Zurich University of Applied Sciences

Cost-benefit analysis of road accident prevention programmes in Switzerland from 1975 to 2007

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Abstract

The goal of this study is a cost benefit analysis (CBA) of road accident prevention measures realized in Switzerland in the period from 1975 to 2007. The actual number of road accident casualties is estimated by combining police report and accident insurer data. The societal costs of road accidents (direct costs, productivity losses and intangible costs) and effectiveness of public and private prevention measures in reducing the number of accidents are estimated. The return on investment (ROI) is calculated by comparing the costs and benefits of prevention measures.

The main results are a ROI of 1.54 for all public and private prevention interventions, a ROI of 9.43 for public prevention programmes (without investments in the safety of road infrastructure), a ROI of 5.81 for alcohol prevention measures, a ROI of 16.31 for promotion of bicycle helmet wearing, a ROI of 8.06 for the combined prevention measures introduced in the year 2005 and a ROI of 101.03 for the measures aiming at the imposition and promotion of safety-belt. The effect of all interventions between 1975 and 2007 is substantial with 13’484 fatalities and 909’213 casualties prevented and a total of CHF 72’816 million avoided, thanks to prevention.

Ziel der Studie ist eine Kosten-Nutzen-Analyse (KNA) der Programme zur Prävention von Strassenverkehrsunfällen, die zwischen 1975 und 2007 in der Schweiz durchgeführt wurden. Durch eine Verbindung der Informationen aus den Unfallberichten der Polizei mit den Daten der Unfallversicherungen wird die Zahl der Verkehrsopfer ermittelt. Die gesellschaftlichen Kosten der Strassenverkehrsunfälle (direkte Kosten, Produktivitätsverluste und intangible Kosten) und der Wirksamkeit von privaten und öffentlichen Präventionsmassnahmen werden geschätzt. Der Return on Investment (ROI) wird durch den Vergleich der Kosten mit dem Nutzen der Präventionsmassnahmen ermittelt.

Die wichtigsten Ergebnisse sind ein ROI von 1,54 für die Gesamtheit der öffentlichen und privaten Massnahmen, ein ROI von 9,43 für öffentliche Präventionsprogramme (ohne Investitionen in die Sicherheit der Strasseninfrastruktur), ein ROI von 5,81 für Programme zur Alkoholprävention, ein ROI von 16,31 für die Massnahmen zur Förderung des Tragens von Fahrradhelmen, ein ROI von 8,06 für die Verkehrssicherheitsmassnahmen des Jahres 2005 und ein ROI von 101,03 für die Massnahmen zur Erhöhung der Sicherheitsgurttragequote. Der Effekt aller von 1975 bis 2007 durchgeführten Massnahmen war erheblich: Dank der Prävention konnten 13’484 Todesfälle und 909’213 Verkehrsunfallopfer verhindert und Kosten in Höhe von insgesamt 72’816 Millionen Schweizer Franken vermieden werden.

Le but de cette étude est l’analyse coûts-bénéfice (ACB) des mesures de prévention routière mises en œuvre en Suisse au cours de la période allant de 1975 à 2007. Le nombre de victimes d’accident de la route est estimé en combinant rapports de police et données des assureurs. Les coûts sociaux des accidents de la route (coûts directs, pertes de productivité, coûts immatériels) et l’efficacité des mesures préventives publiques et privées réduisant le nombre d'accidents sont estimés. Le retour sur investissement (RSI) est calculé en comparant les coûts et les bénéfices des mesures de prévention.

Les principaux résultats sont un RSI de 1.54 pour toutes les interventions de prévention publiques et privées, un RSI de 9.43 pour les programmes publics de prévention (sans les investissements dans la sécurité des infrastructures routières), un RSI de 5.81 pour les mesures de prévention contre l'alcool au volant, un RSI de 16.31 pour la promotion du port du casque à vélo, un RSI de 8.06 pour les mesures préventives combinées mises en place en 2005 et un RSI de 101.03 pour les mesures visant à promouvoir et imposer le port de la ceinture de sécurité. L'effet de toutes ces interventions menées entre 1975 et 2007 est substantiel, avec 13 484 décès et 909 213 blessés évités et un total de 72 816 millions de francs suisses épargnés grâce à la prévention.

Keywords

economic evaluation, prevention, return on investment, cost benefit analysis, road accidents

ökonomische Evaluation, Prävention, return on investment, Kosten-Nutzen-Analyse, Strassenverkehrsunfälle

évaluation économique, prévention, retour sur investissement, analyse coûts-bénéfices, accidents de la route

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Summary

Objective

Carry out a cost-benefit analysis (CBA) of road accident prevention measures in Switzerland between 1975 and 2007. Identify the gains of prevention efforts in terms of casualties prevented and the return of investment in monetary terms.

Methodology

The CBA proceeds with the following steps:

1. Estimate the actual number of road accident casualties by combining two datasets on road accident casualties.
2. Determine the societal costs (including direct costs, productivity losses and intangible costs) of road accident casualties.
3. Identify the relevant public and private road accident prevention measures and estimate their costs.
4. Estimate the effectiveness of the prevention measures identified on the evolution of casualties from 1975 to 2007.
5. Carry out the CBA by comparing the benefits of the prevention measures with the costs of the prevention measures
6. Carry out a sensitivity analysis of the results.

Data sources

The main data sources for the study are the *Swiss Federal Statistical Office* road accident data base containing information on every single accident reported to the police between 1975 and 2007 and a dataset extracted specifically for this study from the accidents insurances database. The accident insurance database contains detailed information on the costs of road accident victims (medical costs, workdays lost, and disability pensions) and the severity and type of their injuries. Numerous other data from public and private institutions and organizations is also employed.

Results

The main results of the CBA are the following: The return of investment (ROI) of all public and private prevention measures carried out between 1975 and 2007 is of CHF 1.54 for every franc invested in prevention measures. The following numbers of casualties are prevented by these measures: 13’484 fatalities, 17’316 permanently disabled, 98’861 severely injured, 82’822 moderately injured and 710’214 slightly injured.

The ROI of prevention programmes aimed at an increased use of safety devices and safer behaviour is of CHF 9.43 for each franc. The ROI of alcohol prevention measures is CHF 5.81, the ROI of bicycle helmet wearing promotion CHF 16.31, the ROI of the combined measures introduced in 2005 CHF 8.06. Measures aiming at the imposition and promotion of safety-belt usage have an exceptionally high ROI of CHF 101.03 per franc invested.

The precision of the results is limited by the numerous assumptions made in the successive steps of the CBA, the limitations in the data available and the difficulties in the statistical estimation of the effects of prevention measures on the evolution of casualties. Nonetheless these results are a conservative estimate of the ROI of road accident prevention measures as the factors influencing possible benefits are always estimated with a conservative approach and factors influencing costs with a generous approach.

Conclusion

The analysis shows the importance of public efforts in the substantial reduction of road casualties in the period between 1975 and 2007 as most of the measures responsible for this development are a result of public policy. The case of road accident prevention in Switzerland is thus an example of a successful prevention strategy.

List of abbreviations

ASTRA	Swiss Federal Roads Office (Bundesamt für Strassen)
bfu/CAP	Swiss Council for Accident Prevention (Beratungsstelle für Unfall-verhütung)
CBA	cost-benefit analysis
CHF	Swiss Franc
DALY	disability-adjusted life year
DW	disability weight
FOPH	Swiss Federal Office of Public Health (Bundesamt für Gesundheit)
FSIO	Swiss Federal Social Insurance Office, Switzerland (Bundesamt für Sozialversicherungen)
FSO	Swiss Federal Statistical Office (Bundesamt für Statistik)
FRS	Fund for Road Safety (Fonds für Verkehrssicherheit)
GBD	global burden of disease
L	average duration of disability
QALY	quality-adjusted life year
ROI	return on investment
seco	State Secretariat for Economic Affairs (Staatssekretariat für Wir-schaft)
SSUV	Service of centralisation of the statistics of accidents insurances (Sammelstelle für die Statistik der Unfallversicherung)
SUVA	Swiss Accident Insurance Fund (Schweizerische Unfallversiche-rungsanstalt)
UVG	Unfallversicherungsgesetz (federal law on accident insurance)
YLD	years lost due to disability
YLL	years of life lost
ZHAW	Zurich University of Applied Sciences Winterthur (Zürcher Hoch-schule für angewandte Wissenschaften Winterthur)
GDP	gross domestic product

Glossary

correction factors of non-reported casualties	A part of road accidents are not reported to the police and thus do not appear in official statistics. The correction factor is an estimate of the ratio of true number of casualties to the number of reported casualties.
cost benefit analysis (CBA)	Analysis comparing the costs and benefits of an intervention. Both cost and benefits are measured in monetary terms and discounted to their present value. A CBA allows the calculation of the *ROI* of an intervention.
direct cost	Cost of resources used to deal with the consequences of disease or accident. They usually include costs of health care, assistance to individuals affected and may also comprise administrative costs and material damage.
disability-adjusted life years (DALY)	Indicator developed by the WHO to assess the global burden of disease. DALYs are computed by adjusting age-specific life expectancy for loss of healthy life due to disability. The value of a year of life at each age is weighted, as are health decrements from disability from specified diseases and injuries.
intangible cost	Value of health and quality of life lost due to a disease or injury.
labour participation rate	Ratio of number of of employed and self-employed individuals to the number of individuals in working-age (15-64/65 years).
production or productivity losses	Production losses due to workdays lost as a consequence of a disease, illness or accident. These costs are also sometimes called indirect costs.
return on investment (ROI)	Number of monetary units gained for every monetary unit invested. The ROI is calculated as the difference between the benefits and the costs of the intervention over the costs of the intervention. A ROI of 0 thus means that the benefits of the intervention were equal to its costs.
sensitivity analysis	Sensitivity analysis involves repetition of an analysis under different assumptions to examine the impact of these assumptions on the results.

societal perspective	A CBA with a societal perspective considers all the relevant costs of an intervention and its resulting benefits to the society as a whole (including individuals, private companies and public authorities).

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1 Introduction

The general goal of the economic evaluations of health promotion and accident prevention efforts is a comparison between the monetary costs of prevention and health promotion measures and the gains obtained in terms of casualties prevented and in monetary terms.

This cost-benefit analysis (CBA) of road accident prevention in Switzerland is part of a research project commissioned by the Swiss Federal Office of Public Health (FOPH) to the Winterthur Institute of Health Economics (WIG)[1] and the Institute of Economic Research (IRENE) of the University of Neuchâtel, which includes CBAs of prevention measures in the fields of road accidents, alcohol abuse and tobacco in Switzerland in the last 10 to 33 years[2] and an exploratory study on obesity.

In this context a CBA of road accident prevention measures, with a special focus on the effect of alcohol, is useful and important for a number of reasons:

- The immediate temporal link between road accident prevention measures and their effect on health makes it relatively easy to quantify the effectiveness of these measures. If, for example, a new law introducing a lower limit for blood alcohol content leads to a lower number of accidents, this effect should be observable in the year in which the new law is introduced. In contrast, the health effects in other prevention and health promotion fields may be observable only after several years.
- The detailed available data on accidents (Federal Statistical Office (FSO) data on accidents recorded by police) and consequences of accidents (accident insurer data on accident costs and type of injuries) allow a detailed analysis over a long time period of 33 years. The combination of these two datasets also allows an estimation of the actual number of road accident casualties in Switzerland which is underestimated by the FSO road accident data.
- Although fatalities in road accidents have declined substantially since the beginning of the 1970s, road accidents are still responsible for considerable societal costs in Switzerland. A recent study estimates these costs at CHF 14 billion for the year 2003 (Sommer et al. 2007b).
- There may be important links between different prevention fields. In this regard it is of particular interest to identify the effects of measures against alcohol abuse aimed at the whole population as well as measures aimed exclusively at drivers on the number of road accident victims and the severity of the accidents.

The analysis is carried out on 4 categories of road users (cars and lorries, motorcycles and mopeds, bicycles, pedestrians) in 5 categories of injury severities (dead, permanently disabled, severely injured, moderately injured, slightly injured).

[1] The WIG is part of the School of Management and Law of the Zurich University of Applied Sciences.

[2] The time period considered will depend on the data availability.

To our knowledge this is the first CBA of road accident prevention measures in Switzerland for the length of the time period (1975 to 2007), the number of prevention measures and types of costs considered.

Our CBA of road accident prevention measures proceeds with the following steps. In section 2 we estimate the actual number of road accident casualties by combining the information in the FSO and the SSUV road accident datasets for 4 categories of road users and 5 categories of severity of injury. The societal costs (including direct costs, productivity losses and intangible costs) for each of these 20 road accident casualty categories are estimated in section 3. The next step is the identification of the relevant public and private road accident prevention measures and estimation of their costs in section 4. We then estimate the effectiveness of the prevention measures identified on the evolution of the 20 casualty categories from 1975 to 2007 (section 5). The last step of the CBA consists of the comparison of the benefits of the prevention measures (number of prevented casualties multiplied by the societal cost per prevented casualty) with the costs of the prevention measures (section 6). We carry out a CBA for the total of public and privately financed road accident prevention measures and for single prevention measures. Section 6.4 is a sensitivity analysis of these results. In section 8 we summarize the main conclusions of our analysis.

2 Evolution of road accidents victims in Switzerland

We dispose of two different datasets reporting the number of casualties from road accidents in Switzerland:

1. The *Swiss Federal Statistical Office* (FSO) road accident data containing information on every single accident reported to the police between 1975 and 2007.
2. A dataset extracted specifically for our study from the Service of centralisation of the statistics of accidents insurances (SSUV) database. It is based on all accident insurance claims related to road accidents in Switzerland between 1984 and 2006.

Table 1 compares the characteristics of the two datasets and presents the major differences. The two datasets cover different populations. We assume that the SSUV data contains the actual number of casualties in the reference population of the employees covered by accident insurance, as the insured and the employers have a strong incentive to report accidents to the insurers: In contrast to the basic health insurance there are no co-payments by the patients on medical costs and accident insurance covers the wage of the employee absent from work because of an accident. However, only part of the population is covered by an accident insurance and therefore included in the SSUV data. FSO data covers the Swiss population but does not contain all accidents. Although an accident should be reported to the police if someone is injured, many accidents (especially self-inflicted) are not reported. We thus combine the two datasets in order to estimate the actual number of accidents.

Table 1 Comparison of FSO and SSUV data

subject	**FSO**	**SSUV**
type of census	accidents on public roads reported to the police (based on accident protocols) note: from 1991 to 1992 the questionnaire and the definition of slightly and severely injured changed, causing a break in the data	casualties reported to SSUV by the insurers includes off-road accidents The information on slightly, moderately and severely injured cases is extrapolated from a random sample covering 5% of total cases. Complete information on casualties granted a disability pension and fatalities.
aggregation of data	detailed information to every single accident (circumstances of the accident, objects and persons involved, etc.)	aggregated yearly data per age, gender, injury and road user category, and type of insurance
age	all	15 to 63
circumstances of the accident	many details, including location, weather, time, alcohol, use of safety devices	none
road user categories	over 30 categories	5 categories (bicycle, motorcycles and mopeds, cars, lorries, none = pedestrians), before 1995 only 4 as lorries were part of the car category

population	everyone injured in an accident in Switzerland, including tourists from abroad.	based on the individuals covered by accident insurance: all employees working more than 8 hours per week + registered unemployed persons = 50% of Swiss population + foreign cross-border commuters = 3.82 million individuals not included: all non-employed (children, students, non-registered unemployed, retirees, housewives) (3.3 million) + self-employed (0.47 million) includes Swiss residents covered by accident insurance injured in an accident abroad
consequences of the accident	all accidents, including those with only material damage	only injured victims, no accidents with only material damage
type of injury / injury category	3 categories: [3] **fatality** **severely injured** *before 1992*: fractures of any kind, concussions, interior injuries, severe cuts, lacerated or contused wounds *from 1992 on*: severe visible damage inhibiting normal activities during at least 24 hours **slightly injured** *before 1992*: minor injuries resulting in no or only temporary disablement *from 1992 on*: small injuries without noteworthy loss of blood or slightly limited mobility but able to leave the site of the accident independently	detailed information on length of stay in a hospital and costs of treatment **fatality** **permanently disabled** (granted a disability pension) We construct 3 injury categories based on the length of stay in a hospital: **severely injured** (more than 7 days in hospital) **moderately injured** (1-7 days in hospital) s**lightly injured** (no days in hospital)
year	1975 - 2007	1984-2006, however injury categories only reliable up to 2002, because there may be some shifts between them (i.e. a severely injured may be granted a disability pension several years after the accident)
demographic information of the victim	age, gender	age, gender
canton	cantonal data	no cantonal data
costs	estimated material damage per accident by the police officer	days spent in hospital (only those insured by SUVA), degree of invalidity, daily allowances paid, reimbursed days, medical costs, disability pensions

[3] FSO (1991:12) and http://www.bfs.admin.ch/bfs/portal/de/index/infothek/erhebungen__quellen/blank/blank/svu/02.Document.86560.pdf, page 11, retrieved 17.4.2009.

2.1 Extrapolation of total number of road accident casualties

This section describes the procedure used to calculate the actual number of casualties in road accidents between 1975 and 2007 by combining the information contained in the FSO and the SSUV datasets. As far as we know this is the first extrapolation of the number of road accident casualties over a period of 33 years for Switzerland, as previous studies were limited to the extrapolation for single years (Ecoplan 1991; Allenbach 2000; Ecoplan 2002; Sommer et al. 2007b).

The extrapolation proceeds with the following steps:

1. Assuming that within a certain age group individuals without accident insurance have the same probabilities to suffer an accident as those with accident insurance it is possible to calculate the total number of casualties, by dividing through the age group and gender specific labour participation rate.[4] This procedure can be used only for the age groups from 15 to 65 years, for which we dispose of accident insurance data.
2. By comparing the number of FSO casualties with the number of casualties according to the extrapolation of the SSUV data on the labour participation rate (see previous paragraph) we obtain a correction factor of the number of unreported casualties.
3. No SSUV data is available for children and the elderly. Assuming that accidents involving children and the elderly are reported as often to the police as the accidents of those insured by an accident insurance, we can extrapolate the number of casualties of children and the elderly by applying the correction factor of the number of unreported casualties in the previous paragraph.
4. Because the SSUV data are available from 1984 to 2006, the FSO data have to be extrapolated on this basis for the whole period from 1975 to 2007.

In addition to these three steps a number of additional difficulties have to be considered in the extrapolation procedure:

- The FSO data have a structural brake from 1991 to 1992 owing to a change in the data entry form used by the police to report road accidents. Thereby the definition of the injury categories was changed. We estimate this brake by linear regression (see appendix 1 for more details).
- The SSUV data include the category “severely injured covered by other accidents insurance companies (not SUVA)” which includes severely as well as slightly injured casualties. The information on the number of days spent in hospital used to define our injury categories is missing for this category. We

[4] Available from FSO (2009), Table 3.1.2.5 for the years 1991-2007. For earlier years (1984-1990) the values of 1991 was used.

split these casualties into the severely and slightly injured casualties and add them to their respective groups.[5]

- Apart from the distinction between employed and non-employed persons the FSO and the SSUV data refer to different spatial populations: The FSO data include tourists involved in road accidents in Switzerland and the SSUV data include individuals with an accident insurance in Switzerland that are involved in a road accident abroad. According to the FSO[6] these groups are of similar size and therefore do not have noteworthy influence on the estimate of total casualties.
- Because in the SSUV data the road user category “lorry and commercial vehicle” is only separated from the “car” category after 1995, we merge these categories into one.

The extrapolation is thus made for the following 4 road user categories

- car, lorry and commercial vehicle occupants
- motorcyclists and moped riders[7]
- cyclists
- pedestrians

and the following 3 injury categories

- slightly injured (FSO definition)
- severely injured (FSO definition)
- fatality

2.1.1 Correction factor for non-reported casualties

The correction factor for non-reported casualties is defined as the ratio of the number of extrapolated casualties reported by the SSUV to the number of casualties reported by the FSO. The results show that the correction factor

- does not differ by gender and age[8],
- is smaller, the more severe the injury category,
- is fairly constant over time except in the bicycle category, where it is increasing,

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[5] We did not need to reallocate some of them into moderately injured category, since this category does not exist in the FSO data.

[6] Citation from Ecoplan (2002:5), which extrapolated the accident numbers with the same data basis.

[7] “Motorcyclist” and “moped rider” in this report are terms that refer both to drivers and to passengers.

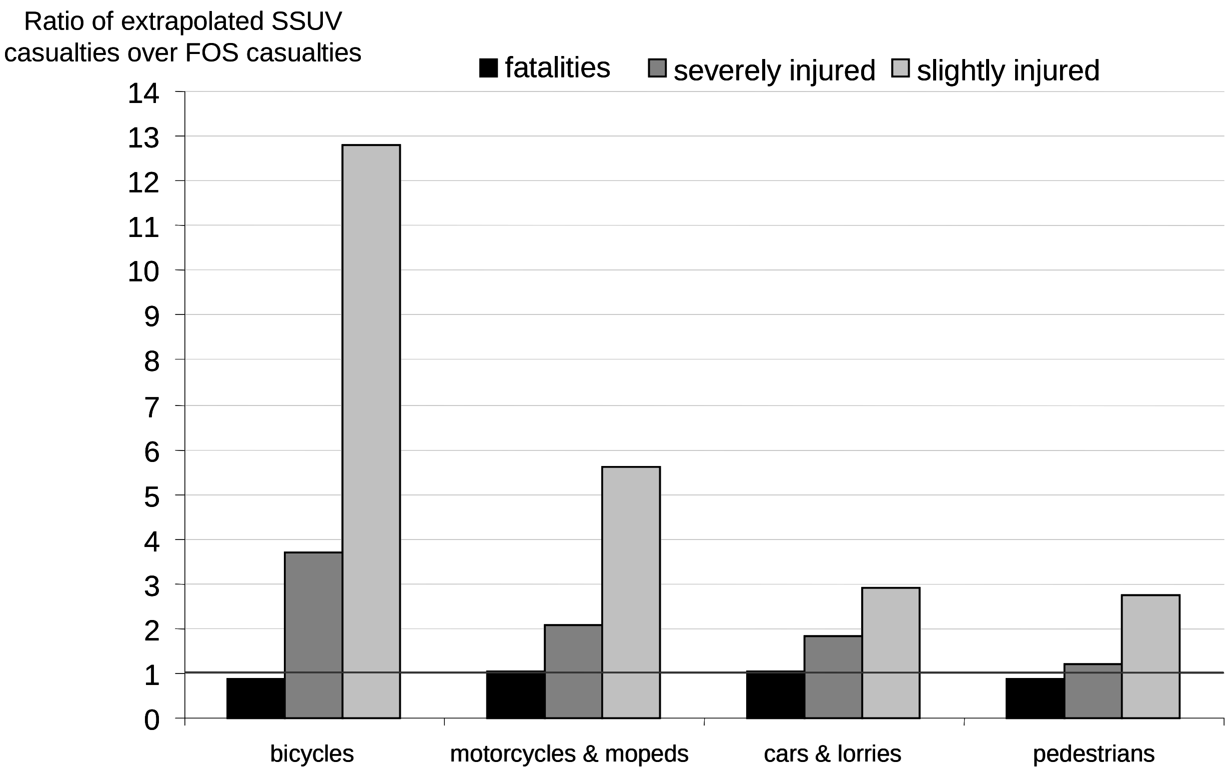
[8] There is one exception as the factor varies significantly between two age groups (55-59 and 60-64). This is due to the fact that we do not dispose of different labour participation rate for these two age groups. However this rate varies significantly in these age groups because of early retirements.

- varies between the road user categories (see figure 1)

The correction factors of severely injured and particularly of slightly injured bicycle riders is exceptionally large. Our request at the SSUV confirmed our assumption that part of this disparity between the datasets is because many bicycle accidents do not happen on public roads (e.g. in the forest) and/or are self-inflicted. Especially the slightly injured casualties are prone not to report the accident to the police, since by definition they can leave the accident site without help or medical treatment.

The correction factors for fatalities are almost 1 in every road user category. This means that for every fatality reported in the FSO data, a corresponding fatality can be found in the SSUV data, which are extrapolated with the labour participation rate. If the correction factor is smaller than 1 (as in the case of bicycles and pedestrians in figure 1), more fatalities were reported in the FSO data than in the extrapolated SSUV data. A possible explanation is that there were proportionally more non-employed fatalities (probably children and retirees) in these road user categories.

Figure 1 Estimated correction factor of non-reported casualties by road user and injury category



Source: own calculations from FSO and SSUV data
see appendix 1 for a detailed list of the used correction factors

2.2 Evolution of road accident victims

We now multiply the number of casualties reported by the FSO with the correction factor to estimate the actual number of casualties for each of the 4 road user categories and each of the 3 injury categories. If the correction factor is lower than 1 (see previous paragraph), we set the correction factor to 1 in order not to loose some fatal accidents that actually happened.

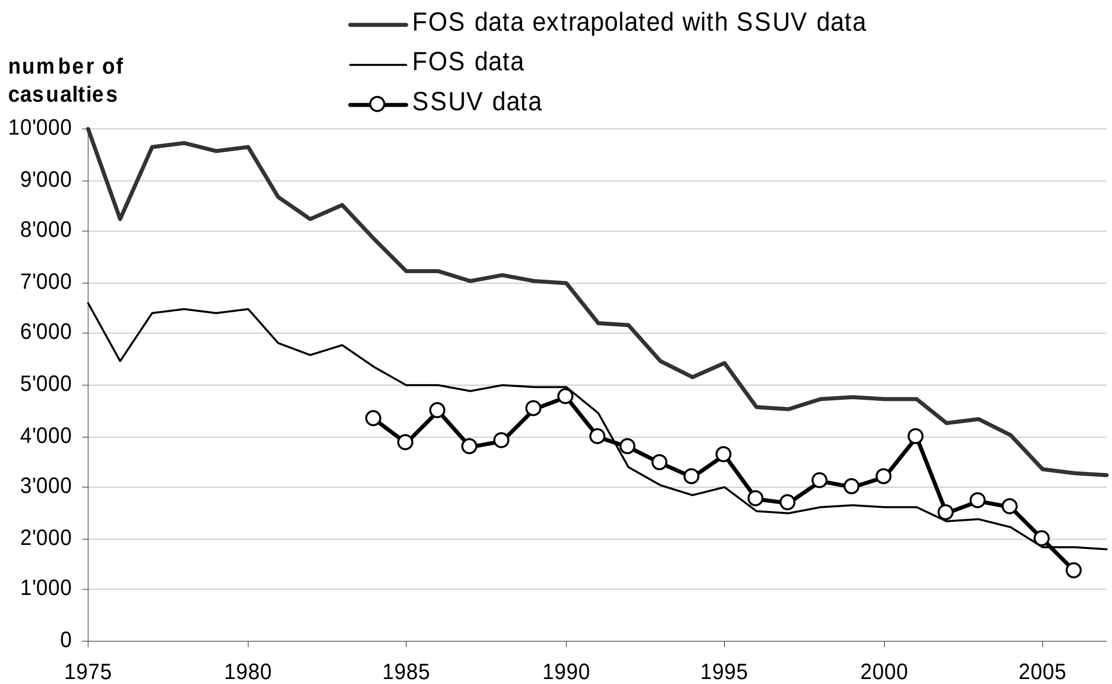
The correction factor is constant over age, gender and time and varies only by road user and injury category. One exception is the road user category *bicycle* where the factor also varies over time for the injury categories slightly and severely injured.

Figure 2 and figure 3 show the evolution of the estimated numbers of casualties for the road user category *cars and lorries*. Figure 2 shows the severely injured, figure 3 the slightly injured (see appendix 1 for figures of the other road user categories).

There is an obvious decline in the number of severely injured casualties. The FSO and the SSUV data are fairly congruent, although the SSUV data lack almost half of the population. The shift from the FSO data to the FSO data extrapolated with the SSUV data is also clearly visible. The shift equals the correction factor, which is constant for the years after 1992 and varies slightly before because of the corrected brake in the FSO data.

The number of the slightly injured car occupants casualties increase over time. This can be explained by the increase in population and by the fact that thanks to

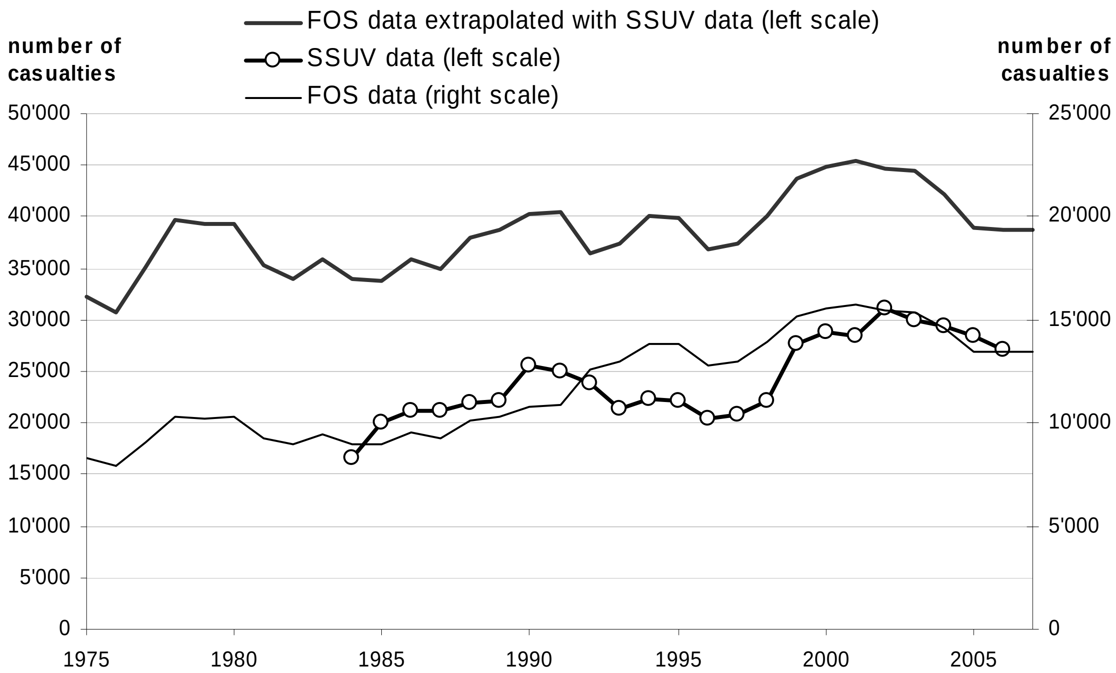
Figure 2 Evolution of severely injured car occupant casualties



Source: own calculations from FSO and SSUV data improved safety of the vehicles[9] some of those who would have been more seriously injured might now be only slightly injured. The FSO and the SSUV data are again fairly congruent, but the FSO data is based on the lower right scale reporting numbers twice as low although the SSUV data lack almost half of the whole population. The result is a much higher correction factor.

Again, the shift equals the correction factor, which is constant for the years after 1992 and varies slightly before because of the corrected brake in the FSO data. The brake between the years 1991 and 1992 is more obvious in this figure as the number of the FSO data increase while the number of the extrapolated FSO data decrease between these years.

Figure 3 Evolution of slightly injured car and lorry occupants casualties



Source: own calculations from FSO and SSUV data

2.2.1 Dividing the severely injured into subcategories

The category "severely injured" according to the FSO data covers all injuries between one day spent in hospital and permanent disability. The resulting costs differ substantially between these casualties and we divide them into 3 subcategories in order to obtain a more precise estimate of the consequences of road accidents. Based on the information in the SSUV data on the days spent in hospital and disability pensions granted we distinguish the following categories: the *moderately injured* (1-7 days spent in hospital), *severely injured* (more than 7 days spent in hospital) and permanently disabled. We assume that the proportion of road accident casualties in these 3 categories is the same between those having an accident insurance and the rest.

[9] The safety belt is an example of a safety device as it alleviates the severity of an injury but does not reduce the probability of having an accident (assuming there is no risk-compensating behaviour, i.e. the driver does not drive more recklessly when feeling safer due to the safety belt).

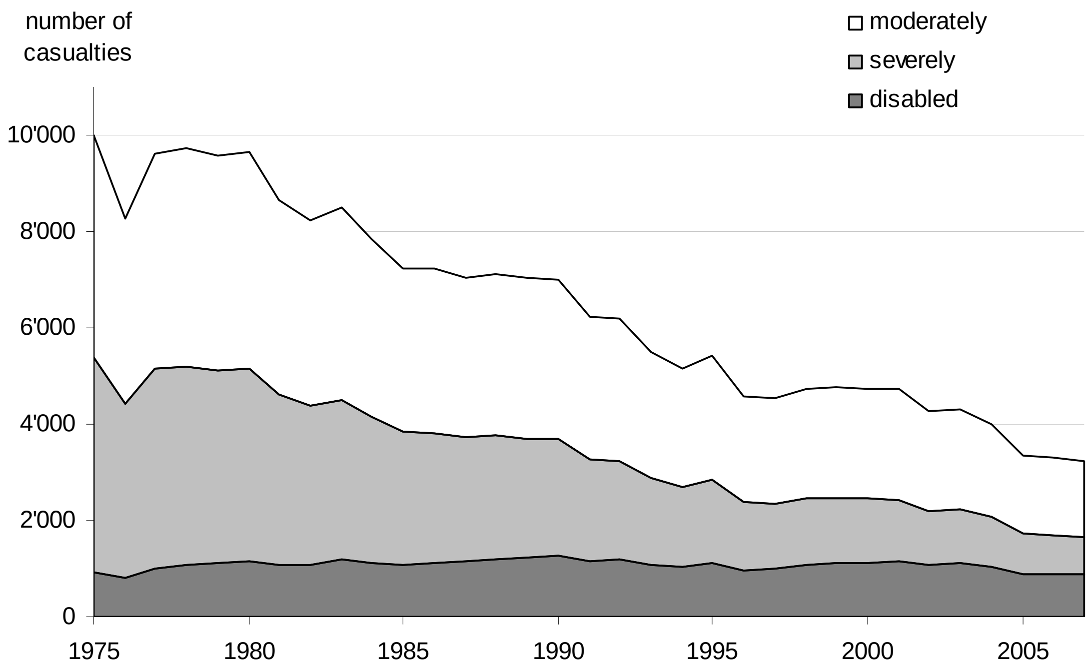
The SSUV data of these injury categories are reliable only up to the year 2002 as there may be some shifts between them in the future (e.g. a severely injured may be granted a disability pension several years after the accident). That is why we could only use the proportions of the years 1984-2002. We applied four-years-average values for the missing years.[10] Depending on the year and road user category

- about 30 to 60% of the severely injured according to the FSO definition are moderately injured according to SSUV definition and
- about 30 to 50% of the severely injured according to the FSO definition are severely injured according to SSUV definition and
- about 5 to 25% of the severely injured according to the FSO definition are permanently disabled and granted a disability pension.

Figure 4 shows how the number of severely injured according to the FSO definition is divided into the 3 categories of severity of injury in the case of car occupants (see appendix 1Appendix for figures of the other road user categories).

We now have numbers of casualties for 4 different road user categories and 5 different injury categories. We will use these 20 categories of casualties as explained variables in our estimation of the effectiveness of prevention measures.

Figure 4 Division of the severely injured FSO category into permanently disabled, severely injured and moderately injured car occupants



Source: own calculations from FSO and SSUV data

[10] Averages of the years 1984-88 were used for the years 1975-83 and averages of the years 1998-2002 for the years 2002-2006.

3 Societal costs of road accidents casualties

This section presents the societal costs of an average road accident casualty. This cost will then be multiplied by the number of accidents avoided thanks to prevention measures in order to obtain the benefit-part (i.e. avoided costs) of our cost-benefit-analysis.

The societal costs of a casualty are usually divided into three groups (WIG 2008):

- direct costs
- productivity losses (also known as indirect costs)
- intangible costs

Severity of injury is the main cost driver as medical costs, productivity losses and intangible costs all increase with the severity of the injury. The type of road user has an influence on the severity of the injury, because for example pedestrians are much more vulnerable than car occupants. The age not only affects the exposition, and thus the risk of having an accident, but also the work days lost due to premature death or permanent disability: The younger the victim, the higher the productivity loss. Men are more frequently involved in accidents than women and there is a higher probability for an avoided victim to be male.[11]

By weighting by gender and age and using average values where no information is available we calculate the cost per injury and road user category. All prices are prices in the year of the accident.

The main source of our cost data is the dataset produced for our study by the SSUV. As shown in table 1 (page 17) this dataset provides the following cost information:

- medical costs
- daily allowance paid
- reimbursed days
- average degree of disability

As the UVG (law on accident insurance) became effective only in 1984, the dataset covers the years from 1984 to 2006. However, since the data of the years after 2002 are still subject to change, we only use data up to the year 2002 and extrapolate for the years 1975 to 1983 and 2003 to 2007.

[11] Some prevention measures not only *aim* at specific groups of the population (i.e. young male drivers) but may also unintentionally *change the behaviour* only of some groups (i.e. the risk-averse or cautious). Therefore the avoided cases could differ in their characteristics because these cases belong to a group that is more or less "expensive" than average.

3.1 Direct costs

Direct costs are divided into

- medical costs
- material damage
- costs of police and consequential legal costs
- administrative costs of insurance companies

3.1.1 Medical costs

We assume that the medical costs caused by those not covered by accidents insurance but by health insurance are equal.[12] According to the UVG, insurance must cover all medical costs (e.g. treatment, transport).[13] The evolution of these costs shows a steady increase parallel to the development of the health care costs.[14] We therefore use this trend in health care costs to extrapolate the medical costs to the years which lack specific cost data.

The data on inpatient medical costs provided by the SSUV is incomplete for an analysis with a societal perspective, as it includes only the payments made by accident insurers and not the substantial subsidies to hospitals by the cantons and the payments by the additional semi-private and private hospitalisation insurance covering a sizeable part of the Swiss population.

Unfortunately it is not possible to isolate the cost of inpatient treatment from total medical costs provided by the SSUV. We use the following information to adjust for the additional costs of inpatient care:

- According to the SSUV (2005:53) inpatient costs were 33% of total medical costs in 2005. This figure refers only to individuals covered by the SUVA and not by the other accident insurers and to the sum of all accidents and occupational diseases.
- According to the health insurance data about 20% of the Swiss population has a semi-private hospitalisation insurance, while 10% has a private insurance.[15] Ecoplan (2002:37) reports that the costs of patients covered by semi-private insurance are twice as high as those of patients without additional hospitalisation insurance, while costs of patients covered by private insurance are three times as high.

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[12] A person covered by accident insurance might consume more health services than a person covered by basic health insurance since she does not have to render a co-payment. This behaviour is termed *moral hazard*. If so, the estimation of the avoided medical costs might be biased resulting in higher benefits and an overestimation of the return on investment.

[13] UVG, Articles 10-14.

[14] *Costs of the health care sector* (FSO 2009:Table 14.5.1.1)

[15] *Statistics of the social insurances* (FSIO 1998:Table B.03-A; 2005:Table KV 5.2).

- In the year 2006 the state covered 53%[16] of the sum of the cost of inpatient treatment (FSO 2008:41). We assume a constant share over time.

Combing this information we add annually 40.6% to the SSUV medical costs in order to include all medical costs borne by the society.[17]

3.1.2 Material damage

In addition road accidents leading to injuries there is a considerable number of accidents resulting only in material damage. Since these accidents are not included in the SSUV data, we were not able to estimate a correction factor for accidents resulting only in material damage. This category of accidents could therefore not be extrapolated and considered in our effectiveness analysis. It is plausible that some prevention measures (e.g. lower speed limits) have prevented several accidents which would have resulted only in material damage. By neglecting this effect and its avoided costs, the return on investment of prevention interventions will be underestimated.

Accidents leading to injuries and death of road users usually also lead to material damage. Although, the SSUV data does not include information on material damage, there are two data sources on these costs:

1. The FSO data include a rough estimate of the material damage made by the police officer at the site of the accident (see Table 1).
2. The study by Sommer et al. (2007b), based on Ecoplan (2002), which assessed the payments made by car insurance companies to cover the material damage suffered by their clients.

The difference between the two sources is substantial. The estimate of the police is much lower than the estimate by car insurance companies, and policemen thus appear to underestimate the actual amount of damage. Sommer et al. (2007b) estimated the costs of material damage *per accident* while we need the costs *per casualty* in our analysis. In order to obtain the costs per casualty we divided total costs of material damage in 2003 provided by Sommer et al. (2007b:103) by our estimated number of casualties in 2003.

However, as we will see in our effectiveness analysis (section 5), some of the prevention measures (i.e. safety-belt, motorcycle and bicycle helmet) are passive prevention measures alleviating the severity of an accident but not preventing the acci-

[16] This share covers only inpatient treatments UVG-insurances had to pay (i.e. acute and rehabilitation). It is the share of the state of the sum of the costs borne by the state and all social insurances, i.e. the remaining 47% are borne by the insurance and are thereby included in the SSUV compilation.

[17] 40.6% is the product of the following calculations: 33% of medical costs are from inpatient treatment. 10% have *private* insurance, generating 300% of the cost. Therefore, 9.9% of the costs are missing in our data. 20% have *semi-private* insurance, generating 200% of the cost. Therefore, another 13.2% of the costs are missing in our data. 53% of the inpatient treatment costs (33% of medical costs) are paid by the state. Thus another 17.5% of the costs are missing in our data. The sum of 9.9%, 13.2% and 17.5% yields 40.6%.

dent itself. In these accidents the prevented material damage may be low or even not existent.

The magnitude of the cost due to material damage associated with each of our 20 categories of casualties (4 types of road users $\times$ 5 types of casualties) is thus highly uncertain. We therefore decide *not* to consider these costs in our base CBA, but to include them in the sensitivity analysis (section 7).

3.1.3 Cost of police and consequential legal costs

Accidents generate also costs to the police and the judicial system. Police costs include labour costs, material and vehicles used by police officers while coping with an accident (e.g. traffic management, reporting, interrogating witnesses). Costs to the judicial system include costs of lawyers and courts for the legal proceedings of the accident. Thereby some costs are borne by insurances generating administrative costs.

To determine these costs, we rely on Sommer et al. (2007b:100ff.) and the Ecoplan study (2002:63-67). In the year 2003, the costs are on average CHF 7'469 per accident reported to the police. For the other years we adjust this value to the index of nominal wages as most costs are labour costs.[18] Because these costs only accrue when the accident is reported to the police, we need to lower the cost for the average (reported or not) avoided accident. Therefore, we divide these costs through the correction factor estimated in section 2, so the costs are higher, the more severe an accident is.

3.1.4 Administrative costs of insurances

When a person is injured in an accident, several insurances have to pay benefits depending on the severity of the injury. While examining the insurance claim and authorizing the payments of the benefits, administrative costs are generated.

The Swiss Federal Social Insurance Office (FSIO) reports the share of the administrative costs from the different insurances in their annual reports (FSIO, several years). Because values for some early years were not available, the values for these years are extrapolated for the missing years.

The medical costs and daily allowances are sometimes paid by the accident insurances and sometimes by the health insurances, depending on the employment status. According to the FSIO data, these two insurance categories have different administrative shares of total costs. Because the proportion of those covered by an accident insurance to those covered by a health insurance is about 1:1 (see section 2), we use the mean value of the two values, which is decreasing over time from 10% to 7.7%.

[18] *Evolution of nominal wages, consumer prices and real wages* (FSO 2009:Table 3.4.2.1.1)

3.2 Productivity losses

The society suffers a loss when a person injured in an accident is absent from work, as the person would have produced valuable goods in this time period. This productivity loss is calculated by multiplying the length of the absence (e.g. number of days) by the value of the production the person would have produced per unit of time (e.g. value of production in monetary terms per day). We make a distinction between the temporary and permanent absences.

3.2.1 Temporary absence from work

Temporary absence from work is defined as the period that lasts from the day of the accident to the day the person can return to work (convalescence period). For those suffering a permanent disability the period ends when the disability insurance starts paying the disability pension. The SSUV dataset contains the information on the number of days of daily allowances paid, which corresponds to the number of days of absence from work. The number of days of absence has increased over time for almost every injury and road user category.[19] We extrapolate this trend to the years where no data is available (1975–1983 and 2003–2007).

The actual period of disability is longer than reported by the insurers, because the insurer starts to pay daily allowances three days after the accident.[20] We therefore add three days to the reported values.

The value of the productivity loss is the value of lost production of the worker, equal to total labour costs or the gross wage including social insurance premiums by the employer. The daily wage is calculated as the yearly gross average income[21] divided by 365. While the share of some insurance premiums paid by the employer is equal for all workers (e.g. disability insurance), other premiums vary across age, employer and/or level of salary (e.g. pension “2. Säule”).[22] We thus add 10% to the reported income. Non-employed do not receive any daily allowances. Because we do not know if an avoided victim was employed or not, we multiply the product of lost working days and daily income with the gross labour-force participation rate.[23]

[19] An exception is the category *fatality*, where the number of days is decreasing. It may seem strange that a dead person receives daily allowances, but this is due to the fact that the injury category *fatality* is defined as “dead at the site or not more than 30 days later”.

[20] See UVG, article 16. These three days are known as “Karenztage” and are usually paid by the employer.

[21] *Yearly gross income of full-time workers*, available from FSO (2009:Table 3.4.3.1). Values before 1991 are calculated according to the index of nominal wages, also available from FSO (2009:Table 3.4.2.1.1).

[22] See „Schweizerische Sozialversicherung – synoptische Tabelle der anwendbaren Beitrags- und Prämiensätze” available from http://www.ahv-iv.info/andere/00134/00225/index.html?lang=de, retrieved 9.4.2009.

[23] *Gross and standardized labour participation rates* (FSO 2009:Table 3.1.2.1)).

3.2.2 Productivity losses due to premature death and permanent disability

If a person dies in an accident, the potential production lost from the moment of death to the moment in which the person would have retired represents the productivity loss to society. The potential production of a person permanently disabled by an accident will also be totally or partially lost to society, depending on the severity of the disability. This loss of production is calculated separately as we need to consider the average age of the victim when the accident happened in order to calculate how many years the victim could have been active in his or her profession.

3.2.2.1 Work days lost due to premature death

Table 2 shows the mean age of the victims at the time of a fatal accident as an average over the 33 years from 1975 to 2007. The evolution over time shows a slight increase of the mean age in every category. The mean age varies significantly by gender and by road user category. A motorcyclist victim of fatal road accident is for example usually considerably younger than a pedestrian victim.

Table 2 Average age at time of a fatal accident (1975-2007)

Means of transport	*male*	*female*
bicycles	45.65	40.91
motorcycles & mopeds	37.82	32.70
cars & lorries	38.13	41.43
pedestrians	56.36	63.23

Source: own calculations from FSO data

The difference between the age the person retires from the labour-force[24] and the age at the time of the accident yields the length of the period. Particularly in the case of pedestrians this difference is negative in several years, because the mean age is higher than the retirement age in those years. Nevertheless, there are some victims who die before reaching retirement age and thus generate productivity losses. For every road user category we thus calculate the mean age of those who were younger than the retirement age at the time of the accident and weight this mean proportionally. We also account for the possibility that the person whose accident was prevented would have died for other reasons before reaching retirement age. This probability is extracted from the mortality table published by the FSO.[25] The future years are discounted by 2%, but corrected by the productivity growth which is assumed to be 1% per year.

[24] Men can retire not earlier than at 65, women at 64, but only since 2005. Between 2001 and 2005 the minimum age was at 63 and 62 before.

[25] available on:
http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/06/blank/dos/la_mortalite_en_suisse/tabl01.html, retrieved 9.4.2009.

Assuming the average accident occurs in the middle of the year, we subtract half a year from the adjusted expected life expectancy and also subtract the time during which the victim received daily allowances. The remaining years are multiplied with the corrected gross average yearly income and the gross labour-force participation rate.

3.2.2.2 Work days lost due to permanent disability

Table 3 shows the mean age of the victims at the time they suffered permanent disability. Because the information whether a victim received a disability pension is only reported in the SSUV dataset, the years before 1984 are not available. For reasons explained in section 2 the data from years after 2002 are not reliable.

Table 3 Average age at accident resulting in permanent disability (1984–2002)

Means of transport	*male*	*female*
bicycles	46.60	43.93
motorcycles & mopeds	38.74	35.48
cars & lorries	39.41	38.68
pedestrians	46.17	46.25

Source: own calculations from SSUV data

The mean age is in general rather constant over time but there is a steady increase in the category “motorcycles and mopeds”. Since we rely on conservative estimations we set the value of the last available year (1984 and 2002, respectively) for the years before 1984 and after 2002.

In this injury category we do not encounter the problem of the mean age being bigger than the retirement age, because disability pensions are only granted if the beneficiary is younger than the retirement age.

The length of the period of productivity losses is calculated as in the case of fatal accidents. The days receiving daily allowances are again subtracted and are substantial with an average of two years. Furthermore, individuals receiving a disability pension may not fall out of the labour force completely if their degree of disability is lower than 100%.[26] We thus multiply the period with the average degree of disability, an information extracted from the SSUV dataset. The degree of disability varies over time, gender and road user category, but in the range between 40 to 50%.

3.2.3 Reoccupation costs

When a worker can not return to his job because of permanent disability or premature death, the company and the society bear costs to replace the lost worker. These costs include

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[26] It may seem too optimistic to believe that everyone suffering from a permanent disability with a degree of disability below 100% will find a job as well paid as the previous one before the accident. This assumption tends to lead to an underestimation of the benefits of prevention because productivity losses would be higher if individuals with disabilities would not be able to find such a job. This assumption is in line with our conservative approach in the estimation of potential benefits of prevention.

- search and selection costs (job announcement, finding the able person)
- on-the-job training

We refer to the Sommer et al. (2007b:79) for the valuation of these costs. Their study is based on a survey with eight companies and estimates the reoccupation costs at 50% of the yearly income of the replaced worker (Ecoplan 2002:42f.). We extrapolate these costs to the 33 year period with the evolution of the gross labour-force participation rate and income.

3.3 Intangible costs

Intangible costs of a road accident are the suffering, pain, grief and loss of happiness caused by the accident, which can be summarized as a loss of quantity and quality of life. Among the different concepts proposed to value this loss (see WIG (2008:20ff.)) we decide to apply the Disability-adjusted life years (DALY) concept. This section gives an overview of our calculation of the DALYs lost by the different categories of casualties. Further details are given in appendix 2.

DALYs are the sum of the Years of Life Lost (YLL) due to premature mortality and the Years Lost due to Disability (YLD). The avoided YLL are calculated as the product of the number of avoided fatalities and the life expectancy at age of death in years. We calculate the life expectancy the same way as we did when calculating productivity losses (see section 3.2.2.1), taking into account the possibility the individual would have died from something else if not dying in a fatal road accident and discounting by 2% per year.[27] The average remaining life expectancy again varies between year, gender and road user category, in the range of 15 to 30 years.

The YLD are the product of the number of avoided casualties, disability weights (DW) and duration of disability L. The DW is a weight factor reflecting the severity of the injury on a scale from 0 (perfect health) to 1 (equivalent to death). DW and L were estimated by experts in the Global Burden of Disease (GBD) study organized by the WHO (Murray and Lopez 1996).

Our SSUV dataset includes detailed information not only on the part of the body affected but also the type of injury (e.g. fracture, dislocation). However, the DW and L for injuries are not very detailed in the GBD study, since its focus is on diseases. We therefore looked for alternatives, but found only one study estimating additional DWs (Haagsma et al. 2008). Unfortunately, all the additional DWs could not be used, because the data from the SSUV does not separately account for those types of injuries (e.g. concussion, whiplash, polytrauma). There are some studies calculating the burden of injuries but they all refer to and use the original DWs and L (Mathers et al. 1999; Begg and Tomijima 2006; Polinder et al. 2007). All other studies estimating intangible costs of road accidents use different approaches (e.g. QALYs).

We align the SSUV data with the less detailed DWs and L from GBD study (Murray and Lopez 1996:214ff.). In case of ambiguities on which DWs and L should be ap-

[27] Productivity increases are neglected as they are not relevant for this concept.

plied, we always use the lower value. In some cases we were not able to find any DWs and/or L and therefore do not account for those injuries (e.g. burns and superficial injuries, see appendix 1 for more details). The SSUV data do not take account of multiple injuries of a victim, but only display the injury generating the highest cost. For all these reasons, we are not able to calculate the total of YLD actually lost, and our estimate of total YLD is thus a lower bound of actual YLD.

For the individuals receiving a disability pension we assume that they will be lifelong afflicted with the disability and we thus calculate L for this injury category in the same way as we did for the YLL.

We then calculate an average product of DW and L per injury and road user category. This product can then be multiplied with the number of avoided casualties, which yields the avoided YLD.

The monetary value applied to a DALY is CHF 50'400 at prices in the year 2007 based on a study by Jeanrenaud et al. (2006) and we deflate it for earlier years according to the consumer price index.

3.4 Overview of estimated societal costs

Table 4 gives an overview of the total societal costs per avoided casualty in the year 2007. The average total cost increases with a factor of 4 from the slightly injured to the moderately injured and then to the severely injured (see last row in table). Total costs of a casualty increase with a factor of 10 from the severely injured to a casualty with a disability pension and then with a factor of 2 to a fatality. The strong increase from the severely injured to the permanently disabled is explained by the much higher productivity losses and intangible costs.

Table 5 shows the DALYs and intangible costs saved due to prevention among car and lorry occupants in the year 2007. Note the low DALY values calculated for the slightly, moderately and particularly for the severely injured. A DALY of 0.0161 means the injuries caused by an accident which lead to a hospital stay of more than 7 days lead to an average loss of only 1.6% of a life year or 6 days in full health. This value appears too low and is due to the inadequate representation of accident injuries in the DALY tables.

Table 4 Average total societal costs per avoided casualty in the year 2007

		type of casualty				
		slightly injured	*moderately injured*	*severely injured*	*disability pension*	*fatality*
type of road user	motorcycles and mopeds	6'430	28'074	84'960	977'507	2'631'597
	cars and lorries	8'860	25'011	111'774	991'010	2'075'388
	bicycles	4'017	22'989	62'490	793'103	1'093'556
	pedestrians	8'822	30'621	84'659	847'359	1'465'921
	average over participants	*7'032*	*26'674*	*85'971*	*902'245*	*1'816'616*
	index of average (slightly injured =1)	*1.0*	*3.8*	*12.2*	*128.3*	*258.3*

Sources: SAI and variety of other sources; own estimations

Table 5 DALYs and intangible costs saved due to prevention among car and lorry occupants in the year 2007

	type of casualty				
	slightly injured	*moderately injured*	*severely injured*	*disability pension*	*fatality*
average DALY per car and lorry occupant casualties	0.0078	0.0175	0.0161	6.1621	23.1525
number of prevented casualties	38,615	4,314	5,011	823	689
number DALYs gained thanks to prevention	301	76	81	5,074	15,956
intangible costs saved due to prevention (million CHF)	15.2	3.8	4.1	255.7	804.2

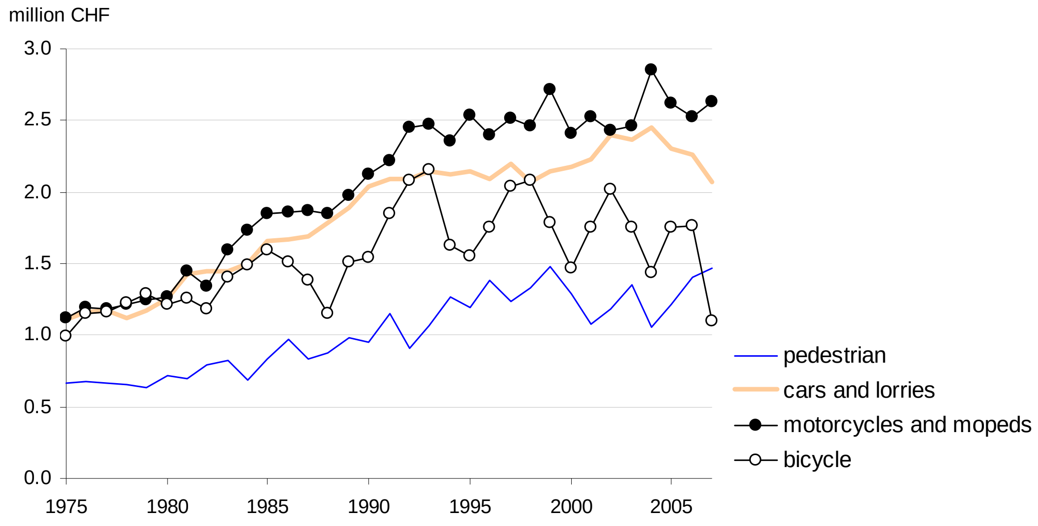
Intangible costs are calculated by multiplying the number of DALYs gained thank to prevention by a VOSL of 50,400 CHF.

Sources: SAI; own estimations

The different average age of the victims is the main reason for the variation between the road user categories.

Figure 5 shows the evolution over time of total costs of fatalities in the four categories of road users. The costs of a fatal accident of motorcyclist or moped rider are substantially higher than those of a fatal accident of a pedestrian, because the average age of motorcyclist is much lower when the accident happens. The age of the victims is also responsible for the variation of costs within a category.

Figure 5 Evolution of total costs per avoided fatality by type of road user

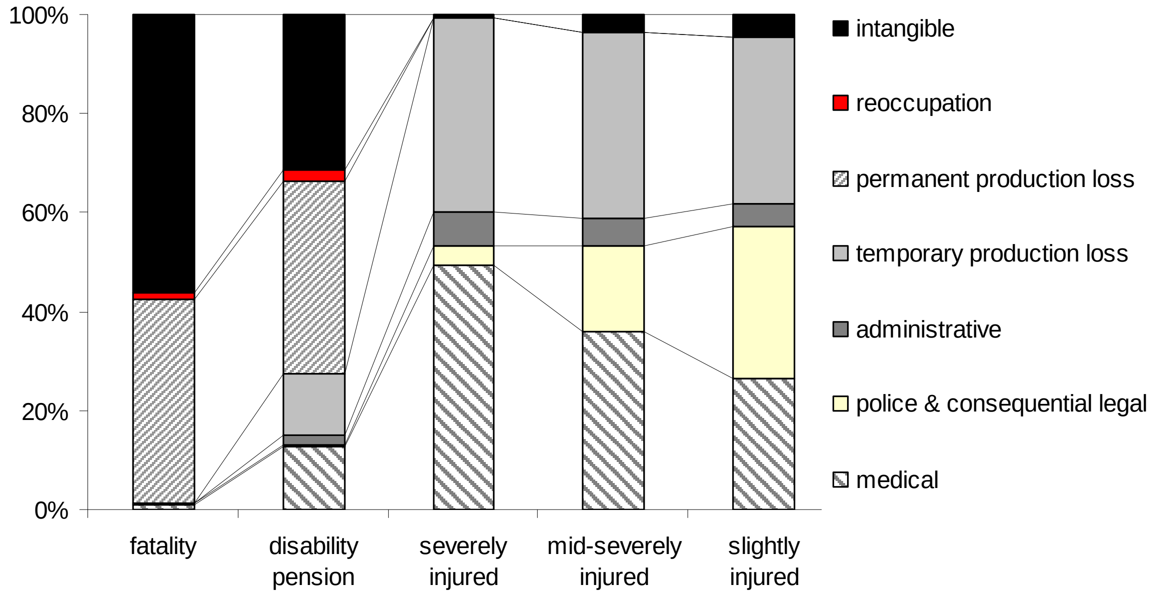


Source: own calculations from multitude of data sources (see text)

Figure 6 shows the share of the different cost categories on total costs category for cars and lorries in the year 2007. The main cost drivers in the less severe injuries categories are medical costs and temporary production loss and to some extent also police and consequential legal costs. The main cost drivers in the severe injuries categories are permanent production loss and intangible costs.

With only 0.7% of total costs, intangible costs appear to be implausibly low in the case of the severely injured. This is most probably because the DALYs proposed by the existing studies do not adequately capture these costs for severely injured casualties of road accidents.

Figure 6 Share of cost categories on total societal costs (cars and lorries, year 2007)



The figure shows the shares of the single cost categories as a graphical decomposition of the absolute values would be indistinguishable due to the huge differences between the absolute cost levels of the single types of casualties (see 3.1). The costs of fatalities and casualties leading to disability pensions are dominated by intangible costs and production losses.

Sources: SAI and variety of other sources, own estimations

4 Costs of road accident prevention

We make the following distinctions regarding the costs of road accident prevention expenditures:

1. Expenditures for a *safer environment*, as investments in safer roads and safety devices for vehicles, or for a *safer behaviour* by road users, as laws limiting traffic speed, educational programmes and information campaigns.
2. *Private* or *public* expenditures.

This section describes the prevention measures considered in our CBA of road accident prevention in Switzerland and how the costs of these measures were estimated. These costs represent the cost side in our CBA of road accident prevention measures.

Our cost estimations are partially based on the report by Basler + Partner (2001) produced for the bfu and the ASTRA as a contribution for the development of a new national road safety policy. The report estimates the total yearly expenses for road security in Switzerland in the year 2000. These costs are extrapolated to the years from 1975 to 2007 and adjusted, when we were able to obtain more detailed information on single prevention expenditures.

4.1 Public expenses

- An important part of public investments in new road infrastructure and maintenance of the existing roads is aimed at the improvement of road safety. Basler + Partner (2001) estimate these costs at 520 to 1'040 billion CHF in 1998, assuming that 5 to 10% of expenses for federal roads and 10 to 15% of the expenses for cantonal and communal roads are aimed at road safety improvement.

We extrapolate these expenditures to the years 1975 to 2007 with data on total road construction investments provided by the FSO and assume a share of 7.5% for national roads and of 15% for cantonal an communal roads. We estimate total costs of safety expenditures in road construction and maintenance at CHF 547 billion for the year 1998. This amount is near the lower bound of the values proposed by Basler + Partner because we believe that some of the costs they consider as safety expenditures are expenditures necessary to assure traffic flows and not road safety.

These total expenditures include the costs of specific interventions to improve the safety of road infrastructure as black spot programs and the construction of roundabouts as these costs represent only a fraction of the total investments in road safety. The costs for the construction of a roundabout are for example estimated at CHF 100'000 in 1998 and about 100 of them were built in 1998 (Basler + Partner AG 2001) leading to a total of 10 billion CHF. But these represent only 1.8% of total expenditures on road safety in that year.

As the part of expenses destined to road safety has clearly increased since 1975 with the growing public awareness for road safety, we assume that the share of expenses in 1975 was 50% below the level of 2007.[28]

- The costs for the public administrative at the introduction of new road traffic regulations are estimated at CHF 250'000 per measure in the year 2000 by Basler + Partner (2001). We calculate the number of new measures introduced between 1975 and 2007 from the appendix of the Sinus Report 2008 (bfu 2008) and deflated the costs with the consumer price index.
- The police play a crucial role in enforcement of road safety regulation and traffic education. The number of police officers engaged full time in road safety promotion is estimated at 10 to 15% of the regular police staff in 2007.[29] We have obtained information on the number of police officers between 1979 and 2007 from the Swiss Federal Office of Police and extrapolated the data for the missing years from 1975 to 1978. We follow Basler + Partner (2001) regarding the costs of a full time police officer (CHF 70'000 in 1999) and multiply by 2 in order to include the full cost of equipment and infrastructure. Costs are extrapolated according to the wage index of the FSO.
- Road safety programmes aiming at a change in behaviour through education are particularly difficult to measure not only because of the multitude of public organizations carrying out programmes but also because many of the programmes of private organizations are partially financed through public funds. The two main organizations financing road safety in Switzerland are the Fund for Road Safety (FRS) and the bfu.[30] We were able to obtain detailed information on the expenditures of the FRS from 1978 to 2007 and use this information to model expenditures on road safety programmes over the whole period of 33 years. Total programme expenditures are estimated at 2.56 times the expenditures of the FRS as many other public and private organizations (e.g. cantons, traffic associations) finance road accident prevention measures. This estimation is in line with the value of CHF 46 million proposed by Basler + Partner (2001) for 1999.

4.2 Private expenses

- Security devices on cars and commercial vehicles are in part voluntary and in part due to regulation on minimal security standards. The number and quality of these devices have greatly increased since 1975 when most cars were

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[28] In an informal conversation with experts of the Swiss Federal Roads Office this estimate was considered as reasonable.

[29] Personal information from police officers of the canton of Geneva and the canton of Zurich.

[30] The FVS (Fonds für Verkehrssicherheit) is financed by a duty on car insurance policies. The bfu (Beratungsstelle für Unfallverhütung) is financed by a duty on motor vehicle insurance policies and spends approximately 45% of its budget on road safety. The bfu also receives substantial financing from the FVS.

barely equipped with simple safety-belts on the front seats. Most new cars are currently equipped with safety-belts with automatic tension mechanism, air-bags, crash zone, structural reinforcements and ABS. Following Basler + Partner (2001) we estimate the cost of the safety devices at CHF 1'250 for a new car and CHF 10'053 for a commercial vehicle in the year 2000. We further assume that the cost in real terms of these devices was only a third in 1975 and that it has since increased in a linear way.[31] Costs of security devices are extrapolated to the whole study period with the FSO data on new vehicle registrations and deflated with the consumer price index.

- The cost of compulsory vehicle safety inspections is calculated according to the approach of Basler + Partner (2001): on average a third of the total number of privately owned vehicles is inspected in a given year and the price of an inspection is estimated at CHF 65 in the year 2000. We use the FSO vehicle stock data[32] and the consumer price index to extrapolate these costs to the whole study period.

The same approach is followed for commercial vehicles which undergo a yearly safety inspection, assuming a price of an inspection of CHF 224 for a lorry and of CHF 110 for a bus.

- The cost of compulsory medical check-ups for elder drivers is also estimated according to the approach of Basler + Partner (2001). We assume that a third of the people above the age of 70 drive a car regularly, that these elderly drivers undergo a medical check-up every second year and that the cost of a check-up was CHF 50 in the year 2000. Costs are extrapolated to the whole study period with the FSO population data and the consumer price index.
- The cost of motorcycle helmets is estimated adapting the approach proposed in Basler + Partner (2001): We assume that 25% of motorcycle drivers buy a new helmet a year and that the average price of a helmet was at CHF 400 in the year 2000. We calculate the number of motorcycle drivers owning a helmet according to the helmet wearing rate calculated by the FSO road accidents statistic before compulsory helmet wearing was introduced in 1981 and at 100% of motorcycle owners thereafter. Following Basler + Partner we also assume that 10% of motorcycle drivers buy a new protective outfit in a given year and that the average price of an outfit was at CHF 1'000 in the year 2000. Costs are extrapolated to the whole study period with the FSO data on motorcycle stock and deflated with the consumer price index.

The expenditures for moped helmets are calculated with the same methodology assuming an average price of CHF 150 in the year 2000.

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[31] We discussed this assumption with experts from the AXA Winterthur Road accident research centre, and they considered it as rather optimistic as the level of security devices on a standard car of 1975 was probably even lower than a third of the level of the year 2000.

[32] *Road vehicle stock per vehicle group* available from FSO (2009:Table 11.2.1).

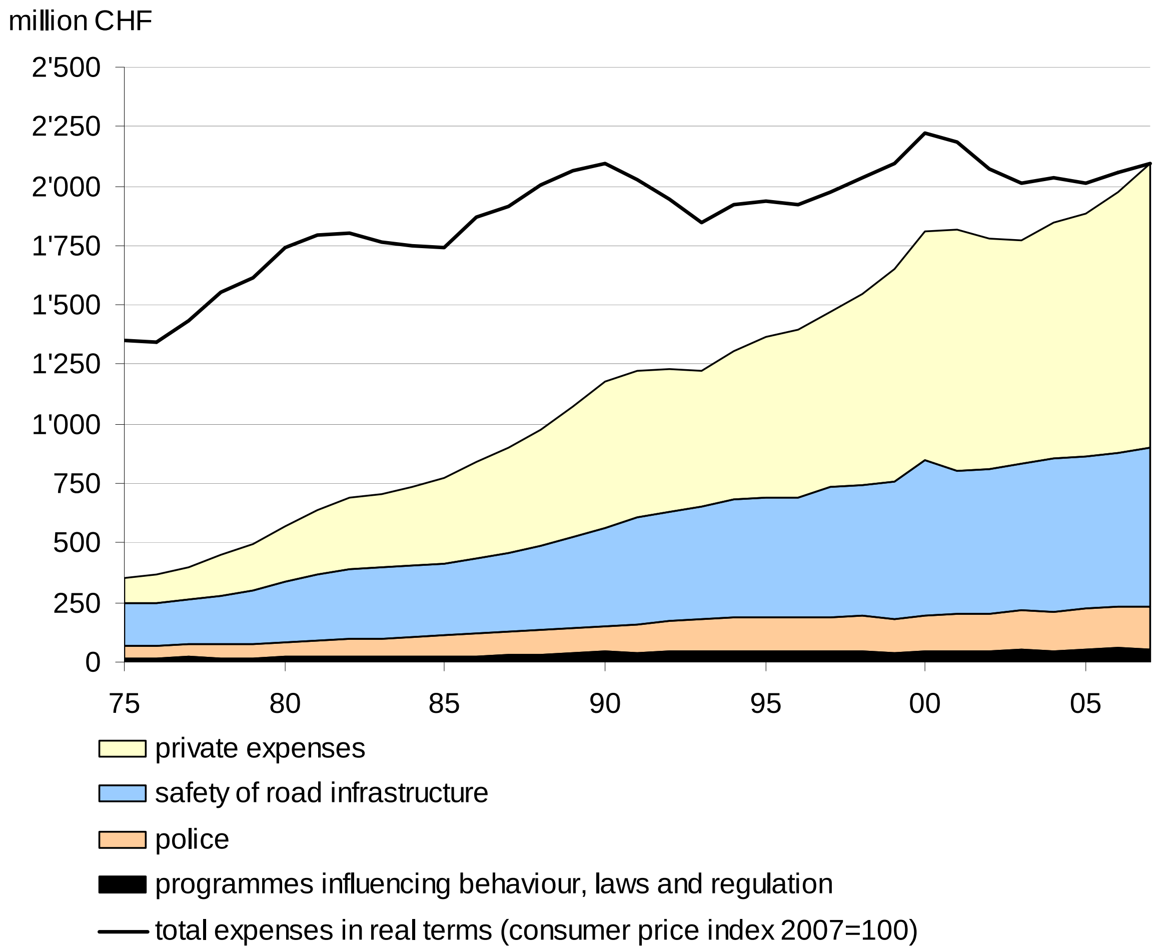
- The expenses for bicycle helmets are estimated under the assumptions that 10% of the population regularly uses a bicycle, that a third of the cyclists wearing a helmet buys a new helmet in a given year and that the average price of a helmet was CHF 100 in the year 2000. The number of cyclists owning a helmet is estimated according to the bicycle wearing helmet quota observed by the bfu.[33] Costs are extrapolated according to the FSO data on total population and deflated with the consumer price index.

4.3 Composition and evolution of prevention expenditures

An overview of the evolution and broad composition of road accident prevention expenditures is given in

figure 7 for the period 1975 to 2007 and table 6 gives a detailed picture of the expenditures in 2007.

Figure 7 Evolution of road safety expenditures from 1975 to 2007



Source: own calculations from multitude of data sources (see text)

[33] bfu, Erhebung der Helmtragquote von Velofahrenden.

We can emphasize the following aspects:

- Private expenses constitute the main share of prevention expenditures with 56.9% of total expenses in 2007. Security devices on new cars and commercial vehicles amount to 40.2% of total expenses.
- Public expenses are dominated by investments in the safety of the road infrastructure with 32.2% of total expenses in 2007. The police forces make considerable efforts for road security with 8.3% of total expenses. The expenses for measures aiming at changes in behaviour and new laws and regulation are relatively modest with only 2.6% of total expenditures.
- Expenses have increased by 214% in nominal terms and 55% in real terms from 1975 to 2007. The increase in real terms was by 59% for programmes influencing behaviour, laws and regulation have increased, by 89% for the police efforts, by 102% for investment in the safety of road infrastructure and 478% for the private expenses.

Table 6 Total expenses in road safety in 2007

	expenses 2007	**percent of total expenses**
total expenses	**2'094'694'059**	**100.0**
measures aiming at changes in behaviour	53'308'549	**2.5**
new laws and regulation	2'139'259	**0.1**
police	174'386'545	**8.3**
road infrastructure	673’500’600	**32.2**
total public expenses	***903'334'953***	**43.1**
security devices cars	450'554'853	**21.5**
security devices commercial vehicles	391'636'365	**18.7**
safety inspections cars	108'167'990	**5.2**
safety inspections commercial vehicles	83'316'796	**4.0**
medical check-ups	8'168'197	**0.4**
motorcycle helmet	66'227'825	**3.2**
motorcycle outfit	66'227'825	**3.2**
moped helmet	6'873'984	**0.3**
bicycle helmet	10'185'271	**0.5**
total private expenses	***1'191'359'106***	**56.9**

Source: own calculations from multitude of data sources (see text)

5 Effectiveness of road accident prevention measures

What was the contribution of public road accident prevention measures taken in Switzerland from 1975 to 2007 on the decline of road traffic victims that took place over this period? This section describes the model and the variables we employed to answer this question and reports the results of our estimation.

The causal path leading to road accidents is highly complex because of the multitude of environmental, technical and behavioural factors leading to an accident, the interaction among these factors and the intrinsic randomness of accidents. However, there is a broad consensus among researchers that behaviour is the decisive factor for the event of a road accident and that excessive speed, alcohol and substance abuse are among the most causal factors (Rumar 1985; Evans 1991; Shinar 2007). An example for the complexity is that safer cars reduce the probability of having an accident and the severity of the injuries for the occupants of the safer car, but may lead to more casualties among other road users, because safer cars usually have higher weight and thus more kinetic energy in an impact with an other vehicle or a pedestrian. Furthermore, safer cars may induce drivers to a riskier driving style (Peltzman 1975).

Human behaviour cannot be dictated by public authorities. New laws aimed at an improvement of road safety are not automatically observed by all road users, as numerous drivers exceed speed limits, do not use the compulsory safety-belt or drive with blood alcohol above the permitted limits. On the other hand, many drivers have a high interest in safety and are ready to spend considerable amounts for the security of their vehicle. People also change their behaviour even if there are no efforts by the government to change their behaviour. The general trend for a healthier and more environment-friendly lifestyle in Switzerland might for example have contributed to a saver driving style by part of the population.

It's unfortunately unfeasible to model the whole complexity of the processes leading to road accidents and how prevention measures might influence them, because we dispose only of very limited data on changes of human behaviour and environmental and technical changes. We are nonetheless able to build a model which considers the changes of some decisive variables and to identify the effects of some of the prevention measures.

5.1 Description of explained variable

As described in section 2 we calculated the number of traffic victims for 4 vehicle categories (car & lorry, motorcycle & moped, bicycle, pedestrian) and 5 injury categories (dead, permanently disabled, severely injured, moderately injured, slightly injured). These numbers are then divided by the number of residents of the canton (or group of cantons) and multiplied by 100'000 thus obtaining the number of victims per 100'000 residents in a canton.

One might object that it does not make much sense to estimate the effectiveness of road accident prevention measures on cantonal data in a country as small as Switzerland, as people exposed to prevention measures in their home canton might have an accident in another canton. We believe the following arguments justify the estimation on a cantonal basis:

- The distinction between cantons is useful as there are important differences between them in behaviour (e.g. level of alcohol abuse, use of safety-belts, and use of public transport), prevention activity (e.g. intensity of police controls) and geography (type of roads, urbanity).
- Merging all cantons with less than 100'000 residents with closely integrated smaller and bigger cantons we reduce the number of cantons from 28 to 18. This increases the probability that a person involved in an accident in a determinate canton is also a resident in that canton.[34]
- The distinction between cantons allows a more precise estimate of effects because of the considerably higher number of observations (18 instead of 1 observation per year).

By choosing the number of victims per 100'000 residents as explained variable we also standardize for the 19.1% increase of the Swiss population between 1975 and 2007. Other studies as Abelson et al. (2003) take the fatalities per number of vehicles or the number of kilometres travelled (Loeb 1987; Fowles and Loeb 1992) as explained variable. We do not choose these approaches because the intensity of vehicle use has significantly changed over the study period and because the data on kilometres travelled is fragmentary and not available for the whole observation period. The number of vehicles will be used as an explanatory variable in our estimation.

5.2 Description of explanatory variables

The explanatory variables used in the estimation model are variables describing observed safety behaviour, variables representing road safety prevention measures and variables indicating confounding factors. Variables representing safety behaviour by road users are of particular importance in our analysis: They may represent explanatory variables as well as explained variables as they often represent an intermediate outcome of policies aiming at a reduction of road accident casualties. The variables representing confounding factors (e.g. the number of licensed vehicles) are included in the model because they may have an influence on the evolution of road accidents which is correlated with the influence of the variable representing behaviour and prevention measures. We explain the way the variables were constructed, the data source and the expected sign of the coefficient of the variable. The most interesting explanatory variables are illustrated in greater detail.

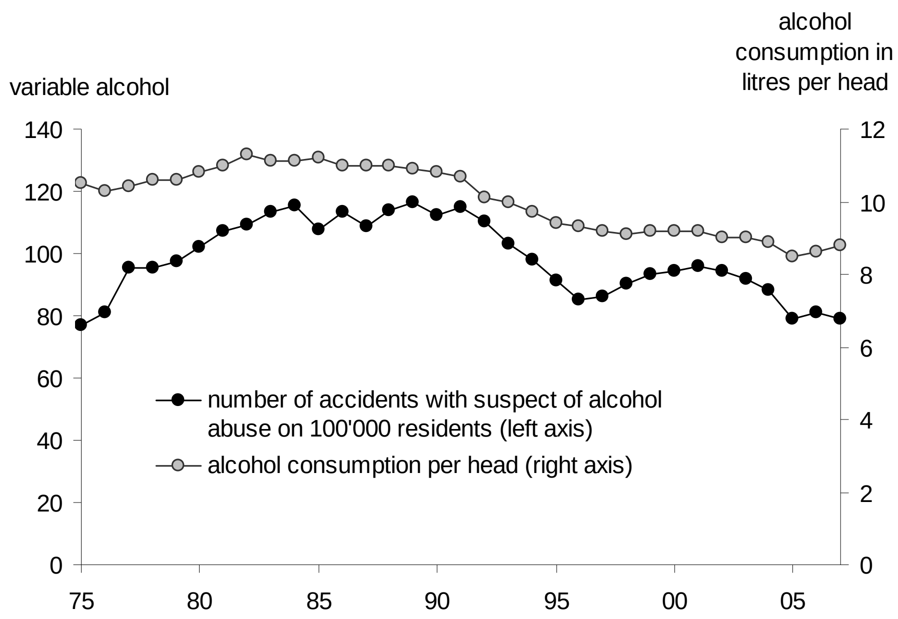
[34] We merge the following cantons: Uri, Obwalden and Nidwalden (UR_OW_NW), Schwyz and Zug (SZ_ZG), Glarus and Graubünden (GL_GR), St. Gallen, Appenzell A. Rh. and Appenzell I. Rh. (SG_AI_AR), Schaffhausen and Thurgau (SH_TG), Neuchâtel and Jura (NE_JU).

5.2.1 Excessive alcohol consumption

Excessive blood alcohol levels are one of the main risk factors leading to road accidents. The police reports of road accidents, on which the FSO road accident data is based, contain the information on whether the police officer suspects that excessive alcohol consumption was part of the factors leading to the accident. We sum these cases for all the accidents in a single canton and calculate the number of cases for 100'000 residents. We thus obtain the variable *alcohol driver* which represents an approximate description of the evolution of alcohol consumptions of drivers on a cantonal level over the whole study period.

The variable *alcohol driver* increased from 1975 to the mid 1980s, a development which is supported by the general increase of alcohol consumption per head in this period.[35] The variable decreases markedly between 1991 and 1998, has a temporal increase until the year 2001 and a strong a decrease in 2005. An analysis at cantonal level reveals substantial differences with particularly high level in most of the French speaking cantons. We expect a positive sign for the coefficient of the variable *alcohol driver*.

Figure 8 Evolution of variable *alcohol driver* (cantonal average)



Sources: Swiss Alcohol Board, FSO, own calculation

5.2.2 Safety-belt wearing rate

Safety belts are a compulsory feature on new cars registered in Switzerland since 1971 but usage remained quite limited until compulsory safety-belt wearing on front seats was first temporarily introduced from January 1976 to May 1977 and then permanently re-enacted in July 1981. This temporary introduction represents a natural

[35] Data on alcohol consumption were provided by Swiss Alcohol Board.(Eidgenössische Alkoholverwaltung 2009)

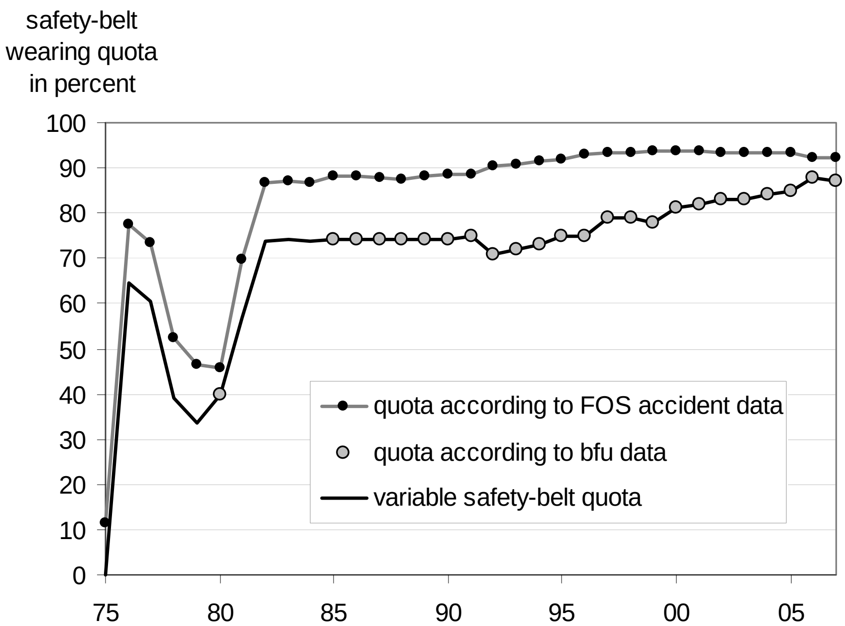
experiment, as we can observe the immediate effect of this measure on the number of traffic victims and the severity of injuries. As a substantial number of drivers did not comply with the law we have to look at the actual safety-belt wearing rate to estimate the effect of safety-belts on the number and severity of road accident casualties.

There are two data sources measuring the safety-belt wearing rate in Switzerland:

- The safety-belt wearing rate survey carried out by the bfu for the first time in 1980 and then every year from 1985 on measures by direct observation of car occupants. This information is available for each of the three language regions in Switzerland.
- The FSO road accident data, based on the police reports of road accidents, contains the information on whether the occupants of the vehicle were using the safety devices (safety-belt or helmet) when the accident occurred. We use this information to calculate the share of individuals making use of a safety device on the total number of individuals involved in accidents in a determinate language region and year.

A comparison of the two data sources over time in the German speaking region shows that the quota derived from the FSO data is always higher than the bfu data.

Figure 9 Construction of variable safety-belt quota (German speaking region)



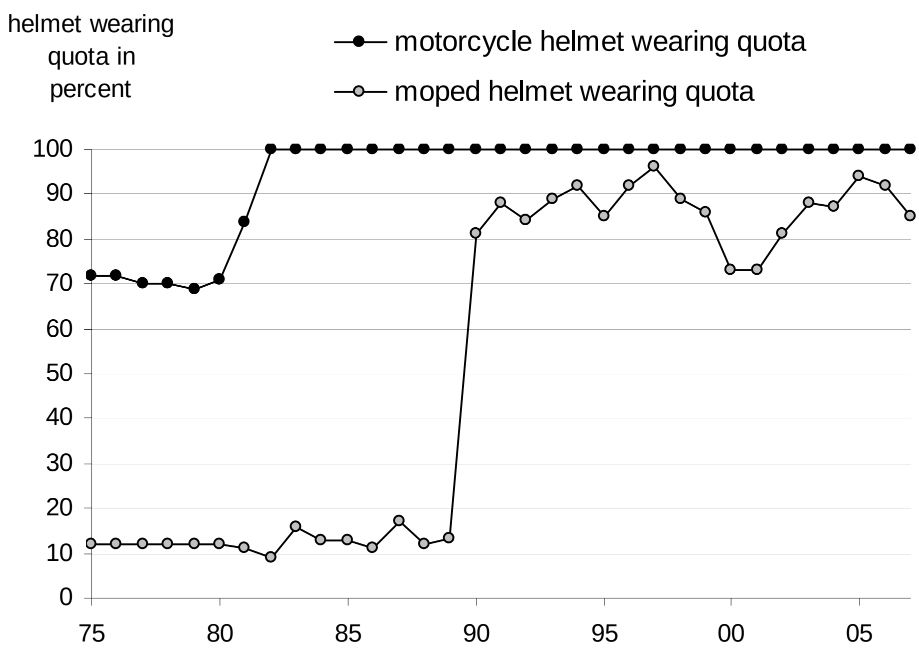
Sources: bfu, FSO, own calculation

We choose the bfu data as a reference for our estimation because it is based on actual observation of behaviour. For the years between 1975 and 1984, in which no bfu data is available, we impute the missing values by subtracting the average difference between the FSO and the bfu quota from the FSO quota. This variable *safety-belt quota* will be used in the model estimations and differs markedly between the language regions with substantially lower levels in the French and Italian speaking parts of the country. We expect a negative sign for the coefficient of the variable *safety-belt quota*.

5.2.3 Motorcycle and moped helmet wearing rate

Compulsory helmet wearing was introduced in 1981 for motorcyclists and in 1990 for moped riders and the actual helmet wearing rate reached 100% soon after the regulation was introduced, as shown by the FSO data. The helmet wearing rate before the introduction of regulation is calculated with the FSO road accident data, based on the police reports of single road accidents, which contains the information on whether the riders were using a helmet when the accident occurred. Figure 10 shows the evolution of the variable *motorcycle-helmet* and *moped-helmet* over time. We expect a negative sign for the coefficients of the *helmet* variables.

Figure 10 Evolution of variable motorcycle-helmet and moped-helmet

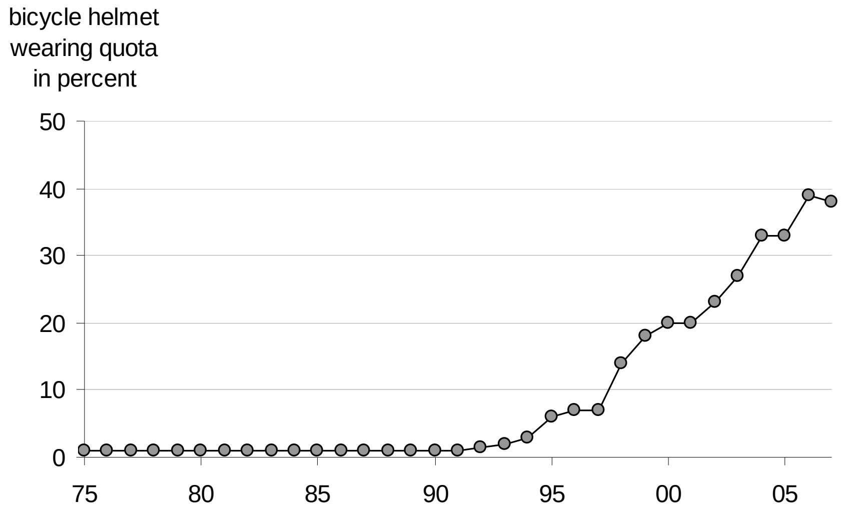


Sources: bfu, FSO, own calculation

5.2.4 Bicycle helmet wearing rate

Bicycle helmet wearing is not compulsory in Switzerland but there have been substantial efforts to increase the use of bicycle helmets through information campaigns carried out in collaboration between the bfu and SUVA. Since 1992 the bfu carries out a yearly bicycle helmet wearing survey by actual observation of the number of cyclists wearing a helmet. We assume that the helmet wearing rate was at 1% before 1992 and create the variable *bicycle-helmet* shown in figure 11. A negative sign of the coefficient is expected.

Figure 11 Evolution of variable bicycle-helmet



Source: bfu

5.2.5 Time trend

The *time trend* variable represents the general decrease or increase of the explained variable owing to factors not represented by other explanatory variables contained in the model. A glance at the series of figures depicting the evolution of the numbers of traffic victims show a sharp decline over time (see section 2 and appendix 1), and the trend variable will thus play a major role.

The following factors may be represented by the time trend:

- Improved security of vehicle safety and improved security of road infrastructure which cannot be represented by specific variables.[36] As illustrated in section 4.3 these represent about 82% of total road accident prevention expenditures in 2007.
- Changes in driving behaviour which are not captured by the explanatory variables representing behaviour changes (e.g. safety-belt wearing rate) but stem from a general change in lifestyle like an increased use of public transport.
- A continuous increase in prevention efforts which is not adequately captured by the explanatory variables contained in the model (e.g. extension radar speed controls).

The report by Abelson et al. (2003) which is one of the main references for our study focuses on the time trend for the explanation of the effects of prevention efforts on the reduction of road accident victims in Australia. The trend is decomposed by ascribing a fraction of it to a determinate preventive factor, e.g. 10% of the trend is ascribed to public road accident prevention programmes.

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[36] We list some of the measures: introduction of airbags in several positions, deformable zones, anti-lock braking system, electronic stability program, lighting of both cars and roads, traffic calmed areas (speed limit 30km/h), more visible pedestrian crossings including islands between lanes, pedestrian under- or overpass, bicycle lane and separate bicycle path.

5.2.6 Number of Vehicles

If more people own a vehicle, more people will be exposed to the probability of having a road accident. The number of vehicles in circulation per 100'000 residents may be seen as a proxy of the exposure to the risk of a road accident. The evolution of the number of vehicles per resident differs among regions, as the number of cars per resident increased only slightly in city cantons as Basel and Geneva since the beginning of the 1980s while it continued to increase in other cantons. We calculate the *number of cars, motorcycles, mopeds and bicycles per 100'000 residents* and expect a positive sign for the effect on the number of traffic victims.[37]

5.2.7 Region

Differences in the road infrastructure, the degree of urbanization and the number of certain professionals (e.g. physicians, police officers) between the cantons may be responsible for differences of victims per 100'000 residents. We construct the following explanatory variables representing these differences

- The variable *urban* represents the fraction of the residents of a canton living in municipalities with more than 29'000 residents.[38] Although a municipality is statistically considered to be a city when its population reaches at least 10'000[39], we assume that the following characteristics only appear in bigger cities: Residents in those urban areas are more likely to have a different commuting behaviour than residents in rural areas, as they are more likely to use public transport in their daily mobility. Furthermore, the traffic speed is considerably lower in urban areas which should lead to less and less severe accidents per resident. We thus expect a negative sign for the coefficient of the effect on the number of traffic victims.
- The variable *mountain* represents the fraction of the unproductive surface (without considering lakes) of a canton on the total surface of the canton.[40] Residents in rural areas are more likely to travel longer distances for the daily mobility and are thus more exposed to the risk of an accident. We thus expect a positive sign for the coefficient of the effect on the number or traffic victims.
- The higher *number of police officers per 100'000 residents* might lead to more intense traffic controls and thus a reduction of traffic victims.[41] A negative sign of the coefficient is expected.

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[37] *Road vehicle stock per vehicle group* available from FSO (2009:Table 11.2.1).

[38] *Balance of permanent resident population per county and municipality* available from FSO (2009: Table 1.2.2.1.15), year of reference: 2005.

[39] See http://www.bfs.admin.ch/bfs/portal/de/index/infothek/definitionen.html, retrieved 17.4.2009.

[40] *Land utilisation per 12 and 15 different type of use*, available from FSO (2009: Table 2.2.2.2), year of reference varies between cantons in the years 1990-1997.

[41] Numbers of police officers were provided by Swiss Federal Office of Police.

5.2.8 Population

Certain categories of fatalities are concentrated in determinate age groups. The group aged between 18 and 24 years is for example highly affected by car and motorcycle accidents, while children and the elderly are especially vulnerable as pedestrians and bicyclists. Demographic changes leading to an increase of the population share of elderly and a decrease of the population share of the younger generation might thus lead to changes in the frequency of certain accidents. We expect a decrease of car and motorcycle casualties as the share of the population between the age of 18 and 24 years decreases, a decrease of pedestrian and bicycle casualties as the population share of the under 18 decreases and an increase of pedestrian casualties as the share of the over 70 increase.[42]

5.2.9 Economy

The business cycle might influence the frequency of road accidents as people are more likely to be on the road for work or leisure activities in an expanding economy than in a recession (Scuffham 2003). The variable *GDP* represents the year on year change of real gross domestic product and the expected sign of the coefficient is positive.[43]

5.2.10 Prevention Measures

We construct a series of variables representing the introduction of new traffic laws and regulations and public information campaigns aiming at safer behaviour by road users. These variables usually assume a value of 0 in the year in which the law has not yet been introduced or the campaign not carried out and the value of 1 in the years in which the law is active or the campaign carried out.[44] We also build indexes representing the increasing number of regulations since 1975 by adding 1 to the index sum when a new measure is introduced.

We distinguish between measures that should lead to a decrease of casualties in all categories of road users (cars & lorries, motorcycles & mopeds, bicycles and pedestrians) e.g. law reducing speed limits, from those which should lead to a decrease of casualties in only one category of road users e.g. the law on compulsory safety-belt use in the front seats of cars. We expect a negative sign of the coefficient of all these variables representing efforts to reduce traffic casualties.

[42] From 1975 to 2007 the population shares of these groups changed from 26.1 to 18.2% for the under 18, from 10.1 to 8.2% for the group between 18 and 24 and from 7.7 to 11.3% for the over 70 of age (see FSO (2009: Table 1.2.1.2.22)).

[43] Source of GDP data: seco, FSO national accounts.

[44] In the year a new regulation was introduced the variable assumes a value of 1 if it was introduced on the 1st of January and a value of 0.5 if it was introduced on the 1st of July.

5.2.11 New laws and regulations

New laws and regulations concerning road safety of are represented with the following variables:

- The variable *law speed* represents the progressive introduction of lower speed limits. The maximum speed limit of 130 kph on highways was introduced provisionally between 1974 and 1976 as a road safety measure. Subsequently from 1977 onwards, this law was permanently enacted together with a maximum speed limit of 100 kph on rural roads. In 1984 the maximum speed limit on urban roads was reduced to 50 kph as a road safety measure. At the same time the maximum speed limit of 120 kph on highways and 80 kph on rural roads was temporarily introduced as a measure against acid rains (forest dieback) (bfu 2008).
- The introduction of a maximum blood alcohol level of 0.5 per mill for all vehicle drivers, and the possibility for police to test drivers' blood alcohol levels with no prior indication of alcohol abuse was introduced in 2005. Existing sanctions were also reinforced, including the increased likelihood of driver's loss of licence. These combined measures are represented by the variable *measures 2005* which takes a value of 1 in the years from 2005 to 2007 and a value of 0 for the remaining years.
- We build an index representing laws and regulations (excluding the measures considered in *law speed* and *measures 2005*) which should lead to a reduced risk for all road users (variable *law all*).
- The law introducing compulsory safety-belt wearing on front seats from January 1976 to October 1977 and then June 1981 is represented by the variable *law safety-belt*.
- The variable *laws car* is an index for the increasing number of laws and regulations which should reduce the severity of the consequences of an accident for the occupants of a car (e.g. compulsory equipment with safety glass, compulsory safety-belts on back seats, compulsory head rests on front seats of cars, children secured on all car seats).
- The laws introducing compulsory helmet wearing for motorcyclists in 1981 and for moped riders in 1990 (variables *law helmet motorcycle*, *law helmet moped*)
- The law increasing the rights of precedence of pedestrians at crosswalks was introduced in June 1996 (variable *law pedestrian*).

5.2.12 Information campaigns

Information campaigns concerning road safety are represented with the following variables:

- Information campaigns which should lead to a decrease of casualties in all road user categories (e.g. for young drivers, for the use of daytime lights and on the introduction of the 0.5 per mill blood alcohol level) are represented by the index variable *campaigns all*.

- Information campaigns for the use of the safety-belts are represented by the variable *campaign safety-belt*.
- Information campaigns for the use of the bicycle helmets are represented by the variable *campaign bicycle helmet*.
- Information campaigns which should lead to a decrease of casualties among pedestrians (e.g. campaigns for the visibility of pedestrians by night) are represented by the variable *campaign pedestrian*.

5.3 Estimation of effectiveness of road accident prevention

We estimate the effect of road safety programmes on the number of casualties in each of the 4 road user categories with a log-level model. The explained variable is thus the logarithm of the number of victims (e.g. the number of severely injured car occupants) per 100'000 residents in a canton and a given year. The explanatory variables are the untransformed level variables described in the previous sections.[45]

The model takes account of possible interdependencies between the severity of the casualty categories of a single road user category. A decrease of the disabled casualties among car occupants due to an increased use of safety-belts may for example result in an increase of the less severe injuries among car occupants, as the road accident in itself is not prevented, but the injuries are less severe. In order to take account of these interdependencies we estimate a seemingly unrelated regression (SUR) system for each of the 4 road user categories, thus obtaining a more precise estimation of the prevention effects than with an isolated OLS estimation of the 20 models.

This estimation approach, which is an extension to the one used by Abelson et. al (2003), has the following advantages:

- The coefficients of the explanatory variables multiplied with the change of the explanatory variable can be interpreted as percentage changes of the explained variable. The model thus takes account of the fact, that it is easier to reduce the number of casualties when the number of casualties is high (e.g. the 579 fatalities of car occupants in 1975), but that it is increasingly challenging to further reduce this number once great efforts to reduce this number have already been realized (e.g. when the number of fatalities of car occupants has been reduced to 191 in 2007).
- The logarithmic transformation of the explained variable reduces heteroskedasticity thus increasing the precision of the estimate of the coefficients of the explanatory variables.[46]

For each of the 4 models (1 road user categories $\times$ 5 severity categories) we dispose of 594 $\times$ 5 observations[47] (18 cantons or groups of cantons over a period of 33 years $\times$ 5 severity categories) and carry out the following estimation procedure: We start with a model containing all explanatory variables which, in theory, may contribute to the explanation of the evolution of type of casualty over time and of the differences between cantons. All variables with a level of statistical significance below 5% are dropped from the model.

[45] Estimation was carried out with STATA/SE 9.2.

[46] In statistics, a sequence of random variables is heteroskedastic if the random variables have different variances. A reduction of heteroskedasticity improves the precision of the estimation.

[47] In several cases, in which some cantons did not register a determinate type of casualty in a given year, we dispose of less than 594 observations as zero values are dropped in a logarithmic transformation.

When we dispose of complementary variables representing a law prescribing certain safety behaviour and the observation of the safety behaviour (e.g. the variable for the introduction of compulsory safety-belt use and the variable for the observed safety-belt wearing rate) we start the estimation procedure with the variable representing behaviour.

The following sections report the results of the 4 model estimations. Each result features the statistically significant explanatory variable(s) and a graph showing the effects of the influence of the time trend, the prevention measure variables and the behaviour variables on the evolution of the casualty explained over period from 1975 to 2007. Estimations of all the variables representing prevention efforts are highly statistically significant with p-values below 0.01. Details of the estimation results can be found in appendix 3.

5.3.1 Results car and lorry occupants

Fatalities of car occupants decrease by

- 1.7% with a year to year time trend,
- 8.0% as the safety-belt wearing rate increases by 10.0%,
- 8.2% as the number of drivers with alcohol abuse per 100'000 residents decreases by 100,
- 22.6% with the introduction of the 2005 prevention measures,

and are further explained by the increased number of cars and regional characteristics (lower in urban and higher in mountain areas).

Figure 12 shows the effect of prevention measures and the time trend on the total number of fatalities in Switzerland. Note that the estimated number of fatalities would have increased without prevention and without the time trend from 579 fatalities in 1975 to 880 fatalities in 2007. This increase would have resulted from the growth of both the population and the number of cars in circulation, and the fact that there were particularly few accidents in 1975 because of a deep recession. The heights of the horizontal bands in a given year correspond to the estimated number of fatalities avoided due to the prevention measures and the time trend in that year. The sum of these avoided fatalities is the total number of fatalities prevented by that measure in the observation period.

The effect of increased safety-belt wearing appears to be the most important effect, but also the fall in the number of drunk drivers has contributed to a reduced number of fatalities. While the effect of the prevention measures introduced in 2005 appears to be comparably modest in the figure, it should be noted that it represents a considerable reduction of 22.6% with regard to the number of fatalities in the year 2005

The time trend also plays a crucial role in the reduction of fatalities of car occupants. As we cannot estimate the weights of the single factors behind the time trend (continuous improvement of car and road safety, general societal trends, continuous increase of prevention measures) we will decompose the trend effect in section 6.

Permanently disabled car occupants decrease by

- 5.2% as the safety-belt wearing rate increases by 10.0%,
- 6.8% as the number of drivers with alcohol abuse per 100'000 residents decreases by 100,
- 21.7% with the introduction of the 2005 prevention measures,

and are further explained by the increased number of cars, by changes in GDP (higher in expanding economy), and regional characteristics (fewer in urban and more in mountain areas).

Figure 12 shows the important effect of the increased safety-belt wearing rate and the measures introduced in 2005.

Severely injured car occupants decrease by

- 4.1% with a year to year time trend,
- 5.5% as the safety-belt wearing rate increases by 10.0%,
- 6.6% as the number of drivers with alcohol abuse per 100'000 residents decreases by 100,
- 2.0% with the introduction of lower speed limits,
- 18.6% with the introduction of the 2005 prevention measures,

and are further explained by the increased number of cars, changes in GDP (higher in expanding economy), the increase of the population over age of 69 (lower as fraction increases) and regional characteristics (lower in urban and higher in mountain areas).

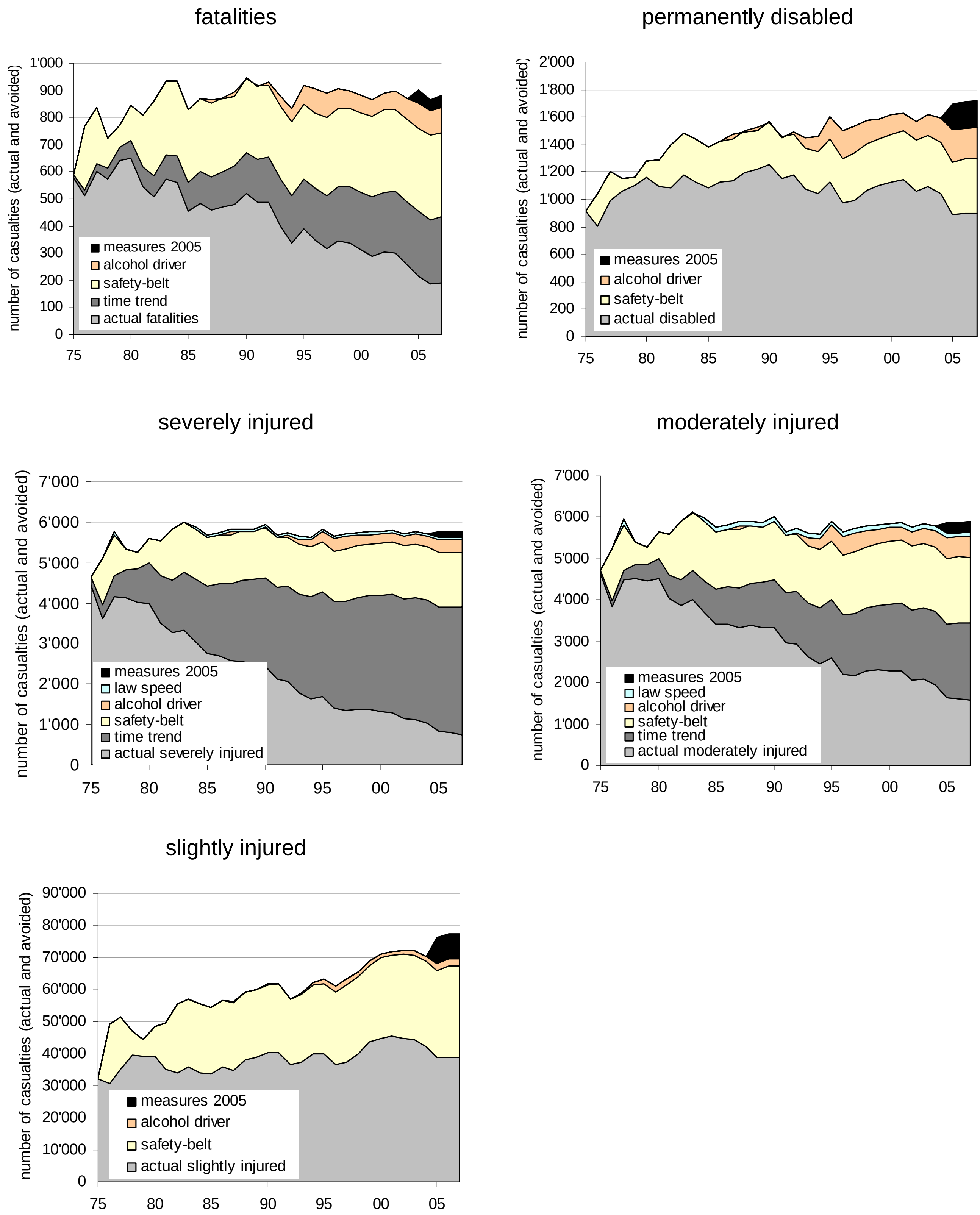
Figure 12 shows that the strong decrease in severely injured is dominated by the effect of the time trend but that the increased safety belt-wearing rate prevented approximately 1'200 of this type of casualties per year since the mid 1980s.

Moderately injured car occupants decrease by

- 1.8% with a year to year time trend,
- 5.7% as the safety-belt wearing rate increases by 10.0%,
- 6.5% as the number of drivers with alcohol abuse per 100'000 residents decreases by 100,
- 3.0% with the introduction of lower speed limits,
- 12.0% with the introduction of the 2005 prevention measures,

and are further explained by the increased number of cars, changes in GDP (higher in expanding economy), the increase of the population over age of 69 (lower as fraction increases) and regional characteristics (lower in urban and higher in mountain areas).

Figure 12 Actual and prevented casualties of car and lorry occupants



Slightly injured car occupants decrease by

- 10.4% as the safety-belt wearing rate increases by 10.0%,
- 1.6% as the number of drivers with alcohol abuse per 100'000 residents decreases by 100,
- 20.4% as the variable *laws all participants*, representing an index for the introduction of new laws which should lead to reduced risk for all road users increases by one index point,

and are also explained by changes in GDP (more in expanding economy), the increase of the population over age of 69 (higher as fraction increases) and regional characteristics (fewer in urban and more in mountain areas).

Figure 12 shows how the number of slightly injured would have increased in absence of the increased safety-belt wearing rate and the introduction of new traffic laws and regulations.

5.3.2 Results motorcycle and moped riders

The effects of the time trend, changes in behaviour and directly measured prevention efforts are considerably smaller on the number of casualties of motorcycle and moped drivers than for casualties of car occupants. The main reason for the decrease of casualties is the marked reduction of the number of mopeds from 10 to 2 mopeds per 100 residents in the period from 1981 to 2007. Surprisingly we detect only a moderate effect of the laws introducing compulsory helmet use, first for motorcyclists in 1981 and then for moped riders in 1990.[48]

Fatalities of motorcyclists and moped riders decrease by

- 4.0% with a year to year time trend,
- 5.5% as the number of drivers with alcohol abuse per 100'000 residents decreases by 100,
- 12.8% with the introduction of the 2005 prevention measures,

Figure 13 shows the contribution of the single factors. Regional characteristics also explain part of the differences between the cantons (fewer fatalities in urban and more in mountain areas).

The decrease of the number of permanently disabled motorcyclists and moped riders is mainly explained by the decrease of the number of mopeds. But the number also declines by

- 1.2% with a year to year time trend,
- 0.6% as the motorcycle helmet wearing quota increases by 10%

[48] A significant effect of helmet laws on both non-fatal and fatal injuries is shown in the recent studies by Dee (2008) and French et al. (2009) for the USA.

- 0.6% as the moped helmet wearing quota increases by 10% and
- 2.2% as the number of drivers with alcohol abuse per 100’000 residents decreases by 100,

Regional characteristics also explain part of the differences between the cantons (more casualties in urban and mountain areas).

The decrease of severely injured motorcyclists and moped riders is due to the decline of the number of mopeds. But the number also decreases by

- 3.1% with a year to year time trend and
- 0.2% as the moped helmet wearing quota increases by 10% and
- 2.3% as the number of drivers with alcohol abuse per 100’000 residents decreases by 100,
- 3.6% with the introduction of the 2005 prevention measures,

As shown in figure 13 the time trend is the main factor explaining the strong decrease in severely injured motorcycle and moped riders.

The decrease of moderately injured motorcyclists and moped riders is due to the decline of the number of mopeds and the decline of the population share between 18 and 24 years. But the number also decreases by

- 2.3% as the number of drivers with alcohol abuse per 100’000 residents decreases by 100,
- 3.6% with the introduction of the 2005 prevention measures.

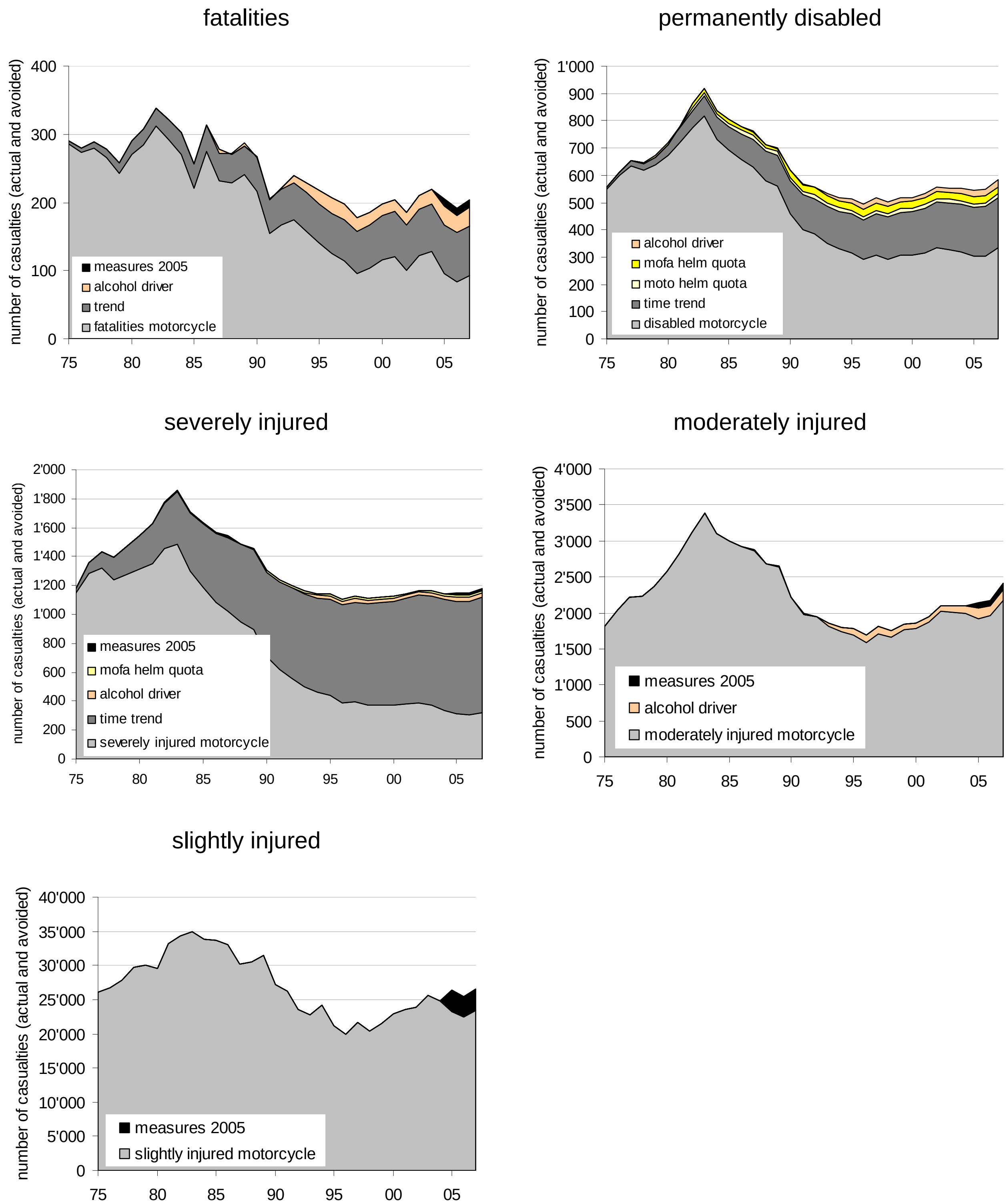
The only prevention measure the number of slightly injured motorcyclists and moped riders is the introduction of the 2005 prevention measures (-13.5%).

5.3.3 Results cyclists

The only prevention variable with an impact on the number of casualties of cyclists is the bicycle helmet wearing rate. The time trend contributes to the decrease of fatalities among cyclists (–2.7) and is positive for the other types of casualties, because number of cyclists and their behaviour has probably changed in ways not captured by the sole variable representing the number of bicycles available (e.g. increased recreational use of bicycles, see section 2). Demographic changes contribute to a reduction of the moderately injured casualties as the share of the over 69 years old increases.

The number of permanently disabled of cyclists is estimated to decrease by 16.1% as the bicycle helmet wearing rate increases by 10 percentage points. The size of the bicycle helmet effect is –18.1% for the severely injured and –17.3% for the moderately injured. No effect of helmet wearing on the slightly injured is detected. As shown in figure 14 the increase of the helmet wearing rate has lead to substantially less casualties among cyclists since the mid 1990s.

Figure 13 Actual and prevented casualties of motorcycle and moped riders



5.3.4 Results pedestrians

The decline in number of casualties among pedestrians is determined by the time trend, reduced alcohol abuse by drivers and the laws introducing lower speed limits (figure 15).

The time trend is particularly strong with a year to year decrease of 4.2% for fatalities, 0.8% for accidents leading to a disability, 2.3% for the severely injured, 3.4% for the moderately injured and 1.5% for the slightly injured. The effect of a decrease of 100 drivers with alcohol abuse per 100’000 residents is a decrease of 3.8% of fatalities and of 4.5% for accidents leading to disability and severe and moderate injuries among pedestrians. The introduction of the lower speed limits leads to a decrease of 9.2% of disabilities and of 9.6% for the severely and moderately injured pedestrians.

The urbanity of the canton and changes in the age structure of the population are the statistically significant confounding variables: the number of pedestrian casualties per resident is higher in the cantons with the degree of urbanity, decreases as the share of children and adolescents in the population declines and the share the elderly rises.

Figure 14 Actual and prevented casualties of cyclists

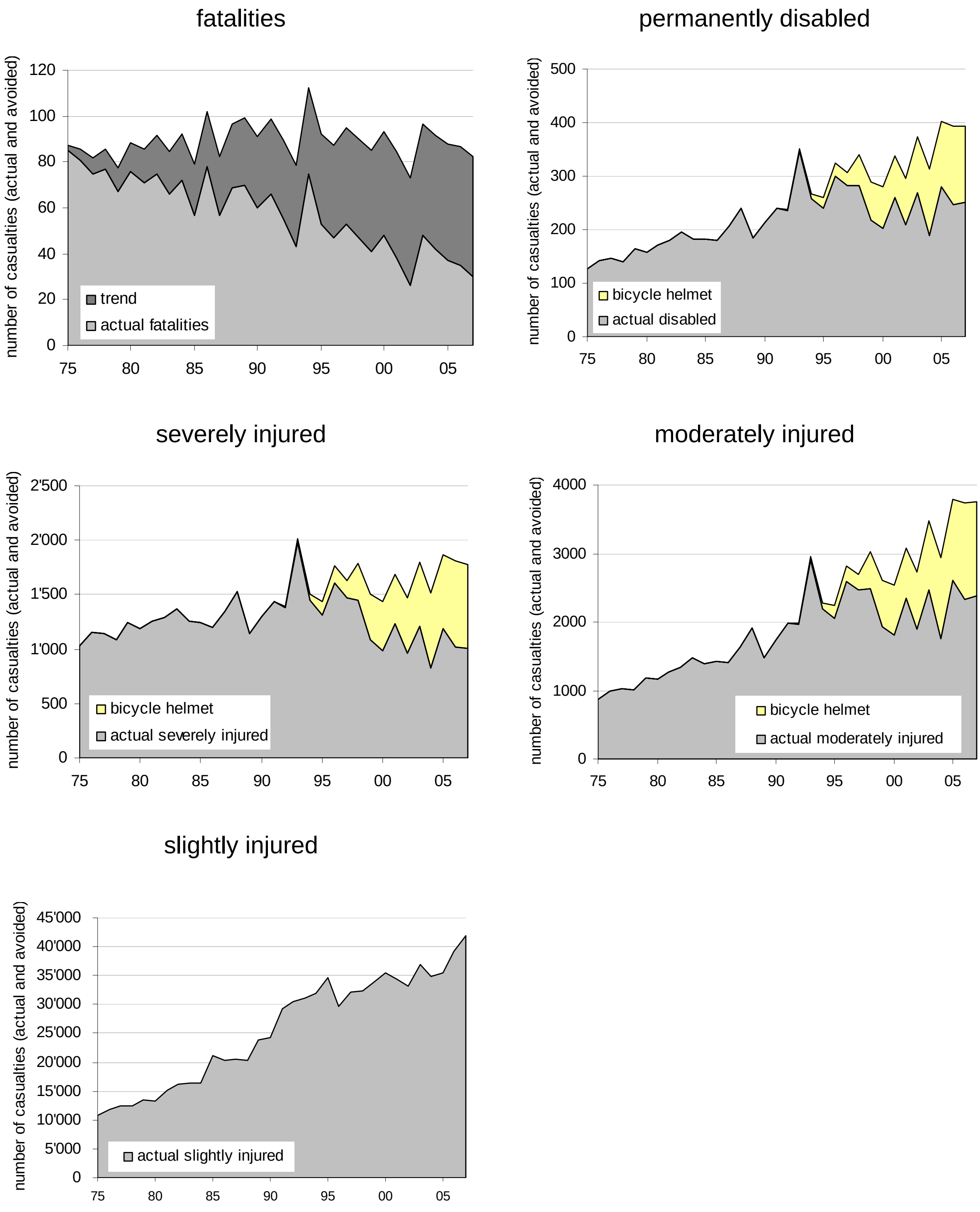
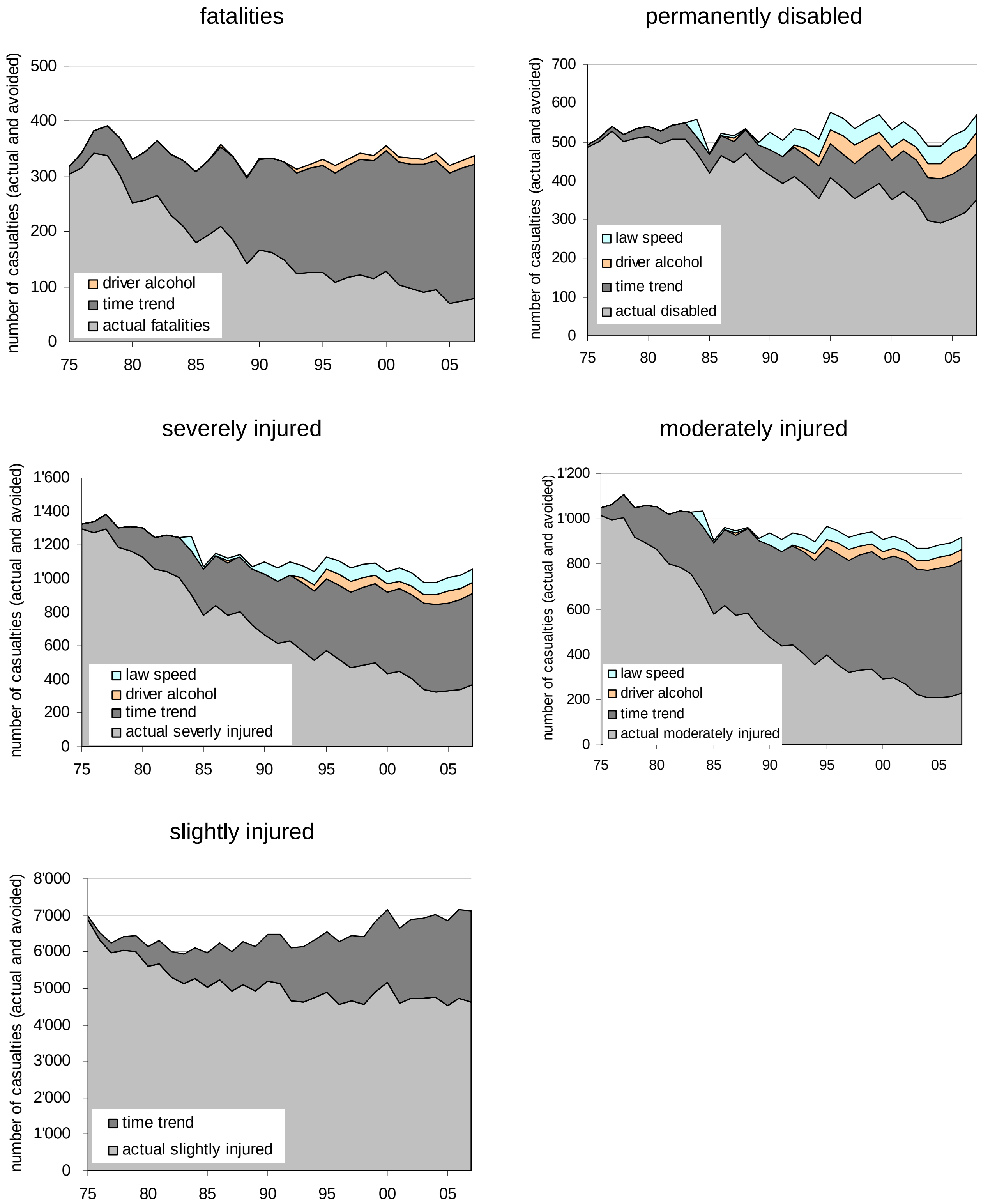


Figure 15 Actual and prevented casualties of pedestrians



6 Cost-benefit analysis of road accident prevention

We are now ready to answer the question of whether the money spent in road accident prevention measures in the period between 1975 and 2007 was worth it, by comparing the costs of prevention efforts described in section 4 with the benefits of prevention in monetary terms. These benefits are first discussed and calculated in section 6.1 by combining the societal cost of prevented casualties (section 3) with the number of casualties prevented thanks to the prevention measures (section 5). We then carry out a cost-benefit analysis (CBA) considering all public and private prevention measures, a CBA considering only public prevention programmes and CBAs of a number of selected prevention measures.

6.1 The monetary benefit of prevention measures

The analysis in section 5 has shown the effectiveness of a number of prevention measures in reducing the casualties among car occupants (*seat-belt*, *measures 2005*, *law all*), bicycle riders (*bicycle helmet*) and pedestrians (*law speed*), a decrease of fatalities as alcohol abuse by road users decline (effect of variable *alcohol driver*) and a significant decreasing trend in the number of casualties of car occupants, motorcyclists and pedestrians (effect of variable *time trend*).

While the effect of prevention measures in terms of a reduction of casualties represents a direct input for our CBA, the effect of reduced alcohol abuse and the time trend are not as clear cut, as they may be due to general social trends which are independent from prevention measures. For our CBA we thus need to define how much of the reduction due to the effects of the variables *alcohol driver* and *time trend* can be ascribed to prevention measures.

Regarding the effect of prevention measures on reduced alcohol abuse by road users we use the results of the parallel economic evaluation of prevention measures against alcohol abuse in Switzerland carried out for the FOPH by Jeanrenaud et al. (2009). In their analysis for the period from 1997 to 2007 the research team estimates that prevention efforts by different actors are responsible for half of the reduction in risk drinking (49.6%) while economic and social factors yield the other half. Although our analysis of road accident prevention covers a longer period (1975 to 2007) this result still appears to be applicable to our study. According to the data on prevention programmes financed by the FRS, the programmes aiming at alcohol abuse by road users started with relatively modest expenses in the mid 1980s and then strongly increased in the mid 1990s. As shown in section 5.2.1 alcohol consumption by road users started to decline only at the beginning of the 1990s. In our CBAs we will thus assume that 50% of the reduction of casualties due to reduced alcohol abuse by road users (effect of the variable *alcohol driver*) is due to prevention programmes.

In order to identify the effects of prevention measures on the time trend we have to assess the importance of the many possible effects influencing the time trend. These effects include the effects of prevention programmes not captured by the other variables, as well as the effects of road safety improvements, of car safety improvements after the deduction of the safety-belt effect, and of improved emergency services and of changes of behaviour and lifestyle. We weight these effects according to previous studies on road accident prevention and distinguish the size of these effects among categories of road users.

Improvement of vehicle safety has had the largest effect according to a number of studies. Broughton et. al (2000) in a study on British road accident data between 1980 and 1996 identify improved car safety as the first cause for the reduction of casualties with an effect of 15% of the reduction of fatalities. A study by Koornstra et al. (2002) comparing the evolution of road safety in Sweden, the United Kingdom and the Netherlands between 1980 and 2000 estimates the contribution of vehicle safety at 1% fatality reduction per year. Broughton (2003) estimates that if all the cars in circulation in 1998 had been at a higher safety level, the number of drivers killed or seriously injured could have been reduced at least by 20% and to 33% if all car had the safety level of the safest available cars. The importance of improved car safety is confirmed by other studies as Graham (1984) of Evans (1991). Note that most of these studies consider time periods in which safety-belts were already utilized by most car occupants.

The effects of improved vehicle and road security are likely to be much higher for occupants cars and commercial vehicles and much lower for motorcycle riders and pedestrians (no effect on bicycles as no time trend was identified). With the exception of improved brakes there have been few improvements in the passive and active safety of motorcycles and pedestrians might even have become more vulnerable in collisions with cars, as the average weight and size of cars increased.[49]

Improved safety of road infrastructure also plays an important role in the decline of road accident casualties over time. Broughton et. al (2000) estimate a resulting reduction of fatalities of 6.5% in Britain between 1980 and 1996. Koornstra et al. (2002) estimate the effect of improved road engineering on the reduction of fatalities at 4% for Sweden, 10% for Britain and 5% for the Netherlands. Improvements in road infrastructure will also have an effect on vulnerable road users as motorcyclists and pedestrians.

In their study on the effects of road accident prevention in Australia Abelson et. al (2003) proceed by estimating the evolution of casualties on a time trend without any other explanatory or confounding variables and then assume that 10% of the trend representing the year to year reduction of fatalities is due to road accident prevention programmes.

Considering the results of these studies we make the following conservative assumptions for the decomposition of the time trend:

[49] Note that we assume that the increased safety level of cars is entirely voluntary as people buy safer cars in order to increase the safety for themselves and their families, although part of this increase might also be due to stricter safety regulations and thus public policy.

- *Cars*: 50% of the time trend effect is attributed to improvements in vehicle and road infrastructure safety, 5% to prevention measures (education, information campaigns etc.) and 45% to independent social, economic and technical changes.
- *Motorcycles*: 34% of the time trend effect is attributed to improvements in road security, 34% to prevention measures (effect of increased helmet wearing not captured by statistical analysis, education, information campaigns etc.) and 32% to independent social, economic and technical changes.
- *Pedestrians*: 34% of the time trend effect is attributed to improvements in road security, 34% to prevention measures (education, information campaigns, outfits increasing visibility for other road users etc.) and 32% to independent social, economic and technical changes.

6.2 CBAs including all road accident prevention measures

The last step of a CBA consists in the comparison of the monetary costs of prevention measures with the monetary benefits. We also report the number of casualties prevented.

The effects of prevention measures were quantified as changes of the number of casualties due to changes of the prevention measures. On the cost side we therefore consider the changes of prevention expenditures with regard to the levels of 1975. An example may be helpful to illustrate this procedure: Regarding the cost of car safety devices we only account for the changes with regard to the level of real expenditures in 1975, when newly registered cars were already equipped with safety-belts and few other safety devices. The changes in real expenditures for safety devices thus represent the costs of additional safety devices.

Benefits are calculated by multiplying the effect of the prevention measure (e.g. number of fatalities prevented by the use of safety-belts in the year 2000) with the corresponding societal cost. The resulting costs saved are then summed over all prevention measures.

Costs and benefits are first calculated at prices of the current years and then discounted to the value of the year 2007 with a discount rate of 2%.

6.2.1 CBA of public and private prevention measures

The total cost of public and private prevention measures from 1975 to 2007 amounts to CHF 28'654 million. The total benefit of these measures amounts to CHF 72'816 million. The return of 1 CHF invested in prevention was thus of 1.54 CHF.

The benefit side is dominated by the increase in safety-belt wearing ratio and the time trend representing improvements of vehicle and road safety (88.5% of adjusted time trend effect) and prevention programmes (10% of adjusted time trend effect).

Table 7 CBA of public and private prevention measures

	costs of prevention			benefits of prevention	
prevention measure	**CHF million**	**in % of total**	**estimated benefit of**	**CHF million**	**in % of total**
measures aiming at behaviour	2'058.3	7.2	time trend	25'302.8	34.7
new laws and regulation	34.0	0.1	alcohol driver	3'621.7	5.0
police	1'880.8	6.6	seat belt	39'160.3	53.8
safety inspections	1'994.6	7.0	measures 2005	1'147.3	1.6
medical check-ups	76.6	0.3	bicycle helmet	1'489.3	2.0
bicycle helmet	75.7	0.3	motorcycle helmet	400.0	0.5
motorcycle helmet + outfit	1'914.1	6.7	moped helmet	647.5	0.9
moped helmet	127.8	0.4	law speed	1'046.7	1.4
security devices	13'146.4	45.9			
road infrastructure	7'345.2	25.6			
total cost	**28'653.6**	**100.0**	**total benefit**	**72'815.7**	**100.0**
ROI:	**1.54**		**number of prevented casualties**		
			fatalities	13'484	
			disabled	17'316	
			severely injured	98'861	
prevention measures from 1975 to 2007			moderately injured	82'822	
present value in 2007 calculated with 2% discount rate			slightly injured	1'019'087	

6.2.2 CBA of prevention programmes

Quantifying the benefits of the mainly publicly financed prevention programmes is challenging as some of the prevention measures aim at an increased usage of safety devices (e.g. bicycle helmets) and thus imply an increase of private expenditures. We nonetheless make a rough CBA of prevention programmes by including these private expenditures.

The results summarized in Table 8 show a return of 9.43 CHF for each CHF invested. The cost side includes police costs as many of the regulations imposing a safer behaviour on road users are only effective, if they are enforced by the police. Note that we do not include the cost of safety belts on the cost side, because they were already a standard safety device in 1975.

The benefit side is dominated by the effect of increased safety-belt wearing rate (73.9% of total benefit). Note that the effect of the time trend is considerably lower than in the CBA of public and private prevention measures (table 7) because we consider only the effect of road safety programmes (5% of time trend effect for car occupants and 34% for motorcyclists and pedestrians).

Table 8 CBA of prevention programmes

	costs of prevention			benefits of prevention	
prevention measure	**CHF million**	**in % of total**	**estimated benefit of**	**CHF million**	**in % of total**
measures aiming at behaviour	2'058.3	39.8	time trend	8'505.8	15.8
new laws and regulations	34.0	0.7	alcohol driver	3'621.7	6.7
police	1'880.8	36.4	seat belt	39'160.3	72.6
bicycle helmet	75.7	1.5	measures 2005	1'147.3	2.1
motorcycle helmet	991.0	19.2	bicycle helmet	1'489.3	2.8
moped helmet	127.8	2.5	motorcycle helmet	400.0	0.7
			moped helmet	647.5	1.2
			law speed	1'046.7	1.9
total cost	**5'167.7**	**100.0**	**total benefit**	**53'924.5**	**100.0**
ROI:	**9.43**		**number of prevented casualties**		
			fatalities	10'229	
			permanently disabled	16'059	
			severely injured	59'112	
prevention measures from 1975 to 2007			moderately injured	64'398	
present value in 2007 calculated with 2% discount rate			slightly injured	710'180	

6.3 CBAs of single prevention measures

6.3.1 CBA of alcohol prevention measures

The effect of alcohol prevention efforts on road accident casualties is contained in the effects of the variables *alcohol driver* and *measures 2005*.[50] We assume that half of the *measures 2005* effect is due to the lowering of the blood alcohol level to 0.5 per mil and the possibility for the police to test for blood alcohol level without signs that the driver may be intoxicated.

On the cost side we sum all expenditures for education and information measures aiming at a reduction of alcohol abuse by road users financed by the FRS. As described in section 4.1 we multiply these expenditures by 2.56 in order to include additional expenses carried out by the traffic associations, the cantons and other public organizations. We further assume that 30% of police efforts for road safety are aimed at the containment of excessive alcohol consumption by road users.

Table 9 CBA of measures against excessive alcohol abuse by road users

	costs of prevention			**benefits of prevention**	
prevention measure	**CHF million**	**in % of total**	**estimated benefit of**	**CHF million**	**in % of total**
alcohol prevention programmes for road users	68.9	11.2	alcohol driver	3'621.7	86.3
new law and regulation year 2005	0.3	0.0	measures 2005 (50% of benefit)	573.7	13.7
police (30% of costs)	546.5	88.8			
total cost	**615.6**	**100.0**	**total benefit**	**4'195.4**	**100.0**
ROI:	**5.81**		**number of prevented casualties**		
			fatalities	717	
			permanently disabled	2'097	
			severely injured	2'485	
prevention measures from 1986 to 2007			moderately injured	3'006	
present value in 2007 calculated with 2% discount rate			slightly injured	22'193	

[50] There is a broad consensus in the road accident prevention literature on the decisive role played by alcohol abuse in many accidents. A recent bfu report by Ewert and Eberling (2009) estimates that the risk of having a severe accident on rural roads in Switzerland is 68% higher for drivers under the influence of alcohol.

We limit the CBA to the period from 1986 to 2007 because the first measures against alcohol abuse by road users were financed by the FRS in 1986 and the alcohol consumption per head increased in Switzerland until the mid 80s. The return of 1 CHF invested on prevention of excessive alcohol abuse by road users is estimated at 5.81 CHF.

6.3.2 CBA of bicycle helmet promotion

The efforts to improve the rate of cyclists wearing a bicycle helmet can be evaluated with relatively straightforward CBA as the costs of prevention arise only as cost of the prevention campaigns and the cost of the bicycle helmets purchased by cyclists. The benefits are identified by the reduced casualties estimated by the variable *bicycle helmet* and the relative societal costs prevented.

Table 10 reports the results of our CBA of bicycle helmet campaigns between 1997 and 2007. The return of 1 CHF invested in prevention is estimated at CHF 16.31. Note that private expenditures for bicycle helmets represent 88% of prevention costs.[51]

Table 10 CBA of bicycle helmet measures

	costs of prevention			benefits of prevention	
prevention measure	**CHF million**	**in % of total**	**estimated benefit of**	**CHF million**	**in % of total**
bicycle helmet campaigns	10.3	12.0	bicycle helmet	1'489.3	100.0
bicycle helmet (private cost)	75.6	88.0			
total cost	**85.9**	**100.0**	**total benefit**	**1'489.3**	**100.0**
ROI:	**16.31**		**number of prevented casualties**		
			fatalities	-	
			permanently disabled	1'099	
			severely injured	6'231	
prevention measures from 1993 to 2007			moderately injured	10'439	
present value in 2007 calculated with 2% discount rate			slightly injured	-	

[51] A recent unpublished estimation by the SUVA confirms the importance of increased bicycle helmet wearing with an estimate of the reduction of accidents leading to severe skull fractures. The estimated number of prevented injuries of this type is 1'119 cases in the year 2006 corresponding to a cost saving of CHF 39 million from the accident insurer perspective.

6.3.3 CBA of year 2005 road safety measures

Evaluating the effects of the road safety measures introduced in 2005 is also relatively simple in our framework. The measures comprise the introduction of a lower maximum blood alcohol level, the possibility for the police to test for blood alcohol level without signs that the driver may be intoxicated, a tightening of sanctions for infractions of traffic laws and several other measures. We assume that the cost for the introduction of these measures was four times the usually assumed cost of the introduction of new laws and regulation (several new regulations were introduced) and that 50% of the increased real cost of road safety efforts by the police in the years from 2005 to 2007 was due to the enforcement of the new regulation.

The results of our CBA of the year 2005 road safety measures are reported in table 11. The return of one franc invested in theses measures is estimated at CHF 8.06.

Table 11 CBA of year 2005 road safety measures

	costs of prevention			benefits of prevention	
prevention measure	**CHF million**	**in % of total**	**estimated benefit of**	**CHF million**	**in % of total**
new law and regulation	1.0	0.8	measures 2005	1'147.3	100.0
police (50% of increased costs)	125.7	99.2			
total cost	**126.7**	**100.0**	**total benefit**	**1'147.3**	**100.0**
ROI:	**8.06**		**number of prevented casualties**		
			fatalities	169	
			permanently disabled	518	
			severely injured	478	
prevention measures from 2005 to 2007			moderately injured	1’001	
present value in 2007 calculated with 2% discount rate			slightly injured	33’136	

6.3.4 CBA of safety-belt wearing

The increased use of safety-belts is the single most important factor for the reduction of road accident casualties in the period from 1975 to 2007.[52] We assume that 20% of police efforts for road safety (1976, 1977, and from 1981 to 2007) are aimed at the enforcement of safety belt use. As these costs represent 98% of total costs the other costs are negligible in comparison. Note that we do not include the cost of safety-belts in our calculations as they are compulsory on newly registered cars since 1971. The benefits are calculated with the estimated effect of the variable *safety-belt*.

The results of our CBA of safety-belt measures are presented in table 12, with a return of 101.03 CHF for each CHF invested in theses measures. The introduction of compulsory safety-belt wearing and its imposition is thereby the measure with the highest return of all the measures considered in our study.

Table 12 CBA of safety-belt measures

	costs of prevention			benefits of prevention	
prevention measure	**CHF million**	**in % of total**	**estimated benefit of**	**CHF million**	**in % of total**
safety-belt wearing campaigns	7.1	1.9	safety-belt	39'169.3	100.0
safety-belt laws	0.5	0.1			
police (20% of cost increase)	376.2	98.0			
total cost	383.8	100.0	**total benefit**	**39'169.3**	**100.0**
ROI:	**101.03**		**number of prevented casualties**		
			fatalities	8'327	
			permanently disabled	9'554	
			severely injured	37'545	
prevention measures from 1976 to 2007			moderately injured	42'996	
present value in 2007 calculated with 2% discount rate			slightly injured	676'959	

[52] The crucial importance of safety-belt has been confirmed by many studies. The recent bfu report on accident with severe injuries on rural roads in Switzerland (Ewert and Eberling 2009) shows that the probability of a severe or lethal consequence of an accident are 6 times higher when an occupant is not wearing a safety-belt.

6.4 Comparison of CBAs of road accident prevention measures

A comparison of the single CBAs of road accident prevention measures may be useful for a better understanding of the magnitude of the effects of specific measures. Table 13 reports the main results of these CBAs and shows their hierarchical structure, i.e. how some CBAs are contained in other CBAs. The CBA of public and private prevention measures (row 1: ROI of 1.54) includes all road accident prevention measures taken and thus includes the measures analysed in the CBA of prevention programmes (row 1a: ROI of 9.43). The difference between these two packages of prevention measures consists of the public investments for road safety and the voluntary private expenditures for safety devices on vehicles. The ROI of these measures is negative with CHF –0.20 for every franc (row 1b). Note that ROI of measures would be positive under slightly less conservative assumptions, as a VOSL of 91,000 CHF used in the evaluation of public infrastructure investments in Switzerland (see Sommer et al. 2007a) or if material damages would be included.

Table 13 Comparison of CBAs of road accident prevention measures

row		costs (CHF million)	avoided costs (benefit) (CHF million)	ROI (benefits–costs) / costs	number of fatalities prevented (benefits)
1	CBA of public and private prevention measures [a]	28’654	72’816	1.54	13’484
1a	CBA of public prevention programmes [b]	5’168	53’924	9.43	10’229
1b (=1–1a)	CBA of public road infrastructure and private prevention measures	23’486	18’892	-0.20	3’255
1aa	CBA of alcohol prevention measures	616	4’195	5.81	717
1ab	CBA of bicycle helmet promotion	86	1’489	16.31	-
1ac	CBA of year 2005 road safety measures	127	1’147	8.06	169
1ad	CBA of safety-belt wearing	384	39’160	101.03	8’327
1ae (=1a–1aa to 1ad)	CBA other prevention programmes	3’955	7’933	1.01	1’016

The table shows the hierarchal structure of the CBAs presented. Row 1 is decomposed into rows 1a and 1b and row 1a is decomposed into rows 1aa to 1ae. The costs, avoided costs and number of fatalities prevented in rows 1b and 1ae are calculated as differences.

[a] Public and private prevention measures include all expenditure for road accident prevention including investments in road infrastructure and the voluntarily private expenditures.

[b] Public prevention programmes include all public expenditures for road accident prevention excluding investments in road infrastructure.

The impressive effect of the increased of the safety-belt is contained in the CBA of prevention programmes made visible by a ROI of 101.03 (row 1ad). Calculating the average ROI of other prevention programmes we obtain a considerably lower ROI of CHF 1.01 per franc spent (row 1ae). Note that in the case of prevention programmes alcohol prevention, bicycle helmet and 2005 measures, for which we were able to isolate the effect on road accident fatalities, show a substantially higher ROI.

7 Sensitivity analysis

A sensitivity analysis illustrates how the results of a study change if the main assumptions and key parameters employed in the study are modified. A sensitivity analysis thus gives an idea of the robustness of the results.

Our sensitivity analysis follows four approaches:

1. We explore how the results change if the estimated coefficients of the explanatory variables representing successful preventions measures vary in the estimated confidence interval.
2. We explore how much several of the key assumptions would have to be modified in order to obtain a ROI of 1 in the single CBAs.
3. We explore how the ROI changes if material damages are considered among the avoided costs.
4. We explore how the ROI changes if we double the value of a statistical life year.

7.1 Lower and upper bound of ROI

The *first part* of the sensitivity analysis focuses on the estimation of the effectiveness of road accident prevention (see section 5). The estimated coefficients of single explanatory variables representing successful prevention measures (e.g. safety-belt wearing rate, introduction of lower speed limits) and the time trend are varied by adding or subtracting the estimated standard error of the coefficient, a measure of the variability of the coefficient. These adjusted coefficients are then entered into the CBA procedure in order to calculate the upper and the lower bound of the ROIs and of the number of fatalities prevented as a result of the prevention measures. The interval between the lower and the upper bound corresponds to a 68% probability range centred on the reference estimate.

The results of the sensitivity analysis (table 14) show an upper and a lower bound of the ROI of on average 20% above or below the reference estimate. The highest variation appears in the CBA of the year 2005 road safety measures. In a sensitivity analysis with a 95% probability range the ROI is on average 40% above or below the reference estimate.

The results of this first sensitivity analysis are in the same order of magnitude as our base estimate and thus support the robustness or our analysis.

Table 14 Sensitivity analysis: upper and lower bound of ROI

	ROI (benefit-cost)/cost			number of fatalities prevented (benefits)		
	lower bound	reference estimate	upper bound	lower bound	reference estimate	upper bound
CBA of public and private prevention measures [a]	1.05	1.54	2.03	10'564	13'484	16'404
CBA of public prevention programmes [b]	7.59	9.43	11.28	8'281	10'229	12'177
CBA of alcohol prevention measures from 1986 to 2007	4.96	5.81	6.67	612	717	821
CBA of bicycle helmet promotion	13.40	16.31	19.22	-	-	-
CBA of year 2005 road safety measures	5.55	8.06	10.56	107	169	230
CBA of safety-belt wearing	84.11	101.03	117.96	6'840	8'327	9'815

Lower und upper bounds are calculated by varying the estimated coefficients of the single explanatory variables (prevention measures, road safety behaviour, time trend) by one standard error (a measure of the variability of the coefficient) within the estimated confidence interval. This variation corresponds to a 68% probability range.

[a] Public and private prevention measures include all expenditure for road accident prevention *including* investments in road infrastructure and the voluntarily private expenditures.

[b] Public prevention programmes include all public expenditures for road accident prevention *excluding* investments in road infrastructure.

7.2 Threshold-values for several key assumptions

The *second part* of the sensitivity analysis focuses on some of the assumptions we made regarding the costs of single prevention measures and regarding the decomposition of the time trend. In order to explore the sensitivity of the results to these assumptions we determine how much these assumptions would have to be changed in order to obtain a ROI of 1 in the single CBAs. We thus identify a threshold value for the assumption, at which the return for a franc invested in prevention is equal to one franc.

A first threshold value analysis focuses on the price of safety-belts. In the base version of the CBAs the price of safety-belts is not considered, as safety-belts were compulsory on new cars since 1971 and thus the compulsory introduction of safety-belt wearing should not have led to additional cost. We relax this assumption, as new safety-belt models might have had higher costs than the simple models used in the first half of the 1970ies, and introduce a cost safety-belt which would have to be paid on all new cars purchased since 1975. We find that only exceptionally high price of CHF 4'180 per safety-belt at prices of 2007 would have been necessary to reduce the ROI of compulsory safety-belt wearing from 101.03 to 0.

A second threshold value analysis focuses on the cost of security devices. As shown in table 15 the cost of these devices would have to be increased by 590% to obtain a

ROI of CHF 0.00 in the *CBA all measures*. This appears an exceptionally high cost, as the resulting price of CHF 8’625 would correspond to approximately a third of the cost of an average new car.

A third threshold value analysis focuses on the share of expenses for road safety in the total expenditures for road construction. In the base estimate we assume a share of 5% for national and of 15% for cantonal and communal roads. In order to obtain a ROI of 0.00 in the *CBA all measures,* the share expenses for road safety would have to have been 56.3% for national roads and 100% for cantonal and communal roads.

A forth threshold value analysis looks at the cost of bicycle helmets. The price of a since helmet would have had to be CHF 1’950 instead of CHF 100 (prices of year 2000) in order to reduce the ROI in the CBA of bicycle helmet promotion from 16.31 to 0.

The outcome of our threshold analysis confirms the robustness of our results as we have to make highly implausible assumptions in order to obtain a ROI of 0.

Table 15 Sensitivity analysis: threshold values for ROI

CBA	Assumption	Value base assumption	Threshold value for ROI = 1
safety-belt	Cost for safety-belt	no cost (safety-belt compulsory since 1971)	CHF 4’180 for a safety-belt at prices of 2007
all measures	Cost for security devices on new cars and commercial vehicles at prices of 2001.	car: CHF 1'250 comm. vehicle: CHF 10'053	car: CHF 8'625 comm. vehicle: CHF 69'366 (+ 590%)
all measures	Share of expenses for road safety in total expenditures for road construction.	national roads: 7.5% cantonal and communal roads: 15.0%	national roads: 56.3% (+650%) cantonal and communal roads: 100% (+566%)
bicycle-helmet	Private cost of a bicycle helmet at price of year 2000.	CHF 100	CHF 1’950 (+1’850%)

7.3 Inclusion of material damage

The third part of the sensitivity analysis focuses on the inclusion of material damages. As outlined in section 3.1.2 we did not consider these costs in the base estimates, due uncertainties in their estimation and the difficulty to assign material cost to the single categories of casualties.

We assign a value of CHF 20’997 to the costs of material damage per casualty in the year 2003. This value was calculated by dividing the total costs of material damage in 2003 provided by Sommer et al. (2007b:103) with our estimated number of total casualties in 2003. As a result the ROI of the *CBA all measures* increases from CHF 1.54 to CHF 2.19 per every franc invested (+42.7%).

This result shows that the ROI of the prevention measures might have be substantially higher, if we had included the material damages into our analysis.

7.4 Higher value of statistical live year

The fourth part of the sensitivity analysis focuses on doubling the value of a statistical life year to 100’800 CHF at prices in the year 2007 and deflating it for the earlier years. The value of 50’400 CHF for a statistical life year in the baseline estimate is rather low compared to other studies estimating the societal costs of road accidents (Nellthrop et al. 2001). The value of CHF 100’800 is in line with another Swiss study wherein the value of CHF 91’000 at prices in the year 2003 is used (Sommer et al. 2007b). As a result of the higher value the ROI of the *CBA all measures* rises from CHF 1.54 to CHF 2.54 per every franc invested (+64.9%).

This result shows that the ROI of the prevention measures might have be substantially higher, if we would have used values for a statistical life, as the used in many other studies.

8 Conclusions

Objectives and procedure

The goal of this study is a CBA of road accident prevention measures realized in Switzerland in the period from 1975 to 2007. In order to carry out this CBA we proceed with the following steps.

1. Estimation of the actual number of road accident casualties by combining the information in the FSO and the SSUV road accident datasets for 4 categories of road users and 5 categories of severity of injury.
2. Estimation of the societal cost, including direct costs, productivity losses and intangible costs, for each of these 20 road accident casualty categories.
3. Identification of the relevant public and private road accident prevention measures and estimation of their costs.
4. Estimation of the effectiveness of the prevention measures identified on the evolution of the 20 casualty categories from 1975 to 2007.
5. The last step of the CBA consists of the comparison of the benefits of the prevention measures (number of prevented casualties multiplied by the societal cost per prevented casualty) with the costs of the prevention measures. We carry out a CBA for the total of public and privately financed road accident prevention measures and for single prevention measures.

Main results

These are the main results of our CBA:

- Main results of the study are the ROIs of a basket of prevention measures and single measures: The ROI of all public and private prevention interventions carried out between 1975 and 2007 amounts to CHF 1.54 for every franc invested in prevention. Considering only public prevention programmes (without investments the safety of road infrastructure) the ROI rises to 9.43. The ROI of alcohol prevention measures is estimated at 5.81, the ROI of promotion of bicycle helmet wearing at 16.31, and the ROI of the combined measures introduced in 2005 at 8.06. Measures aiming at the imposition and promotion of safety-belt use are estimated with an exceptionally high ROI of 101.03. The effect of all interventions between 1975 and 2007 was substantial with 13’484 fatalities and 909’213 casualties prevented and a total of 72’816 million Swiss francs avoided thanks to prevention.
- Measures aiming at changes in safety behaviour thus appear to have a high return, while investments in road infrastructure and safety devices, which by far represent the biggest part of safety expenditures, have considerably lower returns. Furthermore relatively recent interventions, such as the bundle of measures introduced in 2005 have a relatively high economic return.

- The cost side of the CBAs is generally dominated by expenditures in safety equipment, road infrastructure and costs of increased police efforts. The cost side of prevention measures aiming at changes in road safety behaviour (prevention of excessive alcohol, combined measures in the year 2005, promotion of safety-belt wearing) is dominated by the costs of increased police efforts. The only exception is the promotion of increased bicycle helmet use, dominated by the private expenses of bicycle helmets. The benefit side of the CBAs is dominated by the avoided medical costs, avoided productivity losses and avoided intangible costs.

Strengths and limitations

The main strength of this CBA on road accident prevention is that for the first time the multitude of data sources on evolution of road accidents and road accident prevention are combined to study the effectiveness and the economic return on the prevention measures in Switzerland from 1975 to 2007. The actual and prevented number of road accident casualties in 4 road user and 5 severity categories are calculated for this period of 33 years. A detailed calculation of costs of prevention and of benefits prevention (direct costs, production losses and intangible costs of casualties prevented) permit the calculation of the ROI of packages of measures and also some single measures.

The single ROIs calculated and the sensitivity analysis show that investments in road accidents prevention interventions have yielded a positive return. These results can be considered as a conservative estimate of the ROI because we always estimated the factors influencing possible benefits conservatively and the factors influencing costs generously. The estimation of intangible costs is an example as the calculated DALYs represent a very low lower bound of actual intangible costs. In addition, the value of a statistical life year of CHF 50’400 is rather low in the case of road accidents. Moreover material damage was not included in the reference estimate of this study, although it may seem indisputable that prevention has also saved some costs in this cost category yielding an even higher ROI.

The main limitations of the study are that, although we dispose of relatively comprehensive data on road accidents, the data on road accident prevention are relatively scarce forcing us to make a number of assumptions e.g. on the share of safety expenditures in road infrastructure investments and their evolution in time or on the share of resources employed by the road police in the enforcement of alcohol controls. To make sure that these assumptions would not lead to an overestimation of the benefits of prevention we always made generous assumptions regarding the costs of prevention and conservative assumption regarding the benefits.

A second limitation is that the DALY approach we chose to translate the suffering and injuries caused by road accidents into the number of years of life in full health lost does most probably not capture the full loss of quality of life and especially not for the severely injured. In combination with a relatively conservative VOSL of 50,400 CHF this leads to an underestimation of the intangible costs.

A third limitation is that we were able to identify the full effect of many measures, e.g. the increased helmet wearing by motorcycle, moped and bicycle riders, although these effects may be captured by the trend effects.

Overall the analysis shows the importance of public prevention programmes in the substantial reduction of road casualties in the period between 1975 and 2007. The case of road accident prevention in Switzerland thus appears to be an example of a highly successful prevention strategy.

Appendix 1: Details on the calculation the number and type of road accidents

As described in section 2 a number of complications have to be solved in the process leading from the FSO and SSUV road accident data to the 'true' number of road accidents of 4 types of road users and 5 injury categories. This appendix contains a detailed description of how we solved these complications.

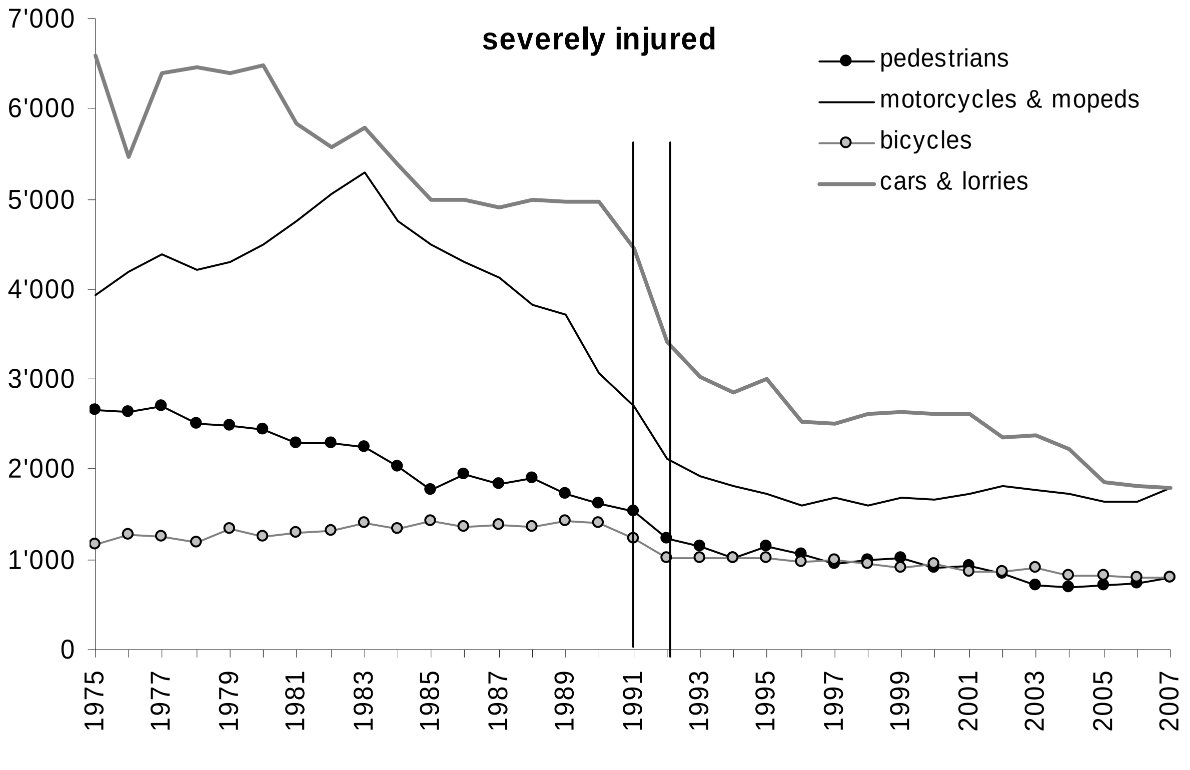
Correction of structural brake in FSO data between 1991 and 1992

The FSO data have a structural brake from 1991 to 1992 due to a change in definition of the injury categories in the entry form used by the police to report road accidents.

A look at the evolution of the casualties indicates an atypical decrease of the severely injured on the one hand (Figure a1.1) and an atypical increase of the slightly injured (figure a1.2) between the years 1991 and 1992 on the other. The explanation is that some of the casualties, which would have been reported as severely injured before 1992, were reported as slightly injured from 1992 on.

We adjust the structural break by multiplying the numbers of casualties *before* 1992 with a correction factor and leaving the numbers as from 1992 unchanged.

Figure a1.1 Evolution of severely injured casualties (all road user categories)



The correction factors are estimated with the following procedure:

- The following ordinary least squares-model is estimated with the time series (1975-2007) of the casualties of each road user category (using the slightly injured motorcyclists as an example):

  explained variable: **slightly_moto**

  explanatory variables:

  → **cons** = intercept

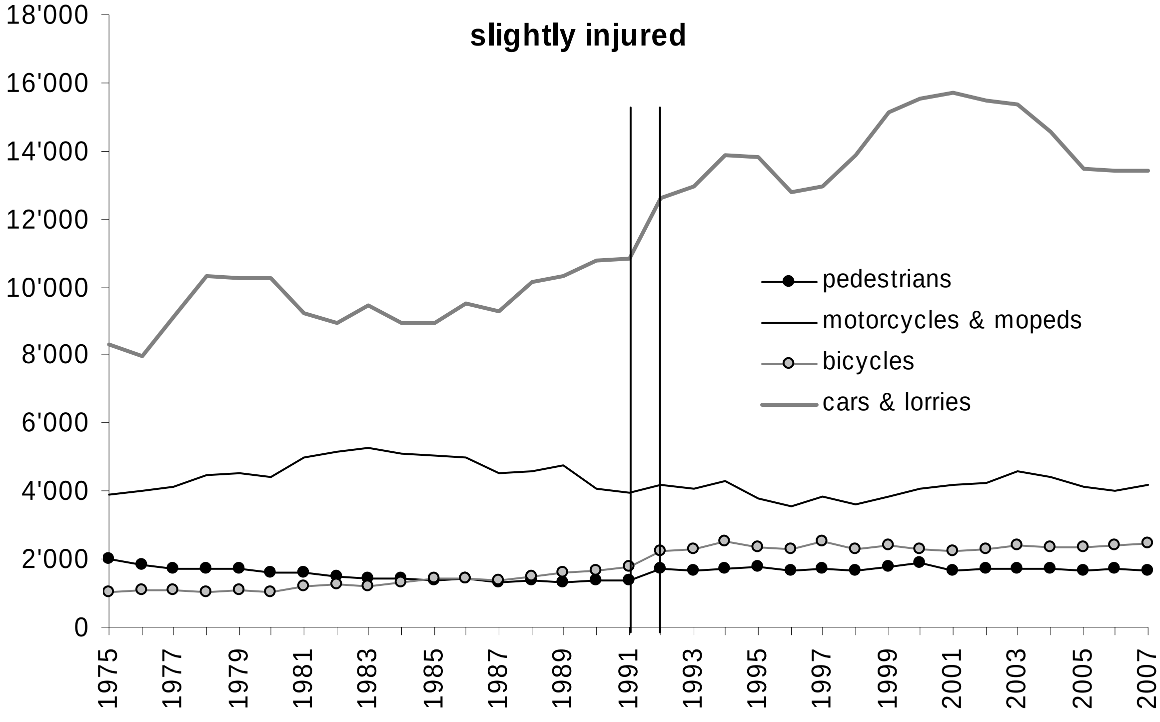
  → **from92**: dummy representing the break between 1991 and 1992 (0 for the years before 1992 and 1 for the years as from 1992). The numbers of casualties are eventually shifted up- or downwards by this coefficient (see figure I.3)

  → **trend**: trend between 1975 and 2007 assuming in values from 1 to 33

  → **trend_from92**: additional trend from 1992 on (assuming values of 0 to 16). This variable is needed for an accurate estimation of the correction factor.

  → **trend_from84**: variable used only for the severely injured motorcyclists between the years 1983 and 1984, as a change of trend is observable

Figure a1.2 Evolution of slightly injured casualties (all road user categories)



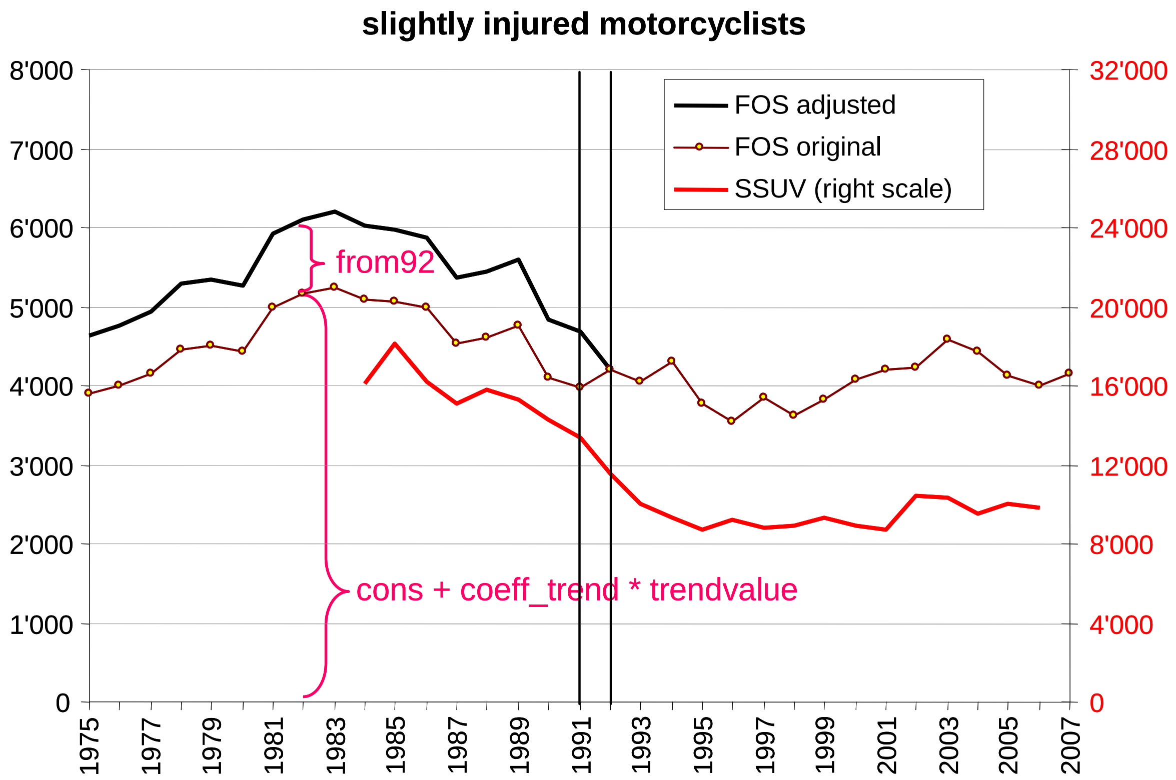
- The correction factor is then calculated in the following way $\left(1+\frac{from92}{cons+trend\times trendvalue}\right)$ and then multiplied with the original FSO value. For example, in the year 1981 for the slightly injured motorcyclists the equation is: $adjustedFOS = originalFOS^{slightly\_moto}_{1981} \times \left(1+\frac{843}{4418+18\times 7}\right) = 4987\times 1.185 = 5911$

Figure a1.3 illustrates the adjustment. The figure shows also a comparison with the SSUV data. In the case of the slightly injured motorcyclists the adjusted FSO values for the years 1991 and 1992 are similar to those from the SSUV which justifies the adjustment.

In the case of severely injured car occupants and motorcyclists the comparison indicates an overcorrection. We correct this overcorrection by downsizing the coefficient **from92** by multiplying it with the following factor:

$$1-\frac{\%\ variation^{91-92}\ SSUV}{\%\ estimated\ variation^{91-92}\ FOS}$$

Figure a1.3 Correction of break within FSO data



Details on the correction factor for non-reported casualties

The correction factor of non-reported casualties was calculated by dividing the number of casualties reported by the SSUV (which were previously extrapolated with the gross labour participation rate) over the number of casualties reported by the FSO (which were previously adjusted for the structural brake between 1991 and 1992).

Table a1.1 shows the detailed used correction factors. They are constant over time except in the bicycle category, where it is increasing, most probably due to the increasing leisure use of bicycles.

Table a1.1 Detailed used correction factors of non-reported casualties

	bicycles			motorcycles & mopeds			cars & lorries			pedestrians		
year	fatal	severely	slightly	fatal	severely	slightly	fatal	severely	slightly	fatal	severely	slightly
all years	1			1	2.09	5.62	1	1.81	2.89	1	1.2	2.74
1975		2.39	6.26									
1976		2.45	6.59									
1977		2.52	6.92									
1978		2.59	7.25									
1979		2.65	7.58									
1980		2.72	7.91									
1981		2.79	8.24									
1982		2.86	8.57									
1983		2.92	8.90									
1984		2.84	8.15									
1985		2.66	9.97									
1986		2.74	9.51									
1987		3.10	10.33									
1988		3.59	9.29									
1989		2.64	10.42									
1990		3.07	10.46									
1991		3.91	11.87									
1992		3.54	13.70									
1993		5.20	13.55									
1994		3.81	12.62									
1995		3.59	14.75									
1996		4.58	12.79									
1997		4.30	12.64									
1998		4.44	14.09									
1999		3.55	14.18									
2000		3.13	15.48									
2001		4.41	15.33									
2002		3.56	14.54									
2003		4.39	15.35									
2004		3.35	14.93									
2005		5.02	15.26									
2006		4.47	16.48									
2007		4.54	16.81									

Figures of the evolution of all casualties by type of road user and type of injury

Figure a1.1 and figure a1.5 display the evolution of the casualties within the road user categories not reported in the main text. They also show a comparison to the values calculated by Sommer et al. (2007b), which is the only study reporting both the number of casualties per road user and injury category and applying the same definition for the injury categories.

The comparison with other studies shows that, with the exception of pedestrians, our values are usually slightly higher. This is probably due to the following:

- The *labour participation rate* used to extrapolate the SSUV numbers to the whole population (not only the employed) is lower than in the other studies because we do not include the self-employed, which are not included in the SSUV data base.
- Sommer et al. (2007b) explicitly take into account *only non-occupational accidents*. By including occupational accidents the enumerator (number of casualties reported by the SSUV) is bigger, so the correction factor is also bigger.
- Except for the case of bicycles we use *correction factors averaged over several* years. If our extrapolated data is compared to studies estimating the correction factor only for a specific year, they will differ.

Other studies calculating the actual number of casualties used different injury categories so we can only compare the numbers of all casualties (figure a1.6). Note that the road user category *cars & lorries* does not always cover the same means of transport. In some studies it includes all other means of transport, while in others it only includes lorries and commercial vehicles. Unfortunately we could not compare our values in the *bicycle* and *motorcycles & mopeds* categories with the Ecoplan study (1991) because its categories are *bicycles & mopeds* and *motorcycles* respectively and mopeds can not be isolated. Figure a1.7 shows the division of the severely injured into permanently disabled, severely and moderately injured for the remaining three road user categories.

Table a1.2 shows how we allocated the numerous road user categories reported in the FSO data into our four road user categories.

Figure a1.7 shows the division of the severely injured into permanently disabled, severely and moderately injured for the remaining three road user categories.

Table a1.2 Allocation of the detailed FSO road user categories

bicycles	motorcycles & mopeds	cars & lorries	pedestrians
- bicycle	- moped - „Kleinmotorrad“ - motorcycle up to 125 ccm - motorcycle over 125 ccm - motorcycle with side car	- car - minibus - bus & trolley bus - delivery van - lorry - articulated lorry up to 3,5 t - articulated lorry over 3,5 t - tractor - work machine - tank lorry	- pedestrian

Figure a1.4 Evolution of severely injured casualties

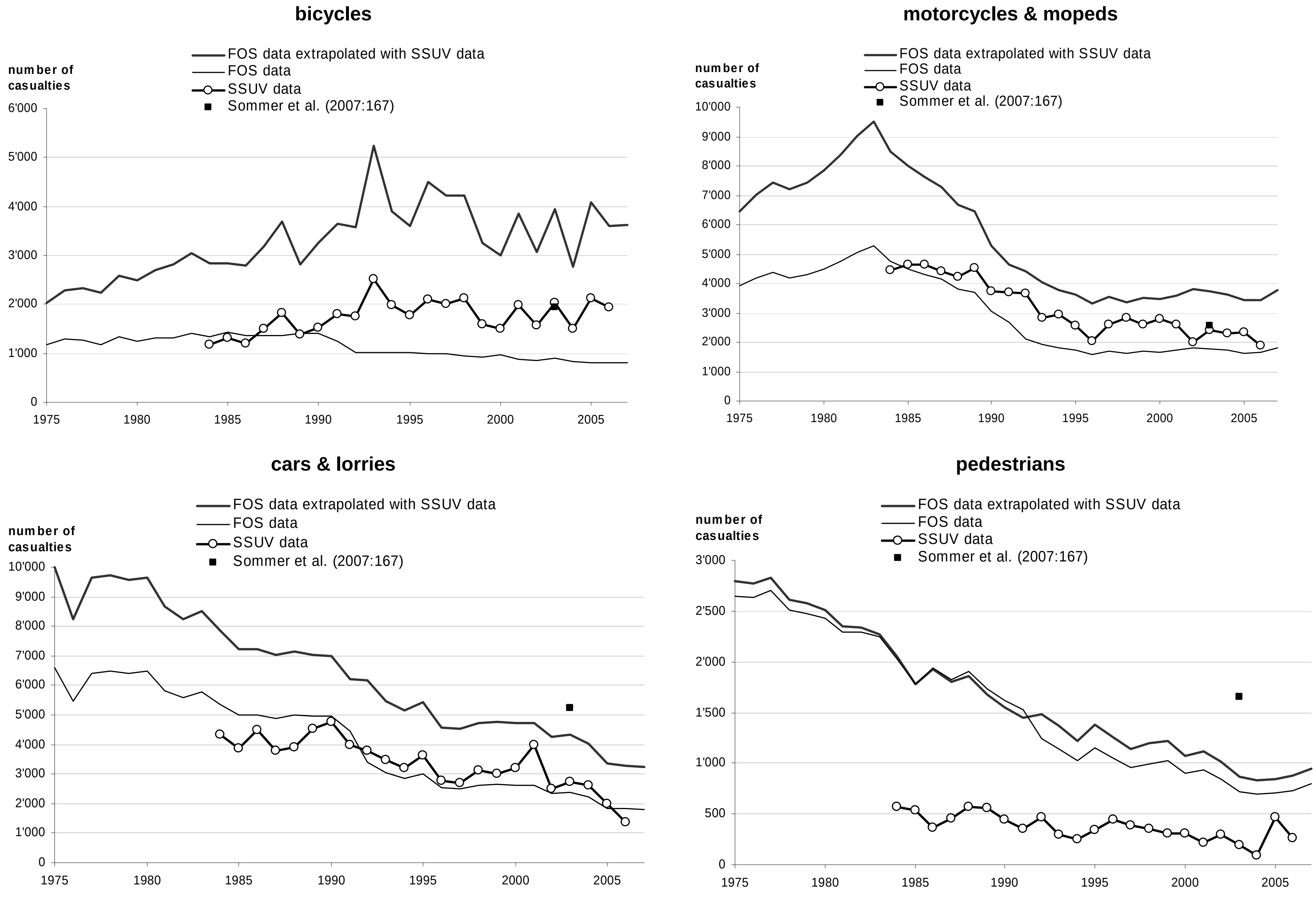


Figure a1.5 Evolution of slightly injured casualties

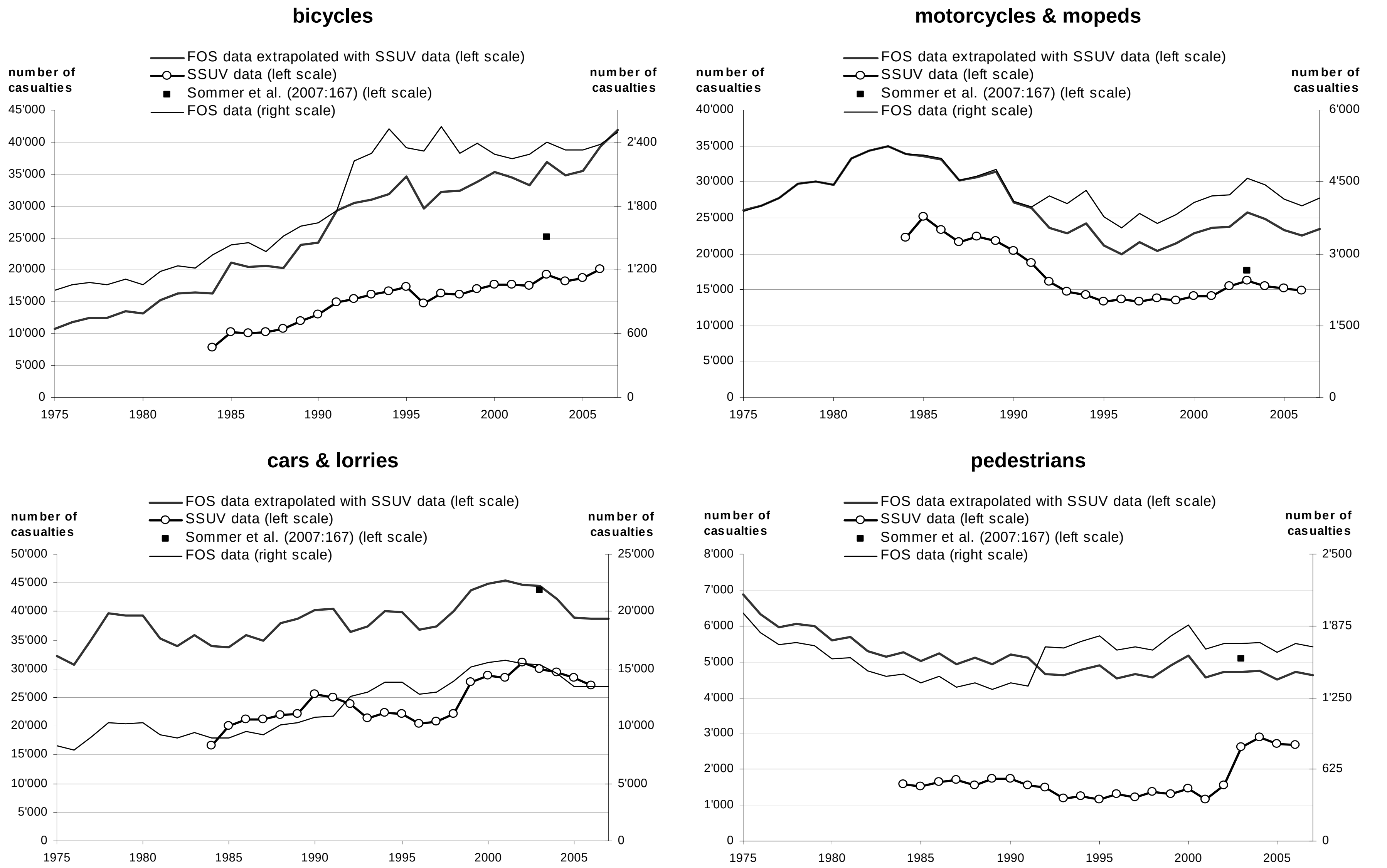


Figure a1.6 Evolution of all casualties except fatalities

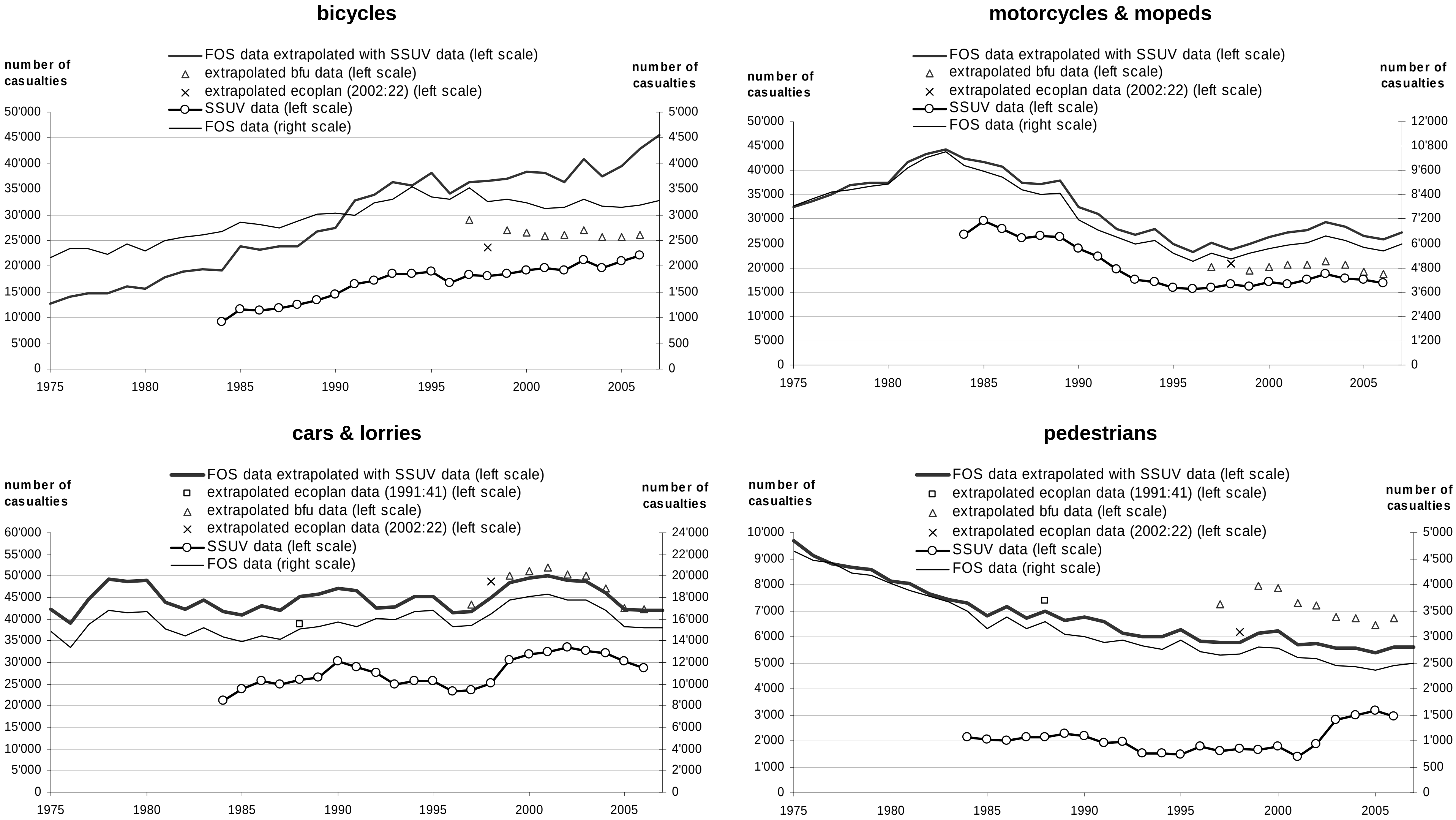
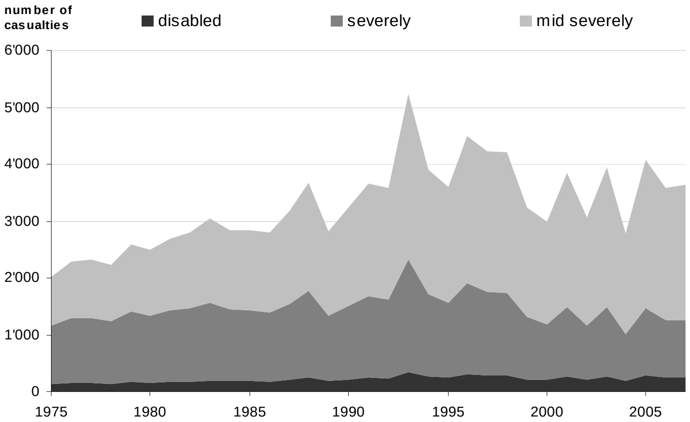
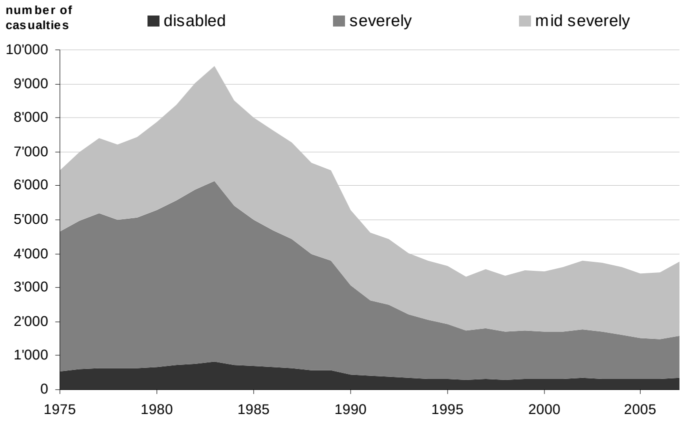


Figure a1.7 Division of the severely injured FSO category into permanently disabled, severely and moderately injured

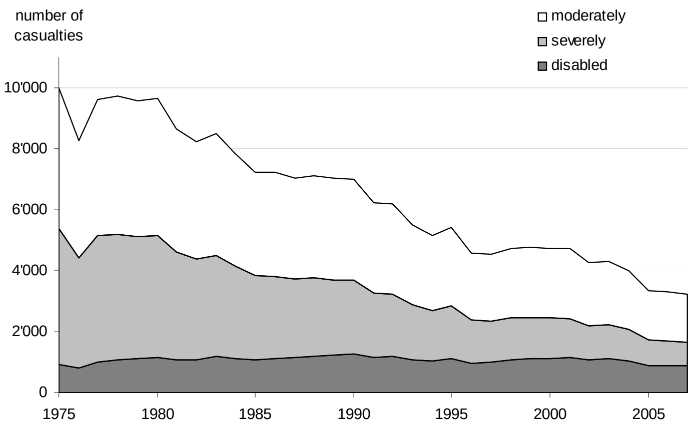
bicycles



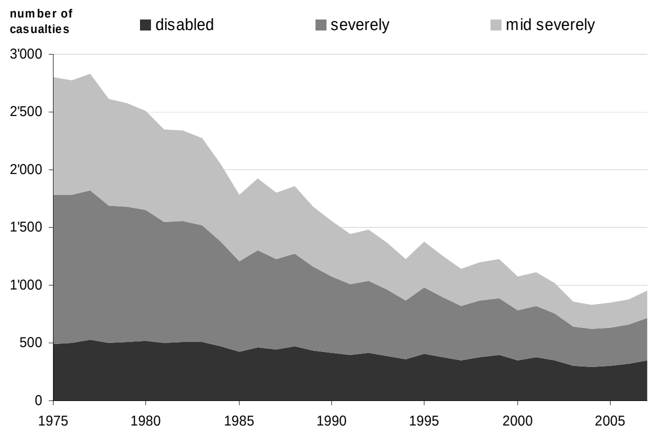
motorcycles & mopeds



cars & lorries



pedestrians



Appendix 2: Procedure of calculation of years lost due to disability

We received the collective absolute and relative numbers of types of injuries and parts of the body affected for each injury and road user category from the SSUV. The numbers are only from those insured by the SUVA. The others could not be taken into account, because the days spent in hospital, which are the basis for our injury categorisation, are not available for those (see section 2.1). We assume that the proportions of the types of the injuries and parts of the body affected are the same for those insured by SUVA as those insured by other UVG-insurers and as the non-insured (non-employed).

The SSUV provided us data for three different time spans: 1987-1991, 1992-1996, and 2002-2006. We multiplied the proportions drawn from the years 1987-1991 with the avoided casualties to calculate avoided year lost due to disability (YLD) for the years 1975-1991. Proportions drawn from the years 1992-1996 were used to calculate avoided YLD for the years 1992-1999. Finally, we used proportions drawn from the years 2002-2006 to calculate avoided YLD for the years 2000-2007.

As an illustrative example table a2.1 shows the proportions of the severely injured bicycle riders drawn from the years 2002-2006. It shows for instance that 10% of the severely injured bicycle riders suffered a fractured hip.

As shown in section 3.3, it was challenging to allocate each type of injury on each part of the body a separate disability weight (DW) and duration of disability (L). The data reported by the SSUV is much more detailed than the DWs and Ls reported by the GBD study. Within some types of injuries the DWs and Ls of the GBD study differ between short- and long-term. We assume that only those receiving a disability pension suffer from a long-term disability and that their disability is therefore life long. That is why we used the short-term DWs for the slightly, moderately and severely injured (table a2.2), while the long-term DWs were only used for those receiving a disability pension (table a2.3). Table a2.4 shows the average duration of the disability until remission (L). These Ls are only used for the short-term injuries (slightly, moderately and severely injured) while the L for the permanently disabled equals the life expectancy at the time of the accident and is calculated the same way as the life expectancy in the case of the YLL (see section 3.3).

We did not apply two concepts which were part of the original GBD study. The first is age weighting. In the GBD study less weight (i.e. smaller DWs) is given to years lived at young and older ages. But in the case of injuries the DWs only slightly differ at some very few injuries (e.g. fractured skull).[53]

The second is the differentiation between treated and untreated cases. Not only because the untreated cases are not part of the SSUV data, have we assumed that every injury, severe enough to have a DW, is treated in Switzerland. In the GBD study the assumption is made that only 80-95% of all injuries are treated in estab-

[53] The GBD study was updated twice (2001-2 and 2004). In the update 2001-2 age weighting was not applied.

lished market economies (Murray and Lopez 1996:418). But in any event, in the case of injuries the DWs again only slightly differ at some very few injuries (e.g. injured nerves).

Whenever possible, DWs and Ls from the GBD study were adopted. There are injuries where no or ambiguous DWs and Ls are available. The following list shows these DWs and Ls and the motivation of our final decisions.

- The GBD study reports different DWs and Ls for amputations. Unfortunately the SSUV data do not report if a limb was amputated. One could assume the following: Every case reported as permanently disabled due to for example a fractured lower leg could actually be due to the amputation of the leg. We consider this assumption to be too dim and therefore can not take amputations into account. We thus underestimate the actual avoided DALYs.
- According to the GBD study some percentage of some injuries (e.g. 5% of fractured femur) are life long. We do not account for these percentages as we assume that they are already represented by the percentages of the permanently disabled reported by the SSUV.
- Murray and Lopez (1996) point out that the DWs for several fractures (e.g. vertebral column, shoulder, kneecap) are only short-term. Long-term DWs are missing. However, the SSUV data shows that some disability pensions were granted due to those injuries. Polinder et al. (2007) do not differentiate between short-and long-term DWs and we therefore adopt the short-term DWs for the long-term.
- DWs for long-term fractured skull and intracranial injury are age-weighted: DWs are higher for those older than 59 (0.404 vs. 0.350). We use a weighted average under the assumption that those older than 59 represent a fifth of the total casualties: (0.404 + 4 x 0.350)/5 = 0.361
- We adopt the DW and L of fractured pelvis for the fractures of trunk, back and fundament.
- DWs of fractured shoulder or upper arm (clavicle, scapula, or humerus) are also age-weighted: (0.153 if age <15, 0.136 else). Again we use a weighted average under the assumption that those younger than 15 represent a fifth of total casualties (0.153 + 4 x 0.136)/5 = 0.139)
- According to Polinder et al. (2007:27) the Ls of fractured wrist and hand bones are different (0.112 vs. 0.070). In the SSUV data these parts of the body are in the same category. Since we do not know the actual prevalence and Murray und Lopez (1996) do not report a separate DW or L for fractured wrist, we use the lower value of L (0.070).
- DW and L for fractured hips are adopted from Polinder et al. (2007), who refer to the GBD study, although the authors of that study do not publish a DW or L for fractured hips.

- DWs and Ls for fractured lower limb and ankle are different (0.271 vs. 0.196 and 0.179 vs. 0.146), but these parts of the body are in the same category in the SSUV data. We assume the prevalence is equal and use the mean value of the two DWs and Ls.
- No DWs and Ls are available for fractures of cervix, rest of head and "other and several not particularly specified". We set the DW to 0. The prevalence is low (<0.1%).
- No DWs and Ls for strains and ruptures of tendons are available. In the categorisation of SSUV, this type of injury is listed together with sprains. We adopt the DW and L of sprains for those types of injuries. DW and L for the rupture of the meniscus are also missing. We assume that this type of injury is most similar to a rupture of tendons and also adopt the DW and L for sprains. Because we assume that ruptures of tendons or of the meniscus are more severe (i.e. generating a bigger loss of quality of life) than sprains, we think this adaptation of the DW and L is conservative.
- Dislocations of other parts of the body than shoulder, elbow or hip receive the same DW (0.074) and L (0.035). We thereby follow the Australian Burden of Disease & Injury study (Mathers et al. 1999:201).
- The category *intracranial, neural, interior or spinal injury* is rather unfortunately combined, since these injuries have highly varying DW. Interior injury, listed as a short-term disability has a DW of 0.208, while neural injuries, listed as long-term injuries, have a DW of 0.064. The terms *intracranial and spinal* are by definition easy to locate *(inside the skull* and *inside the vertebral column)*. However the corresponding DWs are only available for short-term intracranial (0.359) and long-term spinal injuries (0.725). For all the parts of the body missing a DW we use the lowest value (i.e. 0.208 for short-term injuries and 0.064 for long-term injuries).
- A DW for superficial injuries is only reported in the Dutch study (Haagsma et al. 2008:7). The value is very low (0.005) and 75% of the individuals were not willing to trade some lifetime in order not to suffer this kind of injury (i.e. reported a DW of 0). Polinder et al. (2007:27) do not take this injuries into account due to the missing DW. Although 5% of all short-term injuries in our data are superficial, we do not calculate any YLD for this type of injury (i.e. set the DW to 0).
- DWs and Ls for burns vary by the area burnt. We do not have any information on how much of the skin was burnt. As Polinder et al. (2007:27) we do not calculate any YLD for this type of injury (thereby foregoing only 0.5% of all short-term injuries).
- For eye injuries we use the DW and L of open wounds (0.108 and 0.024, respectively), thereby following the Australian study (Mathers et al. 1999:201) and Polinder et al. (2007:27). We also use these values for the category *piercing with foreign particles* because we assume that piercing with a foreign par-

ticle yields an open wound. Murray and Lopez (1996) report a DW for lifelong injury to eyes, which is age-weighted (between 0.298 and 0.301). We use the mean value (0.300) for long-term injuries to the eye in the category “other & not particularly specified”.

- We do not calculate any YLD for the following two categories: *poisoning, toxic effects, insect sting* and *complications & long-term consequences*. There is a DW for poisoning and the SSUV reports some accidents in this category (0.7%). But because the DW is exceptionally high (0.608) and we consider it implausible to include this category into the evaluation of road accidents, we do not apply it. We could not find a DW for the category *complications & long-term consequences*. The decision to drop this category affects less than 1% of all the short-term injuries.
- We could have used the DW of 0.149 for the category *other & not particularly specified* injury. Mathers et al. (1999:202) use it as the average weight over all injuries suffered in a road accident. We consider this value rather big and because the authors do not report the used L, we do not calculate YLD for this category, although thereby foregoing 6% of all and 2.6% of long-term injuries.
- For all other injuries and parts of the body in the matrix no DWs or Ls were necessary, since there were no cases reported in all the years.

Table a2.1 Proportion of different type of injury and of different parts of the body from SSUV dataset (Example: severely injured bicycle riders)

type of injury / injured part of the body	fractures	rupture of the meniscus	dislocation	sprains, strain, rupture of tendon	intracranial, neural, interior or spinal injury	open wounds	superficial injury	bruise, crush	burns, chemical burn	poisoning, toxic effects, insect sting	piercing with foreign particles	complications & long-term consequences	other & not particularly specified	**total**
skull, brain	4.1	0	0	0	7.6	0	0	0	0	0	0	0	0	11.8
face, facial bones, nose, ears	1.4	0	0	0	0	0	0	0	0	0	0	0	0	1.4
eyes, lid, ocular adnexa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cervix, rest of head or not particularly specified	0	0	0	0	0.1	0	0	0	0	0	0	0	0.1	0.2
vertebral column	9.0	0	0	0.1	0	0	0	0	0	0	0	0	0	9.1
trunk, back and fundament	1.7	0	0	0	4.7	0	0	0	0	0	0	0	0	6.5
shoulder, upper arm	8.9	0	3.0	4.4	0	0	0	0	0	0	0	0	0	16.3
forearm, elbow	14.2	0	0	0	0	0	0	0	0	0	0	0	0	14.2
wrist, hand, finger	1.4	0	0.1	0.1	0	0	0	0	0	0	0	0	0.1	1.7
upper limb, not particularly specified	0	0	0	1.5	0.1	0	0	0	0	0	0	0	0	1.6
hip	10.0	0	1.4	0	0	0	0	0	0	0	0	0	0	11.4
femur	2.9	0	0	0	0	0	0	0	0	0	0	0	0	2.9
knee, kneecap	1.5	0	0	2.8	0	0	0	0	0	0	0	0	0	4.3
lower leg, ankle	6.0	0	4.1	0	0	0	0	0	0	0	0	0	0	10.1
foot, toe	1.4	0	0.1	0	0	0	0	0	0	0	0	0	0	1.6
lower limb, not particularly specified	0	0	0	2.8	0	1.4	0	0	0	0	0	0	0	4.2
other and several not particularly specified	0	0	0	0	1.4	0	0	0	0	0	0	0	1.4	2.8
whole body (systemic effects)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total	62.8	0	8.7	11.6	13.9	1.4	0	0	0	0	0	0	1.6	100

Table a2.2 Short-term DW used for slightly, moderately and severely injured

Disability weights (DW) (short-term) *used for slightly, mid-severly, and severly injured*

type of injury / injured part of the body	fractures	rupture of the meniscus	dislocation	sprains, strain, rupture of tendon	intracranial, neural, interior or spinal injury	open wounds	superficial injury	bruise, crush	burns, chemical burn	poisoning, toxic effects, insect sting	piercing with foreign particles	complications & long-term consequences	other & not particularly specified
1 skull, brain	**0.431**				**0.359**								
2 face, facial bones, nose, ears	**0.223**		*0.074*	**0.064**		**0.108**							
3 eyes, lid, ocular adnexa						**0.108**	*0.000*	**0.218**			*0.108*		
4 cervix, rest of head or not particularly specified	*0.000*				*0.208*	**0.108**	*0.000*	**0.218**	*0.000*		*0.108*		*0.000*
5 vertebral column	**0.266**		*0.074*	**0.064**	*0.208*								
6 trunk, back and fundament	*0.247*		*0.074*	**0.064**	*0.208*	**0.108**	*0.000*	**0.218**	*0.000*				*0.000*
7 shoulder, upper arm	*0.139*		**0.074**	**0.064**		**0.108**	*0.000*	**0.218**					*0.000*
8 forearm, elbow	**0.180**		**0.074**	**0.064**				**0.218**					
9 wrist, hand, finger	**0.100**		*0.074*	**0.064**		**0.108**	*0.000*	**0.218**	*0.000*				*0.000*
10 upper limb, not particularly specified				**0.064**	*0.208*	**0.108**	*0.000*	**0.218**	*0.000*				*0.000*
11 hip	*0.372*		**0.074**	**0.064**				**0.218**					
12 femur	**0.372**							**0.218**					*0.000*
13 knee, kneecap	**0.271**	*0.064*	*0.074*	**0.064**				**0.218**					
14 lower leg, ankle	*0.234*		*0.074*	**0.064**				**0.218**					*0.000*
15 foot, toe	**0.077**		*0.074*	**0.064**		**0.108**	*0.000*	**0.218**					*0.000*
16 lower limb, not particularly specified				**0.064**		**0.108**	*0.000*	**0.218**	*0.000*				*0.000*
17 other and several not particularly specified	*0.000*			**0.064**	*0.208*	**0.108**	*0.000*	**0.218**	*0.000*		*0.108*		*0.000*
18 whole body (systemic effects)										*0.000*		*0.000*	*0.000*

bold: adopted from GBD study (Murray and Lopez 1996)

italic: There doesn‘t exist any weight for the specific injury (on this part of the body), we therefore had to make conservative assumptions or don‘t consider it (i.e. set DW to 0), see text for more info.

blank: injury didn‘t happen in this category

Table a2.3 Long-term DW used for "disability pension" category

Disability weights (DW) (long-term) — type of injury / injured part of the body	fractures	rupture of the meniscus	dislocation	sprains, strain, rupture of tendon	intracranial, neural, interior or spinal injury	open wounds	superficial injury	bruise, crush	burns, chemical burn	poisoning, toxic effects, insect sting	piercing with foreign particles	complications & long-term consequences	other & not particularly specified
	used for disability pension												
1 skull, brain	*0.361*				*0.361*								
2 face, facial bones, nose, ears	**0.223**			**0.064**		**0.108**							
3 eyes, lid, ocular adnexa						**0.108**							**0.300**
4 cervix, rest of head or not particularly specified					*0.064*			**0.218**					*0.000*
5 vertebral column	*0.266*		*0.074*	**0.064**	**0.725**		*0.000*						
6 trunk, back and fundament	*0.247*			**0.064**	**0.725**	**0.108**		**0.218**					*0.000*
7 shoulder, upper arm	*0.139*		*0.074*	**0.064**		**0.108**		**0.218**					*0.000*
8 forearm, elbow	*0.180*		*0.074*	**0.064**				**0.218**					*0.000*
9 wrist, hand, finger	**0.100**		*0.074*	**0.064**		**0.108**							*0.000*
10 upper limb, not particularly specified				**0.064**	*0.064*	**0.108**							*0.000*
11 hip	*0.272*		*0.074*	**0.064**				**0.218**					
12 femur	**0.272**												*0.000*
13 knee, kneecap	*0.271*	*0.064*	*0.074*	**0.064**				**0.218**					*0.000*
14 lower leg, ankle	*0.234*		*0.074*	**0.064**									*0.000*
15 foot, toe	*0.077*		*0.074*	**0.064**									*0.000*
16 lower limb, not particularly specified				**0.064**		**0.108**							*0.000*
17 other and several not particularly specified	*0.000*				**0.064**	**0.108**					*0.108*		
18 whole body (systemic effects)													*0.000*

bold: adopted from GBD study (Murray and Lopez 1996)

italic: There doesn't exist any weight for the specific injury (on this part of the body), we therefore had to make conservative assumptions or don't consider it (i.e. set DW to 0), see text for more info.

blank: injury didn't happen in this category

Table a2.4 Duration of disability used for slightly, moderately and severely injured

average duration of the disability until remission in years (L) *used for slightly, mid-severly, and severly injured*

type of injury / injured part of the body	fractures	rupture of the meniscus	dislocation	sprains, strain, rupture of tendon	intracranial, neural, interior or spinal injury	open wounds	superficial injury	bruise, crush	burns, chemical burn	poisoning, toxic effects, insect sting	piercing with foreign particles	complications & long-term consequences	other & not particularly specified
1 skull, brain	**0.107**				**0.067**								
2 face, facial bones, nose, ears	**0.118**		*0.035*	**0.038**		**0.024**							
3 eyes, lid, ocular adnexa						**0.024**	*0.000*	**0.094**			*0.024*		
4 cervix, rest of head or not particularly specified	*0.000*				*0.042*	**0.024**	*0.000*	**0.094**	*0.000*		*0.024*		*0.000*
5 vertebral column	**0.140**		0.035	**0.038**	*0.042*								
6 trunk, back and fundament	*0.126*		0.035	**0.038**	*0.042*	**0.024**	*0.000*	**0.094**	*0.000*				*0.000*
7 shoulder, upper arm	**0.112**		**0.035**	**0.038**		**0.024**	*0.000*	**0.094**					*0.000*
8 forearm, elbow	**0.112**		**0.035**	**0.038**				**0.094**					
9 wrist, hand, finger	*0.070*		0.035	**0.038**		**0.024**	*0.000*	**0.094**	*0.000*				*0.000*
10 upper limb, not particularly specified				**0.038**	*0.042*	**0.024**	*0.000*	**0.094**	*0.000*				*0.000*
11 hip	*0.139*		**0.035**	**0.038**				**0.094**					
12 femur	**0.139**							**0.094**					*0.000*
13 knee, kneecap	**0.090**	*0.038*	*0.035*	**0.038**				**0.094**					
14 lower leg, ankle	*0.093*		*0.035*	**0.038**				**0.094**					*0.000*
15 foot, toe	**0.073**		*0.035*	**0.038**		**0.024**	*0.000*	**0.094**					*0.000*
16 lower limb, not particularly specified				**0.038**		**0.024**	*0.000*	**0.094**	*0.000*				*0.000*
17 other and several not particularly specified	*0.000*			**0.038**	*0.042*	**0.024**	*0.000*	**0.094**	*0.000*		*0.024*		*0.000*
18 whole body (systemic effects)										*0.000*		*0.000*	*0.000*

bold: adopted from GBD study (Murray and Lopez 1996)

italic: There doesn‘t exist any L for the specific injury (on this part of the body), we therefore had to make conservative assumptions or don‘t consider it (i.e. set L to 0)

blank: injury didn‘t happen in this category

Appendix 3: Details of effectiveness estimation

This appendix contains details on the estimation procedure of the effectiveness of prevention measures described in section 5.3.

Two tables are presented for each type of road user:

1. A table listing the variables which according to our theoretical model might influence the evolution of the casualties of this type of road user.
2. A table with the results of the estimation procedures for the 5 categories of severity of injury, containing the estimated coefficients of the variables statistically significant in a 95% confidence interval.

Table a3.1 Summary statistics of explanatory variables

	mean	standard deviation	minimum	maximum	regional disaggregation of data
alcohol driver	364.606	260.061	54	1331	cantonal
bicycle pop	0.428	0.099	0.253	0.532	national
bike helmet quota	9.419	12.512	1	48	language region
car pop	42'920.18	8'139.62	23'235.90	60'476.29	cantonal
gdp	1.486	2.076	-6.96	4.2	national
moped helmet quota	52.798	37.133	9	96	national
moped pop	0.067	0.032	0.023	0.108	national
moto helmet quota	95.537	10.581	68.690	100.000	national
motorcycle pop	0.046	0.024	0.011	0.120	cantonal
mountain	11.173	16.032	0	52.5	cantonal
pop 18 to 24	0.095	0.012	0.080	0.111	national
pop over 70	0.098	0.009	0.077	0.113	national
pop under 18	0.213	0.020	0.186	0.261	national
safety belt quota	64.695	20.504	0	88	language region
urban	0.184	0.218	0	0.883	cantonal

Table a3.2 Variables in model car and lorry occupants

type of variable	name of variable	description of variable
	trend	time trend
confounder	car pop	number of vehicles per 100'000 residents
	car pop sq	number of vehicles per 100'000 residents (squared)
	urban	urbanity of canton (fraction of population living in cities)
	mountain	geography of canton (fraction of unproductive surface)
	gdp	year on year change of real GDP
	pop 18 to 24	fraction of population of age over 17 and under 24
	pop over 70	fraction of population over the age of 69
prevention	police	number of police officers per 100’000 residents
	alcohol driver	road accidents with suspect of alcohol consumption (number of cases per 100’000 residents)
	safety belt quota	safety-belt wearing quota
	law speed	introduction of lower speed limits
	law all	index of laws and regulations which should reduce the severity of accidents for all road users
	law car	index of laws and regulations which should reduce the severity of accidents for car and lorry occupants
	measures 2005	package of road safety measures introduced in 2005

Table a3.3 Estimation results for model car and lorry occupants

Explained variable: log of casualties per 100'000 residents						
	death	permanent disability	severely injured	moderately injured	slightly injured	
intercept	0.9510	2.3831	4.7028	4.9206	4.8450	
	0.4226	0.0689	0.0885	0.0946	0.5465	
trend	-0.0172	0.0051	-0.0413	-0.0185	0.0023	*n.s.*
	0.0051	0.0020	0.0022	0.0022	0.0061	
car pop	0.0001		0.0000	0.0000		
	0.0000		0.0000	0.0000		
car pop sq	0.0000		0.0000	0.0000		
	0.0000		0.0000	0.0000		
urban	-1.8043	-0.7810	-0.7924	-0.7988	-0.2657	
	0.1045	0.0629	0.0627	0.0629	0.0670	
mountain	0.0076	0.0041	0.0041	0.0047	0.0010	
	0.0014	0.0009	0.0009	0.0009	0.0670	
gdp		0.0148	0.0143	0.0145	0.0211	
		0.0059	0.0059	0.0059	0.0074	
pop over 70			-5.7665	-6.5365	19.3189	
			0.8115	0.9450	6.9731	
alcohol driver	0.0082	0.0068	0.0066	0.0065	0.0016	
	0.0008	0.0005	0.0005	0.0005	0.0006	
safety belt quota	-0.0080	-0.0052	-0.0055	-0.0057	-0.0104	
	0.0014	0.0009	0.0009	0.0009	0.0010	
law speed			-0.0198	-0.0301		
			0.0049	0.0057		
measures 2005	-0.2259	-0.2167	-0.1866	-0.1568	-0.2045	
	0.0805	0.0511	0.0509	0.0510	0.0546	
"R2"	0.663	0.556	0.835	0.735	0.296	
n	585	585	585	585	585	

SURE estimation.
Standard errors below value of coefficient.
In estimation procedure variables with a statistical significance below 5% are dropped (except intercept)
n.s.: non statistically significant in 95% confidence interval
estimation with Stata 9.2

Table a3.4 Variables in model motorcycle and moped riders

type of variable	name of variable	description of variable
	trend	time trend
confounder	motorcycle pop	number of motorcycles per resident
	moped pop	number of mopeds per resident
	urban	urbanity of canton (fraction of population living in cities)
	mountain	geography of canton (fraction of unproductive surface)
	gdp	year on year change of real GDP
	pop 18 to 24	fraction of population of age over 17 and under 24
	pop over 70	fraction of population over the age of 69
prevention	police	number of police officers per 100'000 residents
	alcohol driver	road accidents with suspect of alcohol consumption (number of cases per 100'000 residents)
	moto helmet quota	motorcycle helmet wearing quota
	moped quota	moped helmet wearing quota
	law speed	introduction of lower speed limits
	law all	index of laws and regulations which should reduce the severity of accidents for all road users
	campaigns all	index for information campaigns aimed at all road users
	measures 2005	package of road safety measures introduced in 2005
	campaigns moto	index for information campaigns aimed at motorcycle and moped riders

Table a3.5 Estimation results for model motorcycle and moped riders

Explained variable: log of casualties per 100'000 residents						
	death	permanent disability	severely injured	moderately injured	slightly injured	
intercept	2.7093	-0.3601	1.5227	0.5521	3.7074	
	0.0555	0.1639	0.1637	0.1636	0.2173	
trend	-0.0400	-0.0117	-0.0308	0.0137	0.0041	n.s.
	0.0015	0.0049	0.0049	0.0049	0.0065	
motorcycle pop		18.8785	18.7487	18.7221	17.6319	
		1.0376	1.0376	1.0378	1.3192	
moped pop		20.1967	21.1164	21.8918	17.7315	
		1.3508	1.3460	1.3475	1.7138	
urban	-0.8855	0.1615	0.1599	0.1596	0.7447	
	0.0596	0.0496	0.0496	0.0496	0.0630	
mountain	0.0066	0.0035	0.0034	0.0034	0.0021	
	0.0009	0.0007	0.0007	0.0007	0.0008	
pop 18 to 24				0.3175		
				0.1041		
moto helm quota		-0.0006				
		0.0001				
moped helm quota		-0.0006	-0.0002			
		0.0000	0.0000			
alcohol_driver	0.0055	0.0022	0.0023	0.0023		
	0.0005	0.0004	0.0004	0.0004		
measures 2005	-0.1276		-0.0357	-0.0404	-0.1347	
	0.0497		0.0021	0.0024	0.0521	
"R2"	0.7629	0.7871	0.8743	0.6463	0.4623	
n	594	594	594	594	594	

SURE estimation.
Standard errors below value of coefficient.
In estimation procedure variables with a statistical significance below 5% are dropped (except intercept)
estimation with Stata 9.1

Table a3.6 Variables in model cyclists

type of variable	name of variable	description of variable
	trend	time trend
confounder	bicycle pop	number of bicycles per resident
	urban	urbanity of canton (fraction of population living in cities)
	mountain	geography of canton (fraction of unproductive surface)
	gdp	year on year change of real GDP
	pop over 70	fraction of population over the age of 69
	pop 18 to 24	fraction of population of age over 17 and under 24
	pop under 18	fraction of population under the age of 18
prevention	police	number of police officers per 100’000 residents
	alcohol driver	road accidents with suspect of alcohol consumption (number of cases per 100’000 residents)
	law speed	introduction of lower speed limits
	law all	index of laws and regulations which should reduce the severity of accidents for all road users
	campaigns all	index for information campaigns aimed at all road users
	measures 2005	package of road safety measures introduced in 2005
	bike helmet quota	percentage of cyclists wearing a helmet

Table a3.7 Estimation results for model cyclists

Explained variable: log of casualties per 100'000 residents					
	death	permanent disability	severely injured	moderately injured	slightly injured
intercept	0.2889	0.7136	2.8428	2.8459	4.1210
	0.0528	0.0447	0.0447	0.0028	0.0937
trend	-0.0273	0.0280	0.0083	0.0417	
	0.0030	0.0034	0.0034	0.0034	
bicycle pop					3.5907
					0.2125
urban					0.5036
					0.0860
pop over 70				-2.5498	
				0.1392	
bike helmet quota		-0.0161	-0.0181	-0.0173	
		0.0028	0.0028	0.0028	
"R2"	0.149	0.117	0.434	0.229	0.373
n	490	490	490	490	490

SURE estimation.
Standard errors below value of coefficient.
In estimation procedure variables with a statistical significance below 5% are dropped (except intercept)
estimation with Stata 9.1

Table a3.8 Variables in model pedestrians

type of variable	name of variable	description of variable
	trend	time trend
confounder	car pop	number of vehicles per 100'000 residents
	car pop sq	number of vehicles per 100'000 residents (squared)
	urban	urbanity of canton (fraction of population living in cities)
	mountain	geography of canton (fraction of unproductive surface)
	gdp	year on year change of real GDP
	pop over 70	fraction of population over the age of 69
	pop 18 to 24	fraction of population of age over 17 and under 24
	pop under 18	fraction of population under the age of 18
prevention	police	number of police officers per 100’000 residents
	alcohol driver	road accidents with suspect of alcohol consumption (number of cases per 100’000 residents)
	law speed	introduction of lower speed limits
	law all	index of laws and regulations which should reduce the severity of accidents for all road users
	campaigns all	index for information campaigns aimed at all road users
	measures 2005	package of road safety measures introduced in 2005
	campaigns pedestrians	index for information campaigns aimed at pedestrians
	law pedestrian	index of laws and regulations which should reduce the severity of accidents for pedestrians

Table a3.9 Estimation results for model pedestrians

Explained variable: log of casualties per 100'000 residents					
	death	permanent disability	severely injured	moderately injured	slightly injured
intercept	0.0207	0.4620	0.6130 *n.s.*	0.6467	4.2243
	0.5877	0.3078	0.3089	0.3087	0.0296
trend	-0.0423	-0.0088	-0.0227	-0.0337	-0.0147
	0.0049	0.0031	0.0031	0.0031	0.0013
urban		0.8363	0.8362	0.8362	1.2561
		0.0481	0.0481	0.0481	0.0594
mountain					0.0052
					0.0008
pop under 18	5.2383	4.1800	7.3417	6.4614	
	2.2582	1.1780	1.1796	1.1790	
pop 18 to 24			3.9647	2.7743	
			0.1119	0.1049	
pop over 70			-5.0338	-3.9424	
			0.2125	0.1992	
alcohol driver	0.0038	0.0045	0.0045	0.0045	
	0.0007	0.0004	0.0004	0.0004	
law speed		-0.0952	-0.0962	-0.0962	
		0.0363	0.0364	0.0364	
"R2"	0.545	0.591	0.820	0.850	0.500
n	582	582	582	582	582

SURE estimation.
Standard errors below value of coefficient.
In estimation procedure variables with a statistical significance below 5% are dropped (except intercept)
n.s.: non statistically significant in 95% confidence interval
estimation with Stata 9.1

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