injury victims) was studied. We found large regional mortality differences, that could be explained only to a limited extent by regional differences in exposure. In the case of motor vehicle occupants, regional differences in the case fatality seem the major factor behind the observed mortality differences. In the case of cyclists some of the variation in mortality seems to be caused by regional differences in the use of the bicycle. The prosperity level of a region appears to be a strong predictor of mortality differences among motor vehicle occupants and cyclists. A higher income level is associated with lower mortality levels by region. Of the factors more directly related to traffic deaths, traffic density and the availability of advanced trauma care are the most important predictors of regional mortality differences. Both show an inverse relationship with the case fatality.

We examined the relation between prosperity and traffic accident mortality in the industrialized world in a long-term perspective (chapter 3.2).

We studied the cross-sectional relation between prosperity and traffic accident mortality at several points of economic development, from 1962 until 1990.

We established the influence of the exposure (traffic mobility) and the fatal injury rate (i.e the product of the injury risk and the case fatality: the number of deaths per unit of exposure) on those associations. Moreover, we analyzed the shape of of the longitudinal relationship between prosperity and traffic accident mortality between 1962 and 1990. We tried to explain this longitudinal relationship in terms of developments in exposure (traffic mobility) and fatal injury rate. We found that the cross-sectional relation between prosperity and traffic accident mortality has changed in the industrialized world. There has been a reversal from a positive cross-sectional relation in the 1960s into a negative association currently. This reversal took place around 1975, when exposure (traffic mobility) lost its power as major intermediate factor. It appears that, in a long-term perspective, economic development first leads to a growing number of traffic deaths yet later becomes protective. At a certain level of prosperity the growth rate of traffic mobility has the tendency to level off, where the fatal injury rate continues to decline at a similar rate as at lower levels. As in the case of other diseases (e.g. cardiovascular diseases) prosperity growth could not only lead to growing exposures to particular risks, but could also stimulate adaptations, including preventive measures and improvements of medical care.

CHAPTER 4

The development and evaluation of a new instrument for the forecasting and monitoring of injuries is presented in chapter 4. In the mid 1980s we made projections of the burden of injuries in the Netherlands between 1985 and 2000.

We developed an approach for the calculation of the public health impact of different future health scenarios, both with and without government intervention. A major determinant included in the scenarios was the growth of the national economy.

Summary

With the help of a Delphi study (chapter 4.1) we explored autonomous developments in the epidemiology of traffic, occupational and home and leisure injuries between 1985 and 2000. In addition, we estimated the potential effects of different strategies to reduce the amount of public health damage due to unintentional injuries.

Eighty Dutch experts were invited to participate. The response rate was 82%. The experts were asked to give estimates of the rate of change of relevant parameters in the epidemiology of injuries under different sets of possible external conditions.

These parameters included the exposure, injury risk and injury severity by type of activity, and the case fatality by type of injury. In addition, the experts were asked to list policy measures and to assess their potential impact.

The results of the Delphi study were used as input for scenario calculations (chapter 4.2). These were made with the help of a computer model developed by our department. In this way the combined effects of trends in the aforementioned parameters could be calculated. The combination of developments referred to as 'most likely' according to a majority of the Delphi experts was elaborated into the 'reference scenario'. The results of this scenario, assuming modest economic growth (2% annually) and minimal government intervention, showed the following: without major new policy measures, mortality due to unintentional injuries (which had fallen tremendously between 1970 and 1985) would remain more or less at the level of 1985. It was also shown that several 'alternative autonomous scenarios' would probably lead to an increasing burden of injuries in the Netherlands. The results of three health policy scenarios, on the other hand, made clear that a forceful continuation of injury prevention and/or new measures to improve trauma care were expected to be highly effective.

The quantitative results of the future health scenarios were reported to policy makers in 1988 and subsequently used as a framework for continuous monitoring of unintentional injuries in the Netherlands (chapter 4.3). Trends in the epidemiology of injuries since 1985 were compared with observations from the preceding period (1970-1985) and to the future health scenarios (1985-2000). We identified interruptions of the actual mortality trends in the Netherlands, which could already be reported to health policy makers in 1989. In the second half of the 1980s the rapidly declining injury mortality trends slowed down (traffic accidents), were slightly reversed (occupational accidents) or stabilized (home and leisure accidents). The transitions into less favourable developments had been foreseen by Dutch experts.

Because we were able to monitor actual trends in the epidemiology of injuries for more than ten years, we could show the added value of quantitative future health scenarios based on expert opinion. It was shown that our new tool offers a well-defined conceptual framework for continuous monitoring and facilitates the early detection of trend interruptions or reversals.

Moreover, it provides valuable information on possible future developments and on the feasibility of health policy goals.

CHAPTER 5

The thesis ends with a general discussion. In this final section the major results are summarized, and the possibilities and limitations of the applied data and methods are reviewed.

In addition, the findings of this thesis are put in the long-term perspective of the epidemiologic transition theory. The analyses of this thesis have shed some light on the role of injuries as a component of the epidemiologic transition. This subject has not been studied extensively so far.

It is shown, that injury mortality did not change dramatically in the Netherlands over the whole past century. Separate subclasses on the other hand, have shown spectacular changes. During the first half of this century, until 1970, mortality due to accidental drowning and other non-traffic accidents (excluding accidental fall) declined sharply.

This can be explained by similar general factors as those applying to the decline in infectious disease mortality often referred to in studies analyzing epidemiologic transitions: growing prosperity, cultural modernization and the implementation of preventive public health measures have contributed to the disappearance of drowning and other non-traffic accidents as major external causes of death.

In the same period mortality due to traffic accidents and accidental fall rose sharply, probably intermediated by growing prosperity. Traffic accidents and accidental fall seem important examples of "degenerative and man-made diseases". This demonstrates that, since the beginning of this century until 1970, there have been major shifts in the importance of specific external causes of death. Since 1970 other dynamic changes occurred. Around 1970, the mortality from traffic accidents and accidental fall started to decline, in step with the trend reversal for ischemic heart disease in this same period. In the case of traffic accidents this was due to 'autonomous factors' (exposure growth levelling off) and 'adaptations' (preventive measures and improvement of trauma care).

In the case of accidental fall the developments are somewhat different, although the influence of 'adaptations' (improvement of trauma care) seems very likely. Probably, the adaptations have been stimulated by growing prosperity.

Finally, it was shown that since 1970 the importance of intentional injuries as a cause of death has risen. An explanation could not be given. Suicide and interpersonal violence, however, have recently become another public health priority, in addition to the unintentional injuries as addressed in this thesis.

The main lessons from the long-term analyses made seem to be as follows. Specific injury subclasses grow in importance during a specific phase of economic and socio-cultural development. During this phase, new hazards to mankind are introduced, followed by an increasing exposure of the whole population. Subsequently, adaptations are made to the new hazards. These adaptations include preventive public health measures and improvements of trauma care.

Forecasting future developments and early detection of unfavourable trends should help to accelerate the necessary adaptations.

The dynamic nature of injuries, as illustrated in this thesis, makes them one of the most challenging fields for public health. The final section is therefore devoted to major challenges for the future: in surveillance, research and policy. Major surveillance needs are improving the registration of the incidence of injuries and of injury severity. New research should include studies on the long-term consequences of injuries, on determinants of injuries at the individual level, and on the effectiveness of prevention and trauma care. Policy measures should include new preventive efforts in priority areas and the implementation of a new system of regionalized trauma care. These adaptations should help to reduce the still unacceptable burden of injuries in the Netherlands.

Samenvatting

HOOFDSTUK 1

Acute lichamelijke letsels (veroorzaakt door ongevallen, zelfbeschadiging of geweld) vormen een altijd aanwezig en dynamisch volksgezondheidsprobleem. Samenlevingen worden regelmatig met nieuwe risico's geconfronteerd, terwijl steeds weer nieuwe generaties worden blootgesteld aan de risico's die reeds langer in deze samenlevingen aanwezig zijn. Hierdoor is het nodig om ontwikkelingen in de tijd nauwkeurig te bewaken. Dit gebeurt met behulp van monitoringsystemen, die kunnen dienen als basis voor wetenschappelijk onderzoek en gezondheidsbeleid.

Dit proefschrift geeft een beschrijving en verklaring van lange termijn ontwikkelingen op het gebied van acute lichamelijke letsels in Nederland. Het richt zich met name op letsels ten gevolge drie soorten ongevallen: verkeersongevallen, arbeidsongevallen en privé-ongevallen. Er wordt een aantal kwantitatieve analyses gepresenteerd, die verricht werden in het kader van een monitoringsysteem dat in 1985 van start ging.

In deze analyses is uitgegaan van een centraal denkmodel. Hierin wordt de mortaliteit (het aantal sterfgevallen per 100.000 persoonsjaren) allereerst gezien als het produkt van de letselincidentie (het aantal gewonden per 1000 persoonsjaren) en de letaliteit (het aantal sterfgevallen per 100 gewonden). De letselincidentie is op haar beurt weer het produkt van de expositie (bijvoorbeeld het aantal personenautokilometers per 1000 persoonsjaren) en de letselkans (bijvoorbeeld het aantal gewonden per afgelegde personenautokilometer). De letaliteit tenslotte hangt af van de letselernst (de verdeling van de gewonden naar het soort letsel dat werd opgelopen) en de kans op sterfte nadat voor verschillen in letselernst gecorrigeerd is.

Samenvatting

De expositie, letselkans, letselernst, en (voor letselernst gecorrigeerde) letaliteit worden voor een deel bepaald door demografische, economische, sociaal-culturele en technologische factoren. Voor beleidsmakers op het gebied van de volksgezondheid zijn dit "autonome" factoren. Daarnaast is er de invloed van preventieve maatregelen en verbetering van de medische zorg voor letselpatiënten.

De kern van het proefschrift bestaat uit drie onderdelen. Er is onderzocht welke schade acute lichamelijke letsels aan de volksgezondheid berokkenen, hoe dit zich ontwikkeld heeft in de tijd, en welke maatschappelijke kosten zij met zich meebrengen (hoofdstuk 2).

Hiernaast zijn oorzaken van de sterfte (mortaliteit) door acute lichamelijke letsels bestudeerd, met name oorzaken van de sterfte door verkeersongevallen (hoofdstuk 3).

Tenslotte is gekeken naar de waarde van nieuwe kwantitatieve methoden voor het schatten van toekomstige schade aan de volksgezondheid door letsels, en voor de monitoring van ontwikkelingen op dit terrein (hoofdstuk 4).

HOOFDSTUK 2

Met behulp van landelijke registratiegegevens zijn trends op het gebied van verkeers-, arbeids-, en privé-ongevallen in Nederland geanalyseerd (hoofdstuk 2.1). De bijdrage werd vastgesteld van ontwikkelingen in de letselincidentie en de letaliteit aan trends in de sterfte door ongevallen in Nederland sinds 1950. De invloed werd bestudeerd van trends in de expositie en de letselkans op trends in de letselincidentie, terwijl ontwikkelingen in de letaliteit gerelateerd werden aan ontwikkelingen in de letselernst. Hieruit kwam naar voren dat de sterfte door ongevalsletsels in Nederland wordt gekenmerkt door snelle veranderingen. Tussen 1950 en 1970 was sprake van een toenemende sterfte onder invloed van een stijging van de letselincidentie. Dit werd gevolgd door een spectaculaire sterftedaling gebaseerd op een afnemende letselincidentie, in combinatie met een eveneens afnemende letaliteit. Sinds de tweede helft van de jaren tachtig is deze sterftedaling echter afgevlakt ten gevolge van (nieuwe) stijgingen van de letselincidenties bij verschillende soorten ongevallen.

Uit de analyse kwam duidelijk naar voren dat toenemende (of nieuwe) exposities aan ongevalsrisico's in principe ook stijgingen van de letselincidenties en de sterfte met zich meebrengen.

Dit kan worden tegengegaan door maatregelen gericht op vermindering van de letselkans en letselernst (preventie), of de voor letselernst gecorrigeerde letaliteit (medische zorg).

Sinds de tweede helft van de jaren tachtig vindt een dergelijke compensatie in onvoldoende mate plaats in Nederland. Voor specifieke soorten ongevallen heeft dit geleid tot een (weer) toenemende schade aan de volksgezondheid.

Op basis van beschikbare gegevens over het gebruik van gezondheidszorgvoorzieningen is een schatting gemaakt van de directe medische kosten van acute lichamelijke letsels in Nederland (hoofdstuk 2.2). Hiernaast werden economische productieverliezen in kaart gebracht met behulp van gegevens over ziekteverzuim, arbeidsongeschiktheid en sterfte. Bij het schatten van economische productieverliezen werden twee verschillende methoden gebruikt. De eerste methode, de traditionele "human capital" benadering, berekent het potentiele productieverlies van elk slachtoffer vanaf het tijdstip waarop het letsel ontstaat tot aan de gemiddelde pensioengerechtigde leeftijd. Een alternatieve methode, de "frictiekosten" benadering, berekent het werkelijke productieverlies van elk slachtoffer vanaf het tijdstip waarop het letsel ontstaat tot aan het moment waarbij gemiddeld genomen vervanging in het arbeidsproces plaats vindt.

Acute lichamelijke letsels blijken een belangrijke bron van directe medische kosten én economische productieverliezen in Nederland. Bijna tweederde van alle directe medische kosten is het gevolg van ongevallen bij vrouwen (met name privé-ongevallen op bejaarde leeftijd). Daarentegen komt meer dan 80% van de economische productieverliezen door acute lichamelijke letsels op rekening van mannen (met name door de hoge incidentie van verkeers-, arbeids-, en sportongevallen bij jonge mannen). De toepassing van de frictiekosten benadering laat zien dat acute lichamelijke letsels tot de drie belangrijkste oorzaken van economische productieverliezen door "ziekte" behoren. Dit benadrukt de hoge maatschappelijke kosten van letsels, ook in vergelijking met andere ziekten.

HOOFDSTUK 3

Hoofdstuk 3 richt zich op oorzaken van de sterfte door verkeersongevallen. In de eerste plaats werden regionale verschillen in de sterfte door verkeersongevallen in Nederland bestudeerd, waarbij de bijdrage werd vastgesteld van regionale verschillen in expositie (verkeersmobiliteit), letselkans en letaliteit (hoofdstuk 3.1). Er werden aparte analyses uitgevoerd met betrekking tot autogebruikers en fietsers.

Samenvatting

Mogelijke oorzaken van regionale sterfteverschillen naar vervoerswijze werden onderzocht, waarbij de invloed werd bekeken van sociaaldemografische achtergrondfactoren (zoals het regionale welvaartsniveau en de urbanisatiegraad) én factoren die meer rechtstreeks gerelateerd zijn aan de verkeerssterfte (zoals de regionale verkeersinfrastructuur en de medische zorg voor letselpatiënten). Er werden zeer grote regionale sterfteverschillen aangetroffen, die slechts in zeer beperkte mate verklaard konden worden uit regionale verschillen in verkeersmobiliteit. Bij autogebruikers vormen regionale verschillen in letaliteit veruit de belangrijkste factor achter de aangetroffen sterfteverschillen. Bij fietsers kunnen de regionale sterfteverschillen voor een deel verklaard worden uit verschilllen in gebruik van de fiets.

Bij zowel autogebruikers als fietsers vormt het welvaartsniveau een sterke voorspeller van regionale sterfteverschillen. Een hoger welvaartsniveau gaat samen met een lagere sterfte door verkeersongevallen per regio. Van de meer rechtstreeks aan de verkeerssterfte gerelateerde factoren zijn de verkeersdichtheid en de medische zorg in de regio de belangrijkste voorspellers van regionale sterfteverschillen. Een hogere verkeersdichtheid en de beschikbaarheid van geavanceerde medische zorg gaan samen met een lagere verkeerssterfte.

Het verband tussen het welvaartsniveau en de sterfte door verkeersongevallen werd ook bestudeerd in een lange termijn perspectief (hoofdstuk 3.2). Hierbij werd gebruik gemaakt van gegevens uit 21 geïndustrialiseerde landen uit de periode 1962-1990. Het cross-sectionele verband tussen het welvaartsniveau en de verkeerssterfte werd bestudeerd op verschillende momenten in de economische ontwikkeling van deze landen. Hierbij werd de invloed nagegaan van verschilllen in expositie (verkeersmobiliteit) en de kans op dodelijk letsel in het verkeer (het aantal verkeersdoden per motorvoertuig in de bevolking). Tevens werd het longitudinale verband vastgesteld tussen welvaart en de sterfte door verkeersongevallen. De vorm van dit longitudinale verband werd verklaard uit ontwikkelingen in verkeersmobiliteit en de kans op dodelijk letsel.

Het blijkt dat het cross-sectionele verband tussen welvaart en verkeerssterfte in de geïndustrialiseerde wereld is veranderd tussen 1962 en 1990. In de jaren zestig was sprake van een positief verband met welvaart, hetgeen gebaseerd was op verschillen in verkeersmobiliteit. Rond 1975 trad een omslag op naar een negatief verband, zoals waarneembaar in de jaren negentig. Dit komt omdat verschillen in verkeersmobiliteit hun rol als dominante factor achter de waargenomen sterfteverschillen zijn kwijtgeraakt.

In een lange termijn perspectief blijkt het volgende. Economische ontwikkkeling leidt aanvankelijk tot een stijgend aantal verkeersdoden, maar heeft uiteindelijk een beschermend effect. Bij een bepaald welvaartsniveau vlakt het tempo van mobiliteitsgroei af, terwijl de kans op dodelijk letsel blijft afnemen in hetzelfde tempo als in een eerder stadium van economische ontwikkeling. Het lijkt erop dat er aanpassingsmechanismen worden gestimuleerd door welvaartsgroei. Vermoedelijk betreft het hier zowel preventieve maatregelen als verbeteringen in medische zorg.

HOOFDSTUK 4

Hoofdstuk 4 gaat in op de ontwikkeling en evaluatie van een nieuw instrument voor het schatten van toekomstige schade aan de volksgezondheid en het monitoren van ontwikkelingen op het terrein van acute lichamelijke letsels. Halverwege de jaren tachtig werd een methode ontwikkeld voor het berekenen van de volksgezondheidseffecten van verschillende toekomstscenario's, sommige mét en andere zonder beleidsmatig ingrijpen. Een belangrijke achtergrondfactor in alle toekomstscenario's betrof de economische groei tussen 1985 en 2000.

Met behulp van een Delphi-onderzoek (hoofdstuk 4.1) werd geïnventariseerd welke ontwikkelingen tussen 1985 en 2000 verwacht zouden kunnen worden in de epidemiologie van verkeers-, arbeids-, en privé-ongevallen. Enerzijds werden mogelijke ontwikkelingen zonder beleidsmatig ingrijpen (autonome ontwikkelingen) in kaart gebracht, anderzijds werden de potentiele effecten van verschillende beleidsopties geschat. Tachtig Nederlandse deskundigen werden uitgenodigd voor deelname aan het onderzoek. Hiervan deed 82% daadwerkelijk mee. De respondenten gaven schattingen van kwantitatieve veranderingen in diverse belangrijke parameters in de epidemiologie van ongevalsletsels onder verschillende externe condities (zoals verschillende veronderstellingen rond de te verwachten economische groei). De gevraagde parameters omvatten onder meer de expositie, letselkans en letselernst naar type activiteit. Hiernaast werd gevraagd naar ontwikkelingen in de letaliteit naar letseltype. Tevens werd de deskundigen gevraagd om pakketten beleidsmaatregelen te bedenken, en om daar het potentiele kwantitatieve effect van te schatten.

De resultaten van het Delphi-onderzoek werden gebruikt bij het doorrekenen van de effecten van verschillende toekomstscenario's (hoofdstuk 4.2).

Deze berekeningen werden uitgevoerd met een binnen ons instituut ontwikkeld model. Hiermee konden de gecombineerde effecten van trends in afzonderlijke parameters (zoals expositie en letselkans) en afzonderlijke activiteiten (zoals autogebruik, industriële arbeid, en sportdeelname) worden berekend. De combinatie van ontwikkelingen, die volgens een meerderheid van de Delphi-experts als meest waarschijnlijk werd gezien, werd uitgewerkt in een "referentie-scenario".

De resultaten van dit scenario - met als kernaannames een matige economische groei (2% per jaar) en het achterwege blijven van nieuw beleidsmatig ingrijpen - lieten het volgende beeld zien: de sterfte door ongevalsletsels (die scherp gedaald was tussen 1970 en 1985) zou zonder nieuwe maatregelen ongeveer op het niveau van 1985 blijven. Hiernaast werd berekend dat verschillende "alternatieve autonome scenario's" vermoedelijk tot een stijging van de incidentie en sterfte zouden leiden. De resultaten van drie beleidsscenario's lieten echter zien dat deskundigen optimistisch waren omtrent de effectiviteit van een krachtige voortzetting van het preventiebeleid en/of de implementatie van een nieuw pakket maatregelen ter verbetering van de medische zorg voor letselpatiënten.

De resultaten van de scenarioberekeningen werden in 1988 gerapporteerd aan beleidsmakers en vervolgens gebruikt als raamwerk bij de continue monitoring van ongevalsletsels in Nederland (hoofdstuk 4.3). Trends in de epidemiologie van ongevalsletsels sinds 1985 konden vergeleken worden met ontwikkelingen in de voorafgaande periode (1970-1985) én met de uitkomsten van de toekomstscenario's (1985-2000). Op grond hiervan werden interrupties van de werkelijke sterftetrends in Nederland geïdentificeerd, welke reeds in 1989 aan beleidsmakers gerapporteerd werden. In de tweede helft van de jaren tachtig bleek sprake van een afvlakking van de snelle sterftedaling uit de voorafgaande periode (verkeersongevallen), van een omslag naar een lichte sterftetoename (arbeidsongevallen) of van een omslag naar een stabilisatie van de sterftecijfers (privé-ongevallen). Deze overgang naar minder gunstige ontwikkelingen dan in de voorafgaande periode was reeds voorzien door de Nederlandse deskundigen. De monitoring van werkelijke trends in de epidemiologie van ongevalsletsels gedurende meer dan tien jaar heeft ons de gelegenheid geboden om het nieuwe instrument te evalueren. Hieruit hebben we geconcludeerd dat dit instrument toegevoegde waarde heeft op verschillende punten. Het biedt een uitstekend raamwerk voor de continue monitoring van trends, en het lijkt de vroege opsporing van trendinterrupties of trendbreuken te bevorderen.

Het instrument biedt bovendien potentieel waardevolle informatie over mogelijke toekomstige ontwikkelingen, en over de haalbaarheid van beleidsdoelstellingen.

HOOFDSTUK 5

Het proefschrift wordt afgesloten met een algemene discussie. In dit laatste deel worden enkele belangrijke resultaten kort samengevat, en wordt ingegaan op mogelijkheden en beperkingen van de gebruikte gegevens en methoden. Aanvullend worden de bevindingen uit dit proefschrift geplaatst in het lange termijn perspectief van de epidemiologische transitie. Dit betreft de grote veranderingen op het terrein van de volksgezondheid die geïndustrialiseerde samenlevingen gedurende de afgelopen twee eeuwen hebben doorgemaakt. De analyses uit dit proefschrift hebben enig licht geworpen op acute lichamelijke letsels als onderdeel van dit veranderingsproces, waarin de levensverwachting sterk is toegenomen en chronische ziekten de plaats van infectieziekten zijn gaan innemen, waar het de belangrijkste oorzaak van sterfte in de bevolking betreft. Lange termijn trends op het gebied van acute lichamelijke letsels betreffen een onderwerp dat nog relatief weinig bestudeerd is. Er werd zichtbaar gemaakt dat de totale sterfte door acute lichamelijke letsels (veroorzaakt door ongevallen, zelfbeschadiging of geweld) gedurende de afgelopen eeuw op vrijwel hetzelfde niveau is gebleven in Nederland. Aan de andere kant hebben aparte deelrubrieken wél spectaculaire wijzigingen ondergaan. Vanaf het begin van deze eeuw tot ongeveer 1970 was er sprake van een scherpe daling van de sterfte door verdrinking en andere niet-verkeersongevallen (uitgezonderd accidentele val). Deze daling kan worden verklaard op grond van dezelfde algemene factoren die vaak genoemd worden in analyses van de dalende sterfte door infectieziekten gedurende de epidemiologische transitie: toegenomen welvaart, sociaal-culturele modernisering, en collectieve preventie hebben bijgedragen aan het verdwijnen van verdrinking en andere niet-verkeersongevallen als belangrijke "externe doodsoorzaken". In dezelfde periode was sprake van een enorme stijging van de sterfte door verkeersongevallen en accidentele val. In beide gevallen heeft de toegenomen welvaart waarschijnlijk een belangrijke rol gespeeld bij deze ontwikkelingen. Verkeersongevallen en accidentele val lijken voorbeelden van "degenerative and man-made diseases" (degeneratieve en door de mens zelf veroorzaakte aandoeningen).

Samenvatting

Vanaf het begin van deze eeuw is er sprake geweest van een belangrijke verschuiving in het patroon van doodsoorzaken binnen de acute lichamelijke letsels : verkeersongevallen en accidentele val namen de plaats in van verdrinking en andere niet-verkeersongevallen.

Vanaf 1970 zijn vervolgens weer andere dynamische veranderingen opgetreden. Na 1970 ging de sterfte door verkeersongevallen en accidentele val dalen, hetgeen een grote gelijkenis vertoont met de trendbreuk die ongeveer tegelijkertijd bij ischaemische hartziekten kon worden waargenomen. Bij verkeersongevallen is de trendbreuk gebaseerd op een combinatie van 'autonome ontwikkelingen' (de groei van de verkeersmobiliteit begon af te vlakken) en 'aanpassingsmechanismen' (bestaande uit collectieve preventie en verbeteringen van de medische zorg voor letselpatiënten). Bij de accidentele val is sprake van een iets andere achtergrond van de trendbreuk. Maar ook bij deze deelrubriek hebben 'aanpassingsmechanismen' (verbetering van de medische zorg) een belangrijke rol gespeeld. Vermoedelijk zijn deze aanpassingsmechanismen, zowel bij verkeersongevallen als bij accidentele val, mede onder invloed van welvaartsgroei tot stand gekomen.

Tenslotte werd ook zichtbaar gemaakt dat het aandeel van de 'opzettelijk toegebrachte letsels' in de sterfte door externe doodsoorzaken sinds 1970 is toegenomen. Hiervoor kon geen verklaring worden gegeven. Onderkend moet worden dat zelfmoord en geweld nieuwe prioriteiten in het volksgezondheidsbeleid zouden moeten zijn, in aanvulling op de ongevalsletsels.

De belangrijkste conclusies, die uit de lange termijn analyses getrokken kunnen worden, zijn als volgt. Specifieke deelrubrieken binnen het veld van de acute lichamelijke letsels kennen een toenemend belang als doodsoorzaak in een bepaalde fase van economische en sociaal-culturele ontwikkeling. In deze fase worden nieuwe risico's geïntroduceerd in de samenleving, hetgeen gevolgd wordt door een toenemende blootstelling aan deze risico's in een steeds groter deel van de bevolking. Dit leidt tot aanpassingsmechanismen die bevorderd lijken te worden door welvaartsgroei. Deze aanpassingsmechanismen omvatten zowel preventieve maatregelen als verbeteringen van de medische zorg voor letselpatiënten. Het anticiperen op mogelijke toekomstige ontwikkelingen, en de vroegtijdige onderkenning van ongunstige trends, zouden een versnelling van noodzakelijke aanpassingsmechanismen teweeg moeten brengen.

Samenvatting

De dynamiek binnen het terrein van de acute lichamelijke letsels, zoals geïllustreerd in dit proefschrift, maken dit veld één van de grootste uitdagingen op het gebied van de volksgezondheid.

Het laatste stuk uit dit proefschrift is daarom gewijd aan belangrijke uitdagingen voor de toekomst : in registratie, wetenschappelijk onderzoek en beleid.

Met prioriteit dient de registratie van de letselincidentie en de letselernst verbeterd te worden. Nieuw wetenschappelijk onderzoek zou zich in elk geval moeten richten op de lange termijn gevolgen van letsels, op oorzaken van letsels op individueel niveau, en op de effectiviteit van letselpreventie en medische zorg voor letselpatiënten. Het beleid dient zowel nieuwe preventieve inspanningen te omvatten als de implementatie van een nieuw systeem van regionale traumazorgnetwerken. Deze aanpassingsmechanismen moeten zorgen voor een verdere vermindering van het nog steeds veel te hoge aantal gewonden, overledenen en gehandicapten ten gevolge van acute lichamelijke letsels in Nederland.

About the author

Ed van Beeck was born on May 2th, 1958, in The Hague, the Netherlands, where he finished secondary school (gymnasium-Beta) in 1976. That same year he started to study at Erasmus University Medical School in Rotterdam. In 1984 he obtained his medical degree. In 1984/1985 he worked as a physician at the Division of Military Health Care of the Ministry of Defence in The Hague. In 1985 he started working at the Department of Public Health of Erasmus University Medical School. From 1985 until 1988 he was a full-time researcher involved in the "Injury and Traumatology Scenario study" initiated by the Steering Committee on Future Health Scenarios. From 1988 onwards he has combined injury research with several tasks in academic teaching and management. In the period 1988-1995 he worked for the sector of Health Sciences of Erasmus University Medical School (including the Department of Public Health, the Department of Epidemiology and Biostatistics, and the Department of Medical Informatics). He worked as the teaching coordinator of this sector and helped to establish the Netherlands Institute for Health Sciences (NIHES). In the period 1992-1995 he was the managing director of NIHES, which started a comprehensive international post-graduate training programme at that time.

Since 1996 he works full-time at the Department of Public Health again. He is head of the section on education and training of this department and works as a senior researcher in injury epidemiology. He is a member of several committees related to the the teaching of medical students at Erasmus University Medical School. In addition, he is a member of several national and international committees and working groups involved in injury research and surveillance.

He is married to Nandy Knulst and has two children: Tarik and Elise.

Dankwoord

Bij het schrijven van een proefschrift hoort altijd een uitgebreide lijst te bedanken personen. Dit geldt zeker voor dit boekje, dat een lange ontstaansgeschiedenis kent. Hierin zijn velen mij behulpzaam geweest bij de verschillende soorten activiteiten waarmee ik me bezig hield.

Het proefschrift kent zijn oorsprong in het scenario-project "Ongevallen en traumatologie". Als jonge analytisch ingestelde arts wilde ik halverwege de jaren tachtig mee gaan werken aan het tot stand komen van een meer rationele manier van besluitvorming in het gezondheidszorgbeleid. Ik was overtuigd van de noodzaak van kwantitatieve onderbouwing. Daarom leek het maken van vooruitberekeningen met betrekking tot ongevallen en hun gevolgen mij zeer zinvol. Tijdens mijn werkzaamheden als dienstplichtig arts was ik geconfronteerd geraakt met de grote gevolgen die ongevalsletsels kunnen hebben voor het sociaal en maatschappelijk functioneren van mensen. Bovendien zou ik veel kunnen leren wat mij in mijn latere carrière als beleidsmaker goed van pas zou komen. Zonder enige ervaring met wetenschappelijk onderzoek heb ik me daarom indertijd aangemeld voor het uitvoeren van het scenario-project. En daar heb ik nooit spijt van gekregen.

Over wie ik het meeste moet bedanken voor de kans die ik toen kreeg, ben ik niet geheel zeker, maar ik kies voor Paul van der Maas. Het ontspannen gevoel, dat jij bij mijn sollicitatiegesprek reeds bij me opriep, maakte mij toen al zeker dat ik me bij "jouw" instituut zeer op mijn plaats zou gaan voelen. Dat is later alleen maar bevestigd in de vele activiteiten waar wij samen mee te maken hebben gehad. Ten tweede wil ik Ruud Lapré noemen, die als voorzitter van de scenario-commissie zo'n belangrijke inbreng had bij het proces waarin wetenschappers en deskundigen uit het veld van letselpreventie en traumazorg elkaar vonden.

Ook wil ik al diegenen bedanken die mij, vooral tijdens die eerste jaren van het scenario-project, met overtuiging en gedrevenheid lieten zien wat een belangrijk en boeiend onderwerp de acute lichamelijke letsels zijn binnen de volksgezondheid. Ik noem de leden van de scenario-commissie en de respondenten van ons Delphi-onderzoek. Zonder hen was dit proefschrift nooit geschreven. Apart wil ik noemen professor Goris, die vanuit de traumatologie aan het project deelnam en toen ontwikkelingen in gang heeft gezet waar het beleid op dit moment op voortbouwt. Ook ben ik bijzondere dank verschuldigd aan Wim Rogmans, met name voor de wijze waarop hij vele aanbevelingen uit het scenariorapport heeft omgezet in daden. Ik noem de intersectorale samenwerking en de verbetering van de letselregistratie. Dit zal ongetwijfeld de basis gaan vormen voor belangrijk nieuw toekomstig onderzoek en preventiebeleid.

Uit die inspirerende beginjaren wil ik tenslotte nog één persoon speciaal noemen: Theresa van der Starre-Bout, die al ons werk omzette in rapporten die qua lay-out hun tijd ver vooruit waren.

Wie ik ook wil bedanken zijn alle co-auteurs van de artikelen die in dit proefschrift zijn opgenomen. Het zijn stuk voor stuk goede collega's die essentiele bijdragen aan de diverse analyses geleverd hebben, en tevens veel van de in dit proefschrift opgenomen figuren hebben gemaakt. Door hen ben ik bovendien verder gekomen in diverse onderdelen van de wetenschap. Ik noem Dik Habbema, Gerrit van Oortmarssen en Jan Barendregt in verband met de ontwikkeling van het rekenmodel voor vooruitberekeningen in de epidemiologie van ongevallen. Anton Kunst voor zijn hulp bij de analyses van sterfteverschillen. Ook zijn kritisch commentaar op mijn manuscript heeft me zeer goed geholpen. Ik noem Caspar Looman en Gerard Borsboom voor de statistische ondersteuning die ik nodig had. En Leona Hakkaart-van Roijen wil ik bedanken voor de plezierige wijze waarop we gezamenlijk de kosten van letsel in kaart hebben gebracht. Judith Wolleswinkel-van den Bosch moet ik bedanken voor het historisch materiaal dat mij in staat stelde de acute lichamelijke letsels te bespreken in het kader van datgene waarop jij straks zelf promoveert: de epidemiologische transitie theorie.

Naast mijn onderzoek, dat de basis vormt van dit proefschrift, ben ik de afgelopen tien jaar ook sterk betrokken geweest bij het onderwijs aan medisch studenten in Rotterdam. Ook dit is een belangrijke taak, die samen met vele anderen wordt uitgevoerd. Het ontwikkelen en uitvoeren van onderwijs in het vak maatschappelijke gezondheidszorg in een artsenopleiding is geen eenvoudige opgave.

Dankwoord

Van Wim Zweekhorst heb ik geleerd op welke wijze dit op een effectieve en voor studenten boeiende manier kan: met behulp van patiëntgeoriënteerd onderwijs, dat primair gericht is op het opleiden van goede medische hulpverleners. Ik wil jou bedanken voor de vele inspirerende gesprekken die wij gehad hebben, en voor het feit dat je mij zo snel in vertrouwen nam om het onderwijs van ons instituut gezamenlijk tot verdere ontwikkeling te brengen. In dit proces zijn ook anderen vervolgens zeer belangrijk geweest. Dike van de Mheen werd de derde onmisbare schakel in ons onderwijscluster. Zonder jou als "kompaan" in het onderwijs was dit proefschrift waarschijnlijk nooit afgerond. Ik ben dan ook blij dat wij zo'n beetje op hetzelfde tijdstip promoveren. Joke Meulmeester kon als ervaren sociaal-geneeskundige belangrijke aanvullende kennis in ons onderwijs inbrengen. Ik wil jou daarvoor bedanken, maar vooral ook voor je gezelschap als kamergenote en voor de door jou geschreven toneelstukjes, waarin ik me bij gelegenheden kon uitleven. En dan Alice Griffioen. Wat werd jouw besluit, om te stoppen als hoofd van ons secretariaat en te beginnen als logistiek coördinator onderwijs, mij als een geschenk in de schoot geworpen. Dat het onderwijscluster dit jaar twee promoties kent, is zeker ook deels aan jouw voortreffelijke ondersteuning te danken. Ik ben blij dat je je nieuwe taak zo ontzettend leuk vindt.

In de ontstaansgeschiedenis van dit proefschrift is er een periode geweest waarin ik me nauwelijks met onderzoek bezig kon houden. In de eerste helft van de jaren negentig ontstond er een nieuwe organisatievorm binnen de universiteiten: de onderzoekschool. Dit concept is later vaak bekritiseerd, maar ten onrechte. Van Bert Hofman heb ik geleerd wat een onderzoekschool in essentie moet zijn: een federatie van onderzoeksgroepen van topkwaliteit, die gezamenlijk een post-initieel opleidingsprogramma verzorgen met internationale aantrekkingskracht. Ik wil jou bedanken voor de inspirerende periode waarin wij gezamenlijk het Netherlands Institute for Health Sciences (NIHES) op basis van deze visie hebben opgebouwd. Het was beslist de moeite waard.

Tijdens mijn periode bij het NIHES ben ik door velen ondersteund. Met name de secretaresses van het stafbureau, Mariska Olanyi, Soeja de Groot, Marie-Louise Bot en Ineke Buytink, ben ik veel dank verschuldigd. Dit geldt ook voor hen die mijn taken bij het NIHES op voortreffelijke wijze hebben overgenomen: Lex Burdorf, Alita Hidding en Koos Lubbe. Maar bovenal is daar natuurlijk Cilia Kuynders. Wat fijn dat jij gedurende die jaren bij het NIHES "mijn" perfecte secretaresse was.

Het belang van goede secretariële ondersteuning kan niet hoog genoeg worden ingeschat. Door mijn uiteenlopende activiteiten is dit altijd van grote betekenis geweest.

Ook op het secretariaat van het instituut Maatschappelijke Gezondheidszorg kon ik altijd terugvallen. Daarom zeker ook dank aan Else van den Engel, Monique van der Linden, Jolanda Zwetsloot, Els Goettsch en Sonja Deurloo. Een speciaal bedankje verdient Ilse Philips die de lay-out van dit proefschrift heeft verzorgd. Ook Saskia Drent wil ik zeker even apart noemen, met name voor de manier waarop zij mijn diverse stukjes tot één volledig manuscript heeft bewerkt. In dit verband wil ik ook Karen Gribling bedanken voor het verbeteren van het Engels. En Barry de Wit en Yolande te Giffel wil ik graag noemen voor hun voortreffelijke ondersteuning op financieel/administratief gebied.

Ook het belang van werken in een sfeer van goede onderlinge verstandhoudingen zou ik nog even willen onderstrepen. De vele collega's die ik de afgelopen jaren heb gehad wil ik hier graag voor bedanken. Een hoogtepunt was voor mij het cabaret dat wij gezamenlijk hebben opgevoerd bij het 25-jarig bestaan van het instituut Maatschappelijke Gezondheidszorg. Als voorbeeld van fijne collega's wil ik daarom hen noemen, die hieraan meededen en niet elders in dit dankwoord reeds vermeld zijn: Joost van der Meer, Sake de Vlas, Peter Warmerdam, René Eijkemans, Caroline Baan, Petra Beemsterboer en Feikje Groenhof.

Collega's die zeker ook genoemd moeten worden zijn Willem Jan Meerding en Erwin Birnie. Onze samenwerking om te komen tot een nieuw model voor de berekening van kosten van letsels is voor mij echt zeer plezierig. Hierin wil ook de collega's van onze samenwerkingspartner, Consument en Veiligheid, graag betrekken: Saakje Mulder, Marieke Schellart, Paul den Hertog, en Henk Zantvoord. En zeker ook weer de secretaresses die ons zo goed ondersteunen: Joke Broekhuizen en Annerieke Arendshorst.

Tenslotte ben ik beland bij de laatste personen die van cruciale betekenis zijn. Johan Mackenbach heeft mij geleerd wat kwantitatief wetenschappelijk onderzoek inhoudt. Dit proefschrift is een vrucht van onze samenwerking, die jaren geleden tot stand kwam. Jij hebt mijn wetenschappelijke interesse sterk gestimuleerd en hebt mij gevormd tot een onderzoeker die mogelijk iets bij kan dragen aan de kwantitatieve onderbouwing van het gezondheidszorgbeleid. Jouw rol als promotor was essentieel. Je combinatie van enerzijds geduld en begrip, en anderzijds stimulering op momenten waarop het echt even nodig was, heeft mij tot afronding van dit proefschrift gebracht.

En dan mijn ouders en mijn zus Irene: jullie warme steun vanaf mijn jongste jaren is voor mij zo betekenisvol. En Nandy: jouw liefde is de bron van mijn inspiratie.