# Relationships between road safety, safety measures and external factors

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INSTITUTE FOR
ROAD SAFETY RESEARCH

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A scan of the literature in view of model development and topics for further research

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Tony Churchill, MSc & dr. Yvette van Norden
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# Report documentation


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# Summary

The purpose of this literature scan is to examine where literature on the effect of external factors and road safety measures on road safety exists and where it is lacking. This scan will help us to decide which factors to include in a comprehensive road safety model as SWOV is working on, and at the same time identifies promising future research topics. The report is divided into two main road safety topics; firstly, the external influences which are not directly related to road safety management but do affect road safety and, secondly, road safety measures which aim to improve road safety.

External influences that affect road safety have been reviewed by SWOV in six exploration studies; the factors that have been identified by SWOV as relating to road safety are:
- Social and cultural factors
- Spatial planning and policy
- Public health
- Economy
- Mobility
- Technology and environmental protection
- Other factors

As a response to the generated road safety situation the mitigating impact of measures to improve road safety are also of interest in order to model road safety, for both descriptive and predictive purposes. For this reason the influence of individual road safety measures also needs to be identified to improve estimates of road safety. The SWOV book *The summit conquered* (*De top bedwongen* in Dutch; SWOV, 2007) incorporated a selection of the most commonly studied three external influences: demographics, mobility, and modal split, which are the point of departure for the SWOV model of road safety, and goes on to list and describe the various road safety measures that have been applied in the Netherlands during the period 1950 to 2005. Road safety measures can be grouped into broad categories as follows:
- Infrastructural measures
  - Physical measures
  - Road rules
- Vehicle safety
  - Primary safety
  - Secondary safety
- Enforcement, promotion, and education

SWOV wants to understand certain developments in how society could influence or even had influenced road safety, and also how the actions taken to improve road safety affect the resulting safety situation. Understanding of all of these relations is required to understand developments in road safety in the past and to obtain better predictions for future developments of road safety.

The purpose of this study is two fold. Firstly, the summary of known causal relationships between external influences and road safety measures,

respectively, and road safety outcomes in terms of casualties or collisions is presented. These relations can be used for the development of a road safety model. Secondly, knowledge gaps will be identified as well as future research possibilities. As research results fill knowledge gaps the road safety model can be improved with additional relations to safety outcomes, casualties or crashes.

The literature scan is presented largely in tabular format for easy reference by topic, and separated by external influences or road safety measures to compliment the structure of the external influence exploration studies and *The summit conquered*. To summarize the findings a table of available literature as well as knowledge gaps is provided. The report concludes with a short discussion.

This report is intended as a “quick” scan of the literature to guide initial efforts in model development and future research rather than a totally comprehensive literature review. Literature reviews in conjunction with future work are recommended to provide a more thorough and up to date view of the literature, and a specific focus on the details required for the selected model of road safety. In addition to being a scan of the literature this report may be useful as a framework for recording which developments have been included in the model, to which degree, and what remains to be done. Although the information contained in this report will be important in the determination of the areas in which to focus research, the framework for a transparent research selection tool remains an important next step.

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# 1. Introduction

## 1.1. Road safety and its influencing factors

Significant resources are invested annually in measures intended to improve road safety, while at the same time external factors such as mobility and demographics are constantly changing the state of road safety. To date a great deal of research has been focused on the effects of road safety investments but due to the complex and changing nature of road safety the wealth of information collected regarding road safety has not been translated into a comprehensive model of road safety; this is one of the ambitions of SWOV. This report summarizes literature regarding the effects of external influences and road safety measures, where possible expressed in mathematical terms, with the aim of developing a road safety model including as many factors as possible, and also to highlight knowledge gaps in the literature. Identification of knowledge gaps, and barriers to closing these gaps, will be critical to define research questions and to meet the identified need to develop a set of explicit criteria for research project selection (QANU, 2005).

Understanding the effects of road safety measures is important to ensure that positive experiences are carried forward, and that unsuccessful measures are discontinued. In order for this important evaluation of road safety measures to occur several important steps are required:

- Measure is evaluated
  - Possible barriers to evaluation are:
    - Methodological issues or small perceived effect
    - Data issues
    - Liability issues
    - Costs of the above
- Indicators of evaluation are relevant to road safety
- Evaluation findings are shared and applied

Although significant resources are invested in road safety measures the effectiveness of these expenditures may not be evaluated or the evaluations may be poorly designed or employ metrics which may not strongly reflect road safety.

The majority of measures have been studied, but in some cases not the direct effect on road safety; for example, retention and recall are commonly used indicators for the effect of advertising but remembering a road safety advertisement may not result in a behavioural change, which in turn results in fewer collisions or casualties. Many other measures related to road safety, such as enacted laws, are difficult to evaluate due to the interaction of enforcement and social change in response to the new laws.

If available, mathematical models of the relation of the measure to safety indicators or outcomes are desirable (such as safety performance functions or collision prediction models); otherwise, quoted collision or casualty reductions can be considered based on the study methodology and purpose.

The collection of known effects of measures can then be included (more extensively) in predictive or explanatory software.
The purpose of this literature scan is to examine where literature on the effect of external influences and road safety measures on road safety exists and where it is lacking. This scan will help us to decide which factors to include in a comprehensive road safety model as SWOV is working on. The complimentary aspect of this study is to identify research gaps in terms of road safety measures which have not been evaluated, or for which no mathematical relations or quoted resulting reductions can be found. This aspect of the research is potentially more challenging since there are likely methodological or data difficulties which prevented the analysis in the first place. In addition to the identification of these measures, therefore, potential research activities, data and methodology requirements of these activities, and outcomes will be proposed.

To this end the report is primarily a quick scan of the relevant literature, which will provide general relationships, or before and after estimates of the effect of the measure in some cases, and description of models and citations in others. SWOV wants to develop a model in which all external and mediating influences on road safety can be combined to understand and predict traffic *collisions* and *casualties*. The development of such a model requires quantified relationships between the explanatory variables included in the model and the resulting number of collisions or casualties. In all cases limitations of the literature will be identified in terms of what research remains for SWOV to develop the model.

This literature scan is not exhaustive, but does, however, attempt to highlight which topics have been related mathematically to road safety improvements and those for which less literature was found. In all cases the references listed in this report will form a starting point for future model development but should not be regarded as a definitive listing of studies on the measure.

*Section 1.2* will report the literature scan methodology and discuss the types of studies considered and the use of the various types of available mathematical relations for the development of a road safety model. Templates of the tables used for the compilation of findings are also described. *Chapter 2* reports the findings of the effect of the external influences on road safety, as well as the knowledge gaps in mathematical relations to casualties and collision. Similarly, in *Chapter 3* the findings for road safety measures are presented. *Chapter 4* gives a short overview of the findings presented in *Chapter 2* and *3*. The report is concluded with a discussion on future research possibilities in *Chapter 5*.

### 1.1.1. *External influences and road safety measures*

The six SWOV reports which explore the influences of external factors present qualitative descriptions of the relation of the identified factors to risk and mobility. Mobility has been identified as a factor which resides in the domain of DVS/AVV, rather than SWOV, none the less, where possible effects on mobility will be discussed in terms of quantitative relations. The inventory of effects of external influences mainly builds on six SWOV exploration reports (written in Dutch with English summaries):

- *The influence of social and cultural factors on mobility and road safety*, Schoon, C.C. (2005), SWOV report R-2005-7

- *The influence of spatial planning and policy on road safety*, Schoon, C.C. & Schreuders, M. (2006), SWOV report R-2005-14
- *Public health and road safety*, Amelink, M. (2006), SWOV report R-2005-16
- *Economics and road safety*, Wijnen, W. (2008), SWOV report R-2006-30
- *The effects of mobility on road safety*, Wijnen, W. & Houwing, S. (2008), SWOV report R-2006-31
- *Developments in technology and environmental care in the field of traffic and transport, with implications for road safety*, Schoon, C.C. (2008), SWOV report R-2008-4

Some factors/variables which do not fit into this classification will be considered as a separate category. Some examples of these factors are weather, time of the day and month.

*Chapter 2* reports the findings, in tabular format, of the effects of the external influences on road safety, as well as the knowledge gaps in mathematical relations to casualties and collisions. The structure of *Chapter 2* will reflect the layout of the exploration reports to allow convenient use of the reports together in future research.

The SWOV book *The summit conquered* also identifies some external factors, primarily demographics and mobility, and these will be woven into the discussion of the six external influences reports. Discussion of road safety measures is well developed in *'The summit'* and the literature review of known qualitative relations will be formed around this base. The inventory of road safety measures mirrors the compiled list of road safety measures identified in *The summit conquered* (SWOV, 2007) which is a summary of road safety in the Netherlands between 1950 and 2005.
*Chapter 3* reports the findings, in tabular format, of effects of road safety measures, as well as the knowledge gaps of mathematical relations to casualties and collisions. The structure of *Chapter 3* will mirror that of *The summit conquered* for clarity:

- Infrastructural measures
  - Physical measures
  - Road rules
- Vehicle safety
  - Primary safety
  - Secondary safety
- Enforcement, promotion, and education

This literature scan where possible will focus on Dutch literature, but where unavailable, international literature will also be surveyed. In all cases the applicability of the findings to the Dutch road system will be estimated and in cases where literature is present but the validity in the Netherlands is questionable the recommendation may be to undertake a similar study in the Netherlands.

### 1.1.2. *Modelling road safety*

SWOV is developing a model which will describe and predict the safety situation in the Netherlands based on known relationships to road safety. In order to accomplish this, the external influences which generate road safety

risks need to be known as well as the influences of measures to mediate these risks.

The road safety model is anticipated to be founded on the basis of driver demographics, mobility, road type, intersection type and further subdivisions of these based on the known effects of road safety measures. Therefore, the effects of the external influencing factors and road safety measures, where possible or appropriate, should be based on all of the higher level factors. For example, roundabouts are an intersection measure, but should also capture some relation to mobility (resulting changes in traffic volumes or travel times) and demographics of users (increased risk for older cyclists), as well as any other factors found to be important in the literature.

Preference will be given to mathematical relationships such as accident prediction models which relate the measure characteristics directly to collisions or casualties. However, despite the fact that accident prediction models give the 'best' mathematical relationships between measures and collisions and casualties, it can be hard to extend this from a local level to a national model. Alternatives are intermediate measures (e.g. speed changes) and safety performance indicators which can be used to quantitatively compare the performance of different facilities. Finally percentage changes as a result of before and after studies will be reported and limitations and possibilities for further research highlighted. Macroscopic models of economic and social factors are another possible source of information of the contribution of factors to changes in safety, these changes are generally presented as elasticities, i.e. change in dependent variable per percent change in the independent variable.

The combination of the literature scan for external influences and road safety measures into a single report is useful since these two research directions are converging on the road safety model and combination of the two topics is timely to ensure that future work can be combined easily into the initial forms of the road safety model.

Types of road safety models or effect measures encountered during the review of qualitative literature included:

- Before and after studies (Longitudinal analysis of individual sites)
- Cross section studies (Cohort analysis of similar sites)
- Collision Prediction Models (CPM) (Collision data regression analysis)
- Accident Prediction Models (APM) (Collision data regression analysis)
- Accident Modification Factors (AMF) (before/after or cross section studies)
- Road safety time series models including ARIMA (auto regressive moving average), DRAG (route demand, accident and severity), and State-space models.

Safety performance indicators are another mathematical development, but these tools are more appropriate for relative performance than prediction of collisions or casualties and the usefulness in terms of quantifying changes in collisions or casualties is unclear.

In this regard the goal of developing a comprehensive road safety model is the road safety research equivalent of the medical practice of epidemiology. Epidemiology identifies risk factors in the population, here the external influencing factors, and optimum treatments, or road safety measures.

External influencing factors are the starting point in understanding the development of risk and how this risk changes as a result of social changes. Similarly the interaction of road safety measures and safety outcomes in terms of road casualties will need to be understood. Previous studies regarding the effects of road safety measures may have been influenced by external factors which were uncontrolled and therefore form a part of the confounding influence and uncertainty in the results. This confounding can be removed by the explanation of these variations in terms of social factors. Interaction effects among external influencing factors and road safety measures are complex, multi-co-linearity may result in erroneous conclusions of cause and effect due to covariance of dependent variables. Careful analysis of the indicator variables will be required to avoid these unintended links.

There is a long history of road safety research and the complexity of the system seems to be the main barrier to understanding it. The amount of data required to sufficiently describe the system is enormous, and the interactions of the data also multi-faceted. Selection of measures to include for which data is available will likely be the first factors for inclusion to be followed by those for which research is possible and the potential benefits are the greatest.

In the SUNflower-report, Koornstra (2002) presented a target hierarchy for road safety influenced by external factors, see *Figure 1.1*. Extension of this picture with time by connection of several pyramids with time dependencies gives a conceptual model of the road safety system which is in some sense closely related to time series models. Within the external influencing factors and road safety measures the identified factors and measures which will be discussed in this paper are presented in *Figures 1.2* and *1.3*, for external influences and road safety measures respectively.

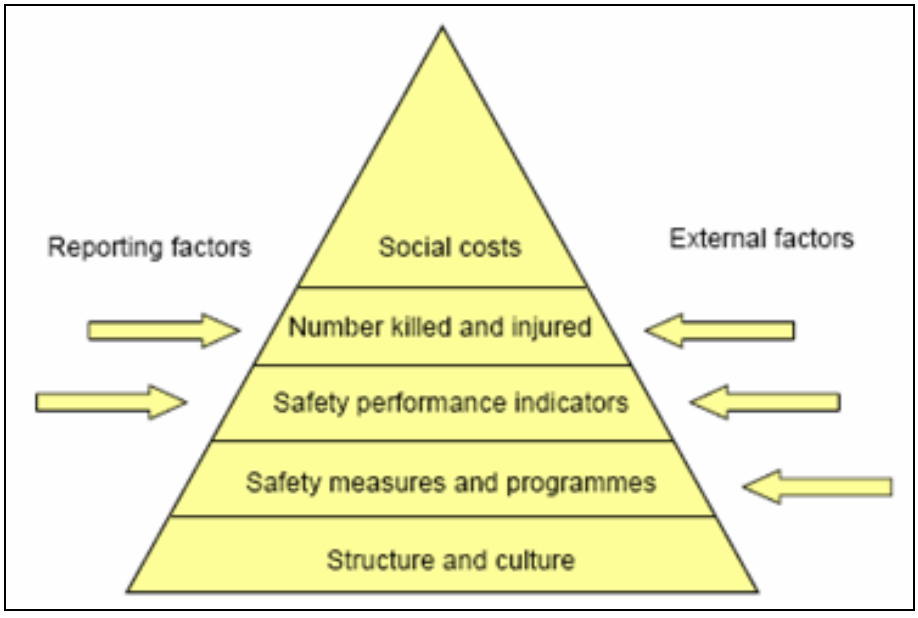


Figure 1.1. *SUNflower target hierarchy*

The time dependent relations among all of these external influencing factors, road safety measures and safety outcomes may be difficult to reveal, and an enormous task; the summary of literature of the factors and measures listed in *Figures 1.2* and *1.3* is a first step toward the ultimate goal. Path analysis may assist in the identification of the casual links among these factors. The inclusion of safety performance indicators (SPI's) will be beneficial in the future and warrant inclusion in the theoretical framework, but in the short term SPI's are of limited value in terms of prediction or explanation of collision outcomes. Continued collection of SPI's may also allow for more consistent modelling of road safety among European Commission nations.

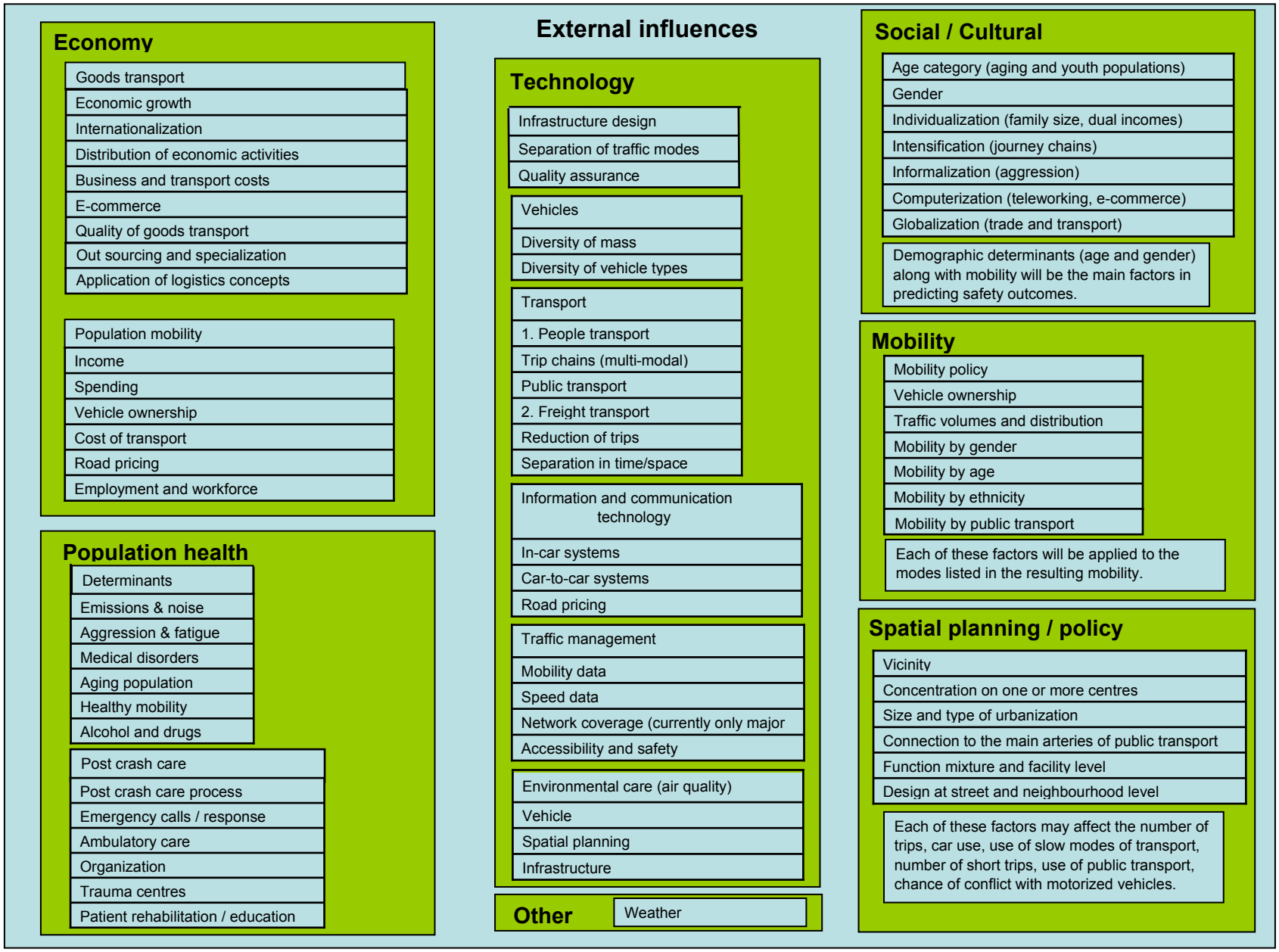


Figure 1.2. *External influences considered within prism theoretical model of road safety*

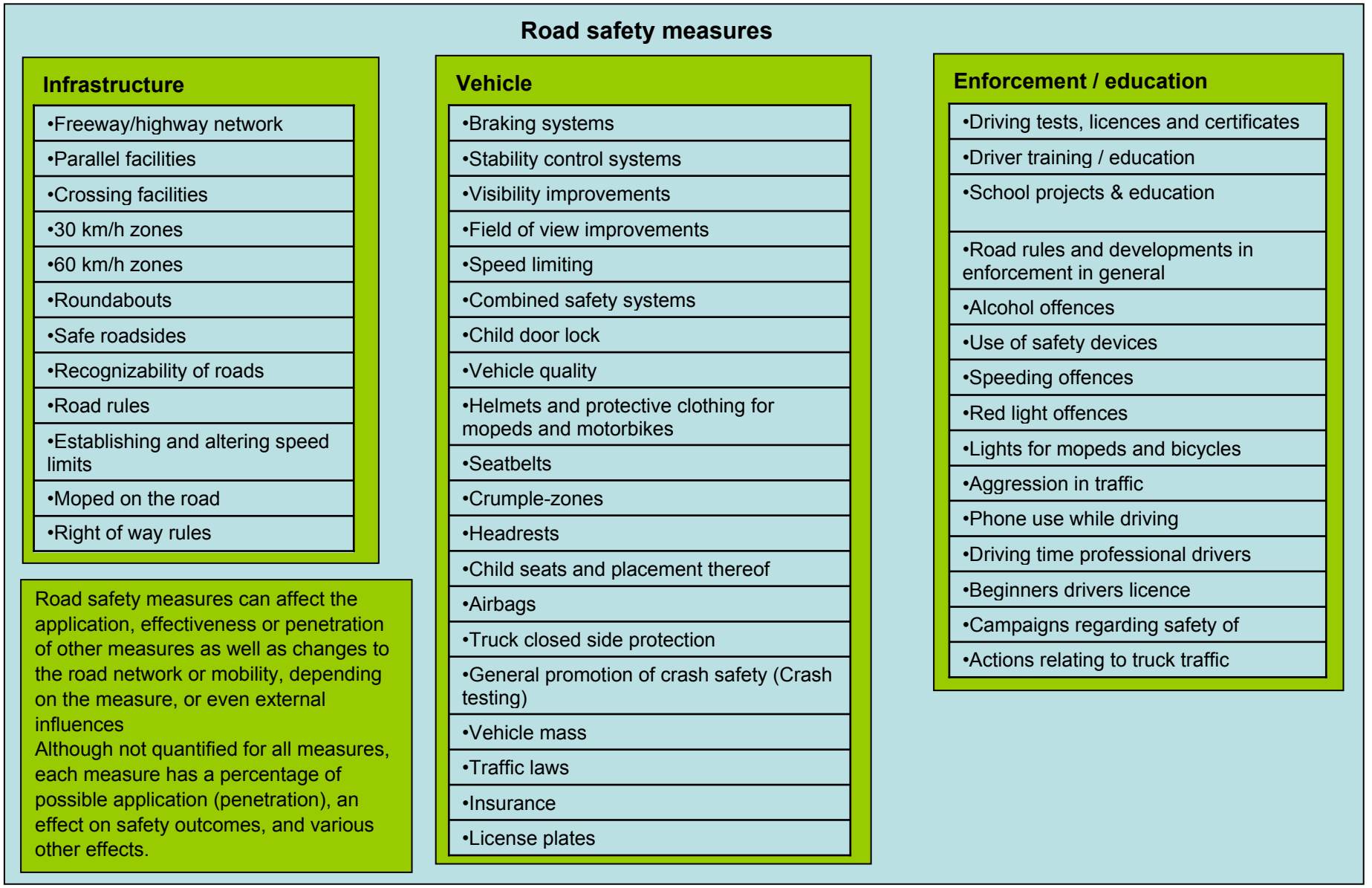


Figure 1.3. *Road safety measures considered within prism theoretical model of road safety*

## 1.2. Literature scan methodology

Each identified external influencing factor or road safety measure will be systematically reviewed for road safety effects according to the following schedule:

- Literature identified in *The summit conquered* and SWOV external influence exploration reports
- Review of road safety literature reviews and meta analyses
  a. Janssen (2005) (VVR), NL
  b. SWOV factsheets, NL
  c. VVR-GIS literature review (Wijnen et al., 2010), NL
  d. Schoon (2000) (NVVP; deel 1), NL
  e. Steunpunt Verkeersveiligheid, BE, various reports (Van den Bossche & Wets, 2003; Van Geirt, 2006; Van Geirt & Nuyts, 2005; Reekmans et al., 2004)
  f. Elvik & Vaa (2004), global
- SWOV Library search
- Scan of articles from subscribed journals including:
  a. Accident Analysis & Prevention
  b. Injury Prevention
  c. Safety Science
  d. Transport Policy
  e. Transportation Research: A, B, C and F

Literature obtained for each measure will be summarized in template form for the external influences (*Table 1.1*), or for the road safety measures (*Table 1.2*).

One of the potential benefits of reviewing the current literature is to assess how applicable the findings are to future work. The majority of collision prediction models, accident modification factors or relationships which have been developed abroad will require re-calibration with Dutch data to obtain new, appropriate coefficients. Therefore, unless the models were developed in the Netherlands, the list of references to models which are all potentially useful in the Netherlands is provided but will require further work. For this reason elaboration of model forms and coefficients will not be presented.

The literature scanned is limited to papers with numerical value relationships or mathematically models. Due to the scope of the project literature relating to the subject that is reviewed but deemed not to provide a numerical relationship is not listed.

The header of each table provides a reference to the related SWOV document and the title of the factor or measure being summarized, as well as where the measure is applied, and the extent of the subject (e.g. number of fatigued drivers or number of roundabouts). A brief qualitative description of the factor or measure is provided as well as the target group or impact area, in terms of location, road user or feature affected, and the victims. The next sections of the table present literature from the SWOV documents, as well as the relevant literature obtained during the literature scan. Finally, the table lists known and unknown relationships as well as data requirements for

their application in the model, or requirements to determine the desired relationship.

Qualitative relationships determined in the exploration reports of external influences are presented in tabular format, with a description of the effect in the literature tables. If influences are to be included in the model then they will need to be quantified. The qualitative relations will be useful for the identification of research, when the empirical relations are not yet known.

Table 1.1. *External influences literature table template. Text in Italics denotes entered fields.*

| ***SWOV document*** | ***Alternate SWOV references (or sub factor)*** |
|---|---|
| ***Section reference*** | ***Name of external influencing factor*** |
| **Application:** | *Level of application; where and to what extent the factor has its influence* |
| **Measure type and description:** | *Description of influencing factor* |
| **Target group:** | *Locations applied; feature impacted; victims affected* |
| | |
| **Literature listed in SWOV document:** | |
| *Author (publication year)* | *Literature description, type of relationship, listed if simple.* |
| | |
| **Additional literature:** | |
| *Author (publication year)* | *Literature description, type of relationship, listed if simple.* |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | *Description of relation (+, -, or +/-), if identified in SWOV report* |
| Influence on injury risk | *Description of relation (+, -, or +/-), if identified in SWOV report* |
| Influence on mobility | *Description of relation (+, -, or +/-), if identified in SWOV report* |
| Influence on mode choice | *Description of relation (+, -, or +/-), if identified in SWOV report* |
| Influence on vehicle fleet | *Description of relation (+, -, or +/-), if identified in SWOV report* |
| Influence on driving population | *Description of relation (+, -, or +/-), if identified in SWOV report* |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | *If yes, type* |
| Barriers / opportunities | *Requirements to determine relationship (e.g. data)* |
| | |
| Additional requirements | *Next research requirements or objectives* |
| | |
| Relation to other factors | *Interactions with other external influence factors* |
| Possible Indicator variables | *Variables best suited to relating factor to collisions or casualties* |

Understanding the relations among the external influences will become more important in future models to understanding the developments of risk with time. For the purposes of this initial literature survey, however, the relations of individual factors are limited to those with the broader external influence areas, rather than all of the sub factors within these areas.

Table 1.2. *Road safety measure literature table template. Text in Italics denotes entered fields.*

| | |
|---|---|
| ***SWOV document*** | |
| ***Section reference*** | ***Name of road safety measure*** |
| **Application / penetration:** | *Level of network application; land use; where measure has been applied and to what extent.* |
| **Measure / factor type and description:** | *Description of road safety measure* |
| **Target group / impact area:** | *Locations applied; feature impacted; victims affected* |
| | |
| **Literature listed in SWOV document:** | |
| *Author (publication year)* | *Literature description, type of relationship, listed if simple.* |
| | |
| **Additional literature:** | |
| *Author (publication year)* | *Literature description, type of relationship, listed if simple.* |
| | |
| **Known relationships:** | (Dutch literature available? ***Y / N*** ) |
| Relation to casualties | *If yes, type* |
| Additional requirements | *Work required for use in model, e.g. Dutch calibration, Data* |
| | |
| Relation to collisions | *If yes, type* |
| Additional requirements | *Work required for use in model, e.g. Dutch calibration, Data* |
| | |
| **Unknown relationships:** | |
| Relation to casualties | *Desired relationship* |
| Barriers / opportunities | *Requirements to determine relationship (e.g. data)* |
| | |
| Relation to collisions | *Desired relationship* |
| Barriers / opportunities | *Requirements to determine relationship (e.g. data)* |

Estimates of road safety measure effects in the literature are for the most part determined for one case and should therefore be considered point estimates, that is to say that the estimates should only be applied in similar conditions to the study. The implied relation of the change is often linear; but since the underlying relationships are often not linear application of the previously observed change at a different condition (e.g. larger traffic volume) may not represent the relationship well. For example, changes in casualties may be a function of initial traffic volume, in which case an observed change in casualties at a relatively low traffic volume is a poor estimator of the effect at a high volume location. In the literature numerous studies were encountered which appeared to be revealing the effect relationship based on several variables, but in the end was a point estimate which potentially allows little transferability due to the specificity of the study.

No perfect evaluation exists, and perhaps the best summary of the state of research has been provided by Elvik (2004):

> “Hundreds of road safety evaluation studies have been reported. There is apparently no lack of evidence regarding the safety effects of very many road safety measures. The large number of studies and the great amount of detail found in these studies give the deceptive impression that very much is known about the effects of road safety measures. Regrettably, the existence of this large body of research does not mean that the effects on road safety of a large number of road safety measures are well known. Few road safety evaluation studies stand up to critical scrutiny. Many of these studies employ flawed study designs and rely on unreliable data, which means that their findings can be rejected on methodological grounds (Elvik, 2002; Hauer, 2002).”

Theory and methodology are transferable, but individual findings generally are not. In fact, separate evaluations of the same measure often reveal different outcomes. As a consequence, and although a great deal of literature is available, the majority of the relationships will still need to be calibrated for use in the Netherlands. In the meantime, reported relationships from high quality literature can be included while calibration in the Netherlands is being completed; where international and Dutch studies are available for the same topic (e.g. roundabouts) the results are approximately of the same magnitude.

Reviewing a broad spectrum of road safety literature, as was undertaken in this project, can indeed be very discouraging. Within specific disciplines there are small pieces of the road safety puzzle which are accepted as the truth. Evaluation of all of the literature combined, however, reveals a multitude of questions regarding the appropriateness of the information we are using, and the many study or data limitations the authors themselves report. Despite cautions or criticisms regarding the use of the values, and in the absence of better or more relevant studies, available values are often applied. In order to ensure the quality of the road safety model developed confirming the quality of the relations used and periodic calibration of the model will become important tasks.

# 2. External influences on road safety

Social activities generate the mobility which results in traffic collisions, but at the same time social factors such as land use development choices may improve road safety or reduce road safety – these relations need to be identified and understood if a continuing improvement in road safety is desired. By understanding the influence of separate factors uncertainties regarding the nature of collisions can be reduced and a better understanding of crash causation can be achieved. In order to understand future developments in road safety it is important to understand how changes in external influencing factors affect road safety outcomes.

The inventory of effects of external influences reported in this chapter mainly builds on six SWOV exploration reports (written in Dutch with English summaries):

- *The influence of social and cultural factors on mobility and road safety*, Schoon, C.C. (2005), SWOV report R-2005-7
- *The influence of spatial planning and policy on road safety*, Schoon, C.C. & Schreuders, M. (2006), SWOV report R-2005-14
- *Public health and road safety*, Amelink, M. (2006), SWOV report R-2005-16
- *Economics and road safety*, Wijnen, W. (2008), SWOV report R-2006-30
- *The effects of mobility on road safety*, Wijnen, W. & Houwing, S. (2008), SWOV report R-2006-31
- *Developments in technology and environmental care in the field of traffic and transport, with implications for road safety*, Schoon, C.C. (2008), SWOV report R-2008-4

The other report used, which does not fit into structure of the other six exploration reports is

- *The influence of weather conditions on road safety*, Bijleveld, F. & Churchill, T. (2009), SWOV report R-2009-9.

The majority of the studies found in the literature review are international literature and the findings are, therefore, not necessarily directly applicable to the Netherlands. In these cases the relationship is listed, but the relation may need to be calibrated for use in the Netherlands, and data requirements will be discussed.

Each sub-section of this chapter will discuss one of the external influence areas, and will provide a general description of the external influence and proceed to list the qualitative relationships and the literature in the tabular format presented in *Chapter 1* (*Table 1.2*).

In reviewing the external influence exploration reports it cannot be denied that each factor affects all of the other factors as well as road safety. This complexity presents severe barriers to understanding the true effects of even a small change in any of the external influences. The complexity of this relationship is likely also one of the reasons that external influence literature, where available, is mostly qualitative in nature. The relation of external influences to collisions and casualties is notably less prominent in the

literature, as compared to road safety measures, and much research remains to quantify these relations and interactions.

Some factors or sub factors may not affect each other. For example, road pricing is unlikely to affect the quality of trauma centres. However, road pricing may affect emergency response times for ambulances, which is another of the public health factors. Due to the multiplicity of relations only the relation of the sub factor being discussed to the other main factors will be noted.

External influencing factors can affect mobility as well as safety. Although the prediction of motorized mobility is the domain of DVS, accounting for changes to the entire mobility including non-motorized modes and public transport is important to the accurate description of exposure and road safety.

Since there haven't been a lot of numerical explorations of the impact of the external influencing factors on road safety or mobility the approach taken will be two fold. Firstly, the general direction (or neutrality) of the effect on safety or mobility will be expressed as a positive (+), negative (–), or unclear (+/–) relation for various sub factors. The use of this ranking, although mostly qualitative, provides a sense of the probable effects based on the external influence reports, which could be employed as a criterion for research selection. Where possible, findings in the literature, references, and relationships with other factors or road safety measures are listed.

## 2.1. Social and cultural factors

The related SWOV report for the social and cultural external influence is:
- *The influence of social and cultural factors on mobility and road safety*, Schoon, C.C. (2005), SWOV report R-2005-7.

From the report the relative relations are presented in *Table 2.1*. These relations are briefly described in the literature tables under the heading of qualitative relationships, but for a more thorough discussion of the relationship the reader is referred to the external influence report.

Table 2.1. *Qualitative relations of social and cultural factors*

| **Social and cultural** | | | | | | |
|---|---|---|---|---|---|---|
| External influencing factors | Influence on fatality risk | Influence on injury risk | Influence on mobility | Influence on mode choice | Influence on vehicle fleet | Influence on driving population |
| Aging population | + | | + | + | | + proportion |
| Age category (including youth) | + | + | + | | | – proportion |
| Individualization | + | + | + | | + | + |
| Informalization | –, + | –, + | | | | |
| Internationalization | + | + | + | | + | ? |
| Intensification | + | + | + | | | |
| Ethnicity | + | + | abs. +; rel. – | – | + | |

| **Social and Cultural, R-2005-7** | **The summit conquered (5.1.2); Public health, R-2005-16 (5.6)** |
|---|---|
| **7.2.1** | **Aging population** |
| **Application:** | National effect, stronger effect anticipated at the local level, ~14% over 65 years in 2007, estimated 25% of population over 65 years in 2040 |
| **Measure type and description:** | Population distribution is currently skewed due to the 'baby boom' generation who will be reaching pension age between 2008 and 2030. Changes in transportation use and an increase in vulnerable road user population present many possible changes to road safety. |
| **Target group:** | The target group of this measure is the aging population, and the potential casualties are largely themselves, but possibly also others. There is increasing focus on provision of measures to enable older drivers to continue to drive. |
| | |
| **Literature listed in SWOV document:** | |
| Davidse (2000) | Graphical representation of risk as a function of age, increased fatality risk for 60+ and larger fatality risk for 75+ |
| | |
| **Additional literature:** | |
| Tay (2006) | Increasing the number of licensed drivers over 60 was not anticipated to increase road fatalities |
| SWOV (2008a) | Functional limitations and physical vulnerability are the two main threats to older drivers. Turning left at intersections is particularly difficult for aging drivers |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | Extension of mobility is anticipated through the increased use of moped cars and scooter cars with less occupant protection, mobility (+), risk (+) |
| Influence on injury risk | Elderly drivers exhibit more cautious driving behaviour and higher compliance with traffic laws, risk (-) |
| Influence on mobility | The aging population with increased licence holders will result in more vehicle trips and km's, mobility (+), risk (+) especially >75 years. Increased demand for travel (+), but during off peak hours (Neutral) |
| Influence on mode choice | Increased travel by other modes such as scoot mobile (+), walking and cycling |
| Influence on vehicle fleet | Increased travel by other modes such as scoot mobile (+) |
| Influence on driving population | Increasing population of older drivers |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | Casualty rates may be deceptive due to self selection of drivers, risk in part mitigated by avoiding risky times or situations. |
| Barriers / opportunities | Evaluation similar to Tay (2006) worthwhile with Dutch data to forecast population distributions. |
| | |
| Additional requirements | Marginal effect of increasing aging drivers on mobility and casualties / collisions needs to be quantifies for the Netherlands. |
| | |
| Relation to other factors | Relation to economy, public health, and to a lesser extent spatial planning and technology |
| Possible Indicator variables | Percentage of population with and without licence above 65 and above 75 years. Mobility and exposure measures also important. |

Table 2.1.1. *Aging population relationships.*

| **Social and Cultural, R-2005-7** | **The summit conquered (5.5)** |
|---|---|
| **7.2.2** | **Age category (including young driver)** |
| **Application:** | National effect; Risk of drivers varies by age group, young drivers are at increased risk relative to other age groups; Youth group growing but at a low rate. |
| **Measure type and description:** | The use of age as a factor in a model of road safety is significant. Young drivers and old drivers are at higher risk. |
| **Target group:** | All drivers have an inherent risk, changes to the population distribution are constant and marginal changes are unknown, youth and aging drivers are likely to be at the greatest risk and the disparity between these groups is expected to increase due to the aging of the population. Enforcement will continue to be important to enforce traffic laws, as well as education. |
| | |
| **Literature listed in SWOV document:** | |
| Bos & Schoon (1998) | Youth licence and vehicle possession |
| | |
| **Additional literature:** | |
| Evans et al. (1998) | Relationships of risk and age, with specific focus on youth and older drivers using US data. Threat to other driver by age also explored. |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | Increase (+) in risk is anticipated due to divergent driving styles. |
| Influence on injury risk | Increase (+) in risk is anticipated due to divergent driving styles. |
| Influence on mobility | Increase (+) in mobility anticipated due to increased vehicle availability for youth |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | Relative decrease of youth and other age groups (-) due to growing elderly group |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | The influence of age category on casualties and collisions by mode could be determined in terms of risk and applied based on changes in proportion of age distribution. |
| Barriers / opportunities | Marginal changes may be different than risk obtained from historical trends. |
| | |
| Additional requirements | Regression of risk by age group, by mode |
| | |
| Relation to other factors | Relation to mobility, economy, spatial planning, and to a lesser extend public health and technology. |
| Possible Indicator variables | Data are available for collisions by age group, mobility and exposure by age group will remain important. |

Table 2.1.2. *Age category relationships*

| **Social and Cultural, R-2005-7** | **The summit conquered (5.1.2)** |
|---|---|
| **7.2.3** | **Individualization** |
| **Application:** | National effect, stronger effect anticipated in urban areas; measures of penetration unknown |
| **Measure type and description:** | As individual importance becomes a dominant factor, the number of households and vehicles are anticipated to increase. Similarly behaviours which benefit the individual will become more common. |
| **Target group:** | Primarily adults and young drivers, but to a lesser extend all groups |
| | |
| **Literature listed in SWOV document:** | |
| Harms (2003) | Individualization as a driver for mobility |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | Increased (+) risk due to selection of (heavier) vehicle for personal safety, and self importance in traffic, including speeding and alcohol offences. |
| Influence on injury risk | Increased (+) risk due to selection of (heavier) vehicle for personal safety, and self importance in traffic, including speeding and alcohol offences. |
| Influence on mobility | Increased trips (+), linked trips, and commute distance |
| Influence on mode choice | |
| Influence on vehicle fleet | Increased (+) fleet size with increased demand for individual travel |
| Influence on driving population | Increased (+) driver population due to increased female workforce |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relationships found, but relation of individualization to vehicle choice may indirectly relate to collision severity. |
| Barriers / opportunities | Difficult to quantify individual or group behaviour and relate to collisions. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strong relation to mobility and spatial planning, and economy and technology to a lesser extent. |
| Possible Indicator variables | The number of households and number of single person homes as well as monitoring of vehicle fleet may be strong indicators of individualization |

Table 2.1.3. *Individualization relationships*

| | |
|---|---|
| **Social and Cultural, R-2005-7** | **The summit conquered (5.1.2)** |
| **7.2.4** | **Informalization** |
| **Application:** | National effect; measures of penetration unknown |
| **Measure type and description:** | As processes become increasingly informal, due to technology among other factors, changes in driver behaviour are anticipated. As a result of changes in behaviour modifications to enforcement practices are anticipated. |
| **Target group:** | All drivers and road users, with a focus on young drivers |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) due to increased rules and enforcement, (+) due to increased aggressive driving |
| Influence on injury risk | (-) due to increased rules and enforcement, (+) due to increased aggressive driving |
| Influence on mobility | |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relationships found |
| Barriers / opportunities | Difficult to quantify individual or group behaviour and relate to collisions. Relation of education level and traffic law compliance level of interest. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strong relation to mobility and technology and public health, also economy and technology to a lesser extent |
| Possible Indicator variables | Level of education by age group and travel mode |

Table 2.1.4. *Informalization relationships*

| Social and Cultural, R-2005-7 | The summit conquered (5.1.2) |
|---|---|
| **7.2.5** | **Internationalization** |
| **Application:** | National effect, more significant in bordering provinces and industrial/distribution areas; no estimated of foreign goods transport mobility in the Netherlands |
| **Measure type and description:** | With increased international truck traffic and cross border travel unfamiliarity of foreign drivers with the Dutch traffic system may increase risk. Other international factors such as international road safety initiatives such as vehicle type approvals and collision testing have mixed effects |
| **Target group:** | International vehicular traffic, primarily goods transport but to a lesser extent cars. |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships** | |
| Influence on fatality risk | (-) increased safety quality of vehicles, (+) admittance of less safe vehicles (4-wheeled mopeds) |
| Influence on injury risk | (-) increased safety quality of vehicles, (+) admittance of less safe vehicles (4-wheeled mopeds) and transport companies with poor safety culture |
| Influence on mobility | (+) increased trans-border travel, vans and freight transport in particular |
| Influence on mode choice | |
| Influence on vehicle fleet | (+) delivery vehicles associated with e-commerce, and international road freight |
| Influence on driving population | (?) Increased tele-work may change the number and age distribution of drivers |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relationships found |
| Barriers / opportunities | There appears to be little information on foreign vehicles in the Netherlands. It may be possible to monitor the prevalence of foreign vehicles on national roadways using new technologies. Political avenues may reach compromises regarding vehicle types. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strong relation to mobility land use and economy, also technology to a lesser extent. |
| Possible Indicator variables | Percentage foreign vehicles by vehicle type. |

Table 2.1.5. *Internationalization relationships*

| **Social and Cultural, R-2005-7** | **The summit conquered (5.1.2)** |
|---|---|
| **7.2.6** | **Intensification** |
| **Application:** | Primarily in dense urban areas, but national also, difficult to quantify size of issue |
| **Measure type and description:** | The 24-hour economy is likely to result in increased stress, and anxiety. Similarly, congestion in traffic may result in more aggressive driving styles and unsafe behaviours such as speeding and following closely |
| **Target group:** | Drivers in general, youth in urban areas and near schools. |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increased stress and fatigue, children are less exposed to traffic as car passenger |
| Influence on injury risk | (+) increased stress and fatigue, children are less exposed to traffic as car passenger |
| Influence on mobility | (+) more combined trips, (+) increased travel time |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Difficult to quantify extent to which stress, anxiety and fatigue, let alone the effect on collisions. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongly related to spatial planning, mobility and economy, to a lesser extent population health |
| Possible Indicator variables | Hours of work, commuting travel times, and urban car density are possible indicators |

Table 2.1.6. *Intensification relationships*

| **Social and Cultural, R-2005-7** | **The summit conquered (5.1.2)** |
|---|---|
| **7.2.7** | **Ethnicity** |
| **Application:** | National effect, but concentrated in urban areas, in the three largest urban areas the population is ~30% immigrants. |
| **Measure type and description:** | Immigrants have different travel patterns than Dutch natives, and these differences are resulting in changes in aggregate travel patterns and therefore also safety. Non-western foreigners travel less by bicycle and more by car, but shorter distances than Dutch nationals. Some Dutch national children are experiencing longer travel times to reach 'white' schools and are therefore have higher exposure to risk. |
| **Target group:** | Immigrants, primarily non-western, and Dutch national children. |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) longer school trips resulting in increased exposure |
| Influence on injury risk | (+) longer school trips resulting in increased exposure |
| Influence on mobility | (+) number of trips by car, but (-) driven distances since foreigners drive half as much as Dutch natives. |
| Influence on mode choice | (-) bicycle use by non-western immigrants |
| Influence on vehicle fleet | (+) more car use by non-western immigrants |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Research regarding compliance and collision involvement of Dutch nationals and immigrants possible, and useful. Sensitive political issue, perception of discrimination possible. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongly related to mobility and spatial planning, and to a lesser extent economy. |
| Possible Indicator variables | Percent immigrants by travel mode, continued monitoring of mobility by ethnicity. |

Table 2.1.7. *Ethnicity relationships*

## 2.2. Spatial planning and policy

The related SWOV report for the spatial planning and policy influence is:
- *The influence of spatial planning and policy on road safety*, Schoon, C.C. & Schreuders, M. (2006), SWOV report R-2005-14

The 'robust' spatial factors, which have been identified as having the largest potential effect, were listed in the report and are presented with qualitative relations in *Table 2.2*. These relations are briefly described in the literature tables under the heading of qualitative relationships, but for a more thorough discussion of the relationship the reader is referred to the external influence report.

From the report the most important conclusions are that:
- The influence of spatial planning on mobility growth is maximum 15%.
- New urban developments are safer than pre-war developments
- Design and policy choices affect road safety for decades
- Less short term effect than social, cultural and economic factors
- Direct and indirect influences of spatial planning are possible, indirect control includes passive designs while direct control is aimed specifically at mobility control.
- Influencing traffic and transportation in general, and specifically road safety can best be achieved through the robust application of spatial designing.

Table 2.2. *Qualitative relations of spatial planning and policy factors*

| **Spatial planning and policy** | | | | | | |
|---|---|---|---|---|---|---|
| External influencing factors | Influence on fatality risk | Influence on injury risk | Influence on mobility | Influence on mode choice | Influence on vehicle fleet | Influence on driving population |
| Vicinity | +/– | +/– | + | +, – | | |
| Concentration on one or more centres | + | | | + | + | |
| Size and type of urbanization | +, - | | | +, – | +, – | |
| Connection to the main arteries of public transport | – | – | | + | relative – | |
| Function mixture and facility level | – | – | + | + | | |
| Design at street and neighbourhood level | – | – | + | + | – | |

| | |
|---|---|
| **Spatial planning, R-2005-14** | |
| **5.2.1** | **Vicinity** |
| **Application:** | Urban design, but also intercity distances; quantification of distances and public transit influence necessary |
| **Measure type and description:** | The distances between surrounding areas and the central urban area affect safety. Smaller distances and better public transportation links reduce unsafe vehicle traffic in the urban area. |
| **Target group:** | Urban motorists by influencing mode choice, and all road users. |
| | |
| **Literature listed in SWOV document:** | |
| Konings et al. (1996) | Evaluation of relation between density, measures of separation and mode choice - primarily car and public transportation |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+/-) Quality of the infrastructure will either improve safety (targeted at non-motorized modes) or detract from safety (focus on cars). |
| Influence on injury risk | (+/-) Quality of the infrastructure will either improve safety (targeted at non-motorized modes) or detract from safety (focus on cars). |
| Influence on mobility | (+) more short trips, (-) shorter travel distances |
| Influence on mode choice | (+) non-motorized modes for short trips and public transit use, (-) reduced car use |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | May be difficult to control for socio-economic factors in mode choice. Exploration of car collisions in the core and travel times by public transport to the vehicle residence may reveal the travel times at which mode shift becomes evident. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Direct impact on mobility and public health (healthy travel), to a lesser extent social and economy. May promote changes in technology (infrastructure design) |
| Possible Indicator variables | Travel times by different modes (including public transit) to the urban centre, residence distance from urban centre for cars in collisions. |

Table 2.2.1. *Vicinity relationships*

| | |
|---|---|
| **Spatial planning, R-2005-14** | |
| **5.2.2** | **Concentration on one or more centres** |
| **Application:** | Provincial / national, measures of penetration not presented but could be defined in terms of number of highly interacting cities |
| **Measure type and description:** | Single centre city development will have shorter travel distances than cities with multiple centres or groups of cities that create a greater metropolitan area, such as the Randstad. Multi centre development within a city may lead to increased mobility among all modes and therefore be less detrimental to safety than a greater metropolitan area, which primarily stimulates car travel. |
| **Target group:** | Urban motorists, all urban road users |
| | |
| **Literature listed in SWOV document:** | |
| Hilbers (1996); Hilbers et al. (1999) | Development of multiple centres within a city with good public transport systems may increase mobility while improving safety |
| Cervero (1996) | Cities with a good balance of population and jobs have 12-15% fewer kilometres travel than cities with a surplus of jobs. |
| | |
| **Additional literature:** | |
| No collision literature found | |
| | |
| Qualitative relationships: | |
| Influence on fatality risk | (+) longer trips between centres, more conflicts between cars and non-motorized transport |
| Influence on injury risk | |
| Influence on mobility | |
| Influence on mode choice | (+) car use in metropolitan multi centre developments, (+) public transport and non-motorized transport in multi centre city developments. |
| Influence on vehicle fleet | (+) increased separation may result in higher car ownership |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Difficult to separate effects since changes to system are difficult, traffic micro simulation may aid planning. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strong relation to mobility, economy, social and cultural , and to a lesser extent technology and public health |
| Possible Indicator variables | Gravity measures between centres in terms of population or demand and time separation by different modes of travel. |

Table 2.2.2. *Concentration on one or more centres relationships*

| **Spatial planning, R-2005-14** | |
|---|---|
| **5.2.3** | **Size and type of urbanization** |
| **Application:** | Urban development, population density is the most convenient indicator, urban areas and transportation corridors account for 40% of the Netherlands and 75% of the population. |
| **Measure type and description:** | Urban density, in combination with a variety of land uses leads to shorter travel distances, less car use, and increased public transport use. Urban infill projects, particularly located near public transport access, are more beneficial to road safety than urban expansion at the fringes. Expansion of the urban areas increases mobility, particularly by car. Maximizing opportunities for infill construction is the most beneficial for road safety. |
| **Target group:** | Urban motorists, all urban road users |
| | |
| **Literature listed in SWOV document:** | |
| Konings et al. (1996) | Study of expansion developments, travel distances, car and public transport use |
| Hilbers (1996) | Comparison between new and redesigned areas |
| | |
| **Additional literature:** | |
| Flahaut (2004) | Framework for logistic regression of spatial data including land use, such as shop proximity |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increasing new developments increase distances and car use, (-) increasing infill and urban density decreases distances and car use |
| Influence on injury risk | (+) increasing new developments increase distances and car use, (-) increasing infill and urban density decreases distances and car use |
| Influence on mobility | (+/-) more urban sprawl (lower urban density) increases mobility, car in particular |
| Influence on mode choice | Expansion developments increase distances, increase use of car and decrease use of non-motorized transport and public transportation; urban infill leads to decreased distances, decreased car use, increased non-motorized transport and public transport use |
| Influence on vehicle fleet | Increased urban density, decreased car use, increased public transport |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Effects on mobility have been explored; these can likely be expanded upon to include impact on collisions and location of collisions and registration address of vehicle. |
| | |
| Additional requirements | Research design based on previous work, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Very strongly related to mobility, strongly related to economy, and to a lesser extent public health. |
| Possible Indicator variables | Population density and distance to the urban core, possibly also vehicle density based on registration. Spatially coded data will be most useful. |

Table 2.2.3. *Size and type of urbanization relationships*

| | |
|---|---|
| **Spatial planning, R-2005-14** | |
| **5.2.4** | **Connection to the main arteries of public transport** |
| **Application:** | Urban; quantification of proportion of development near transport corridors not found |
| **Measure type and description:** | Location of developments with connection to public transport limits car use and stimulated public transport, provided the quality of service is good. Developments near transportation corridors also stimulate walking. |
| **Target group:** | Urban motorists, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Dijst & Van Vossen (1996) | Study of influence of development in cities with existing transportation systems. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) increased public transport use, fewer car kilometres (Possibly (+) more pedestrian trips) |
| Influence on injury risk | (-) increased public transport use, fewer car kilometres (Possibly (+) more pedestrian trips) |
| Influence on mobility | |
| Influence on mode choice | (-) car, (+) public transport |
| Influence on vehicle fleet | (-) fewer cars in fleet |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Effects on development patterns have been explored, use of traffic micro simulation may reveal effect on mobility, leading to a link with collisions. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Very strongly related to mobility, strongly related to economy, and to a lesser extent public health. |
| Possible Indicator variables | OV card may enable data collection regarding travel patterns and preferences based on distance of residence from public transport. Vehicle density may be related to proximity to transportation corridors. |

Table 2.2.4. *Connection to public transportation relationships*

| | |
|---|---|
| **Spatial planning, R-2005-14** | |
| **5.2.5** | **Function mixture and facility level** |
| **Application:** | National, provincial, and urban, difficult factor to assign penetration |
| **Measure type and description:** | The mixture of residences, employment and services are combined in an area; the level of mixing of these functions strongly influences car use. The level of use of facilities also influences mobility, under use of local facilities in favour of distant facilities generates unnecessary car traffic. |
| **Target group:** | |
| | |
| **Literature listed in SWOV document:** | |
| Hilbers (1996) | Shorter trips and increased non-motorized transport benefit safety |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) fewer conflicts due to reduced car travel and increased non-motorized transport |
| Influence on injury risk | (-) fewer conflicts due to reduced car travel and increased non-motorized transport |
| Influence on mobility | (+) increased number of trips, but short trips by non-motorized transport and public transport |
| Influence on mode choice | (-) car use and (+) non-motorized transport and public transport |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Balance of facilities within an area likely highly dependent on personal preferences, trips to favoured stores in another area may be difficult to quantify. GIS may be a useful tool in terms of proximity of facilities |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongly related to mobility, to economy, social and cultural, and to a lesser extent public health. |
| Possible Indicator variables | Facility density and use measures, average distances from residences to facilities. |

Table 2.2.5. *Function and facility mixture relationships*

| **Spatial planning, R-2005-14** | |
|---|---|
| **5.2.1** | **Design at street and neighbourhood level** |
| **Application:** | Urban, local level, large variety of forms, ~50% of residential streets are variants of Zone 30 |
| **Measure type and description:** | The design of neighbourhoods and urban routes in a uniform and safe way improves road safety. Safe routes to school, uniform road characteristics and high quality public transport facilities are all examples of important initiatives at the street and neighbourhood level. |
| **Target group:** | All urban road users |
| | |
| **Literature listed in SWOV document:** | |
| Hilbers(1996); Hilbers et al.(1999) | Relations of age of urban development and road safety performance. |
| VenW (1995) | Form of neighbourhood can influence safety in an area. |
| MuConsult (1999) | Characteristics of the neighbourhood can significantly influence car use in terms of trips and kilometres. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) fewer conflicts due to lower car mobility |
| Influence on injury risk | (-) fewer conflicts due to lower car mobility |
| Influence on mobility | (+) non-motorized mobility, (-) car mobility |
| Influence on mode choice | (+) increased use of non-motorized transport, (-) car use |
| Influence on vehicle fleet | (-) car |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Balance of facilities within an area likely highly dependent on personal preferences, trips to favoured stores in another area may be difficult to quantify. GIS may be a useful tool in terms of proximity of facilities |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongly related to technology (infrastructure), mobility, infrastructure road safety measures, and to a lesser extent economy, social and cultural, and public health. |
| Possible Indicator variables | Possible categorization as non-sustainable safe, somewhat sustainable safe, or sustainable safe; but there are variations within these possible categories. Numerous specific characteristics, posted speed, parking, sidewalks, trees, speed limiting measures… |

Table 2.2.6. *Design at street and neighbourhood level relationships*

## 2.3. Public health

The related SWOV report for the Public health external influence is:
- *Public health and road safety*, Amelink, M. (2006), SWOV report R-2005-16

For the literature tables the aging population factor has been discussed in the social and cultural tables in *Section 2.1*, and is not repeated here. Similarly the post crash care factors have been combined due to the consistent effect on risk and mobility, and the lack of qualitative literature in these areas.

From the report the relative relations are presented in *Table 2.3*. These relations are briefly described in the literature tables under the heading of qualitative relationships, but for a more thorough discussion of the relationship the reader is referred to the external influence report.

Further research directions are also very well presented in the external influence report, and the reader is also referred to this reference for a more detailed discussion of future work and research.

Table 2.3. *Qualitative relations of public health factors*

| **Public health** | | | | | | |
|---|---|---|---|---|---|---|
| External influencing factors | Influence on fatality risk | Influence on injury risk | Influence on mobility | Influence on mode choice | Influence on vehicle fleet | Influence on driving population |
| DETERMINANTS | | | | | | |
| Emissions & noise | – | – | + | | | |
| Aggression & fatigue | + | | | | | |
| Fitness to drive / Medical disorders | | | | | | |
| Aging population | + | + | –, + | | | |
| Healthy mobility | +, +/– | +/– | | | | |
| Alcohol and drugs | + | + | | | | |
| POST CRASH CARE | | | | | | |
| Post crash care process | – | – | | | | |
| Emergency calls / response | – | – | | | | |
| Ambulatory care | – | – | | | | |
| Organization | – | – | – | | | |
| Trauma centres | – | – | | | | |
| Patient rehabilitation / education | – | – | | | | |

| | |
|---|---|
| **Public health, R-2005-16** | |
| **5.3** | **Emissions and noise** |
| **Application:** | National effect more severe in high vehicle density, estimates 4,000-7,500 deaths per year as a result of vehicle emissions (of 140,000 deaths). No estimates for noise. |
| **Measure type and description:** | Vehicle emissions can adversely affect public health, in terms of respiratory health issues. Noise emissions are also detrimental to public health in terms of loss of sleep or hearing loss or heart and vascular disease in extreme cases. |
| **Target group:** | Vehicle design and motorists, all road users are recipients, and those who reside near roads are at elevated risk. |
| | |
| **Literature listed in SWOV document:** | |
| Janssen et al. (2002) | Traffic as a source of emissions, particularly fine particulate matter. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) with lower speeds on motorways and less traffic in cities |
| Influence on injury risk | (-) lower speeds on motorways |
| Influence on mobility | (-) less traffic in cities |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | The effect of emissions has been identified as a public health risk, but may not influence road collisions directly, and the relation may be difficult to reveal. Similarly, sleep loss and stress may be difficult to relate directly to increased collision risk. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongly related to technology and mobility, and to a lesser extent economy and social and cultural. |
| Possible Indicator variables | Difficult to identify, possibly fine particulate matter by region and average noise levels. |

Table 2.3.1. *Emissions and noise relationships*

| | |
|---|---|
| **Public health, R-2005-16** | |
| **5.4** | **Aggression and fatigue** |
| **Application:** | National, Fatigue plays a role in 10-15% of severe collisions, 30% of population is regularly tired. |
| **Measure type and description:** | Participating in traffic safely requires attention and concentration, lack of sleep may result in increased risk or in drivers becoming more aggressive. |
| **Target group:** | Drivers who travel while fatigued, all road users are at risk |
| | |
| **Literature listed in SWOV document:** | |
| Kuiken & Vermeulen (2002) | Stress and aggression in traffic, line jumping is the most common form of aggression (23%) |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increase aggression and fatigue leads to unsafe traffic behaviours |
| Influence on injury risk | |
| Influence on mobility | |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | The effect of aggression and fatigue on collisions will be difficult to determine due to the challenge of measuring fatigue and aggression of involved parties. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongly related to economy and social and cultural factors, technology may aid in detection. |
| Possible Indicator variables | Difficult to identify, possibly hours of sleep by age group, fatigue involvement in in-depth studies. |

Table 2.3.2. *Aggression and fatigue relationships*

| | |
|---|---|
| **Public health, R-2005-16** | |
| **5.5** | **Fitness to drive / medical disorders** |
| **Application:** | national, CBR maintains a list of disorders, but prevalence not reported. |
| **Measure type and description:** | Many factors may reduce the ability to drive a motor vehicle, the Dutch licensing agency, CBR, maintains a list which includes: hearing, diabetes, hypertension and epilepsy among others. |
| **Target group:** | Driving population with identified disorders, all road users |
| | |
| **Literature listed in SWOV document:** | |
| CBR (2000) | Listing of medical disorders |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) better monitoring of medical disorders can limit the number of physically unfit to drive. |
| Influence on injury risk | (-) better monitoring of medical disorders can limit the number of physically unfit to drive. |
| Influence on mobility | |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | The effect of medical disorders on collisions may become more significant as the population ages. It is important to differentiate between involved parties with a medical disorder but 'fit to drive' and those who haven't had a medical but have a disorder (under reporting). |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongly related to economy and social and cultural factors, and spatial planning to a lesser extent, technology may aid in detection / monitoring. |
| Possible Indicator variables | Percentage of drivers by age group with medical disorder, collision involvement of drivers with fitness to drive clearance. |

Table 2.3.3. *Fitness to drive / medical disorder relationships*

| | |
|---|---|
| **Public health, R-2005-16** | |
| **5.7** | **Healthy mobility (Weight, non-motorized transport)** |
| **Application:** | National (global); in the Netherlands increasing car use reducing non-motorized transport; estimated 40% overweight and 10% very overweight, 2015 forecast 15-20% very overweight. |
| **Measure type and description:** | Obesity is a global problem, resulting from many factors including diet, level of activity, and reduced use of non-motorized modes of transport. Risks are elevated due to higher body masses and resulting higher collision energy dissipation forces. |
| **Target group:** | All road users, for trips which are possible by non-motorized modes of transport |
| | |
| **Literature listed in SWOV document:** | |
| Mock et al. (2002) | Higher body weight leads to higher mortality rate for vehicle occupants. |
| | |
| **Additional literature:** | |
| No collision effect literature found | It is unlikely that obesity causes collisions, but rather that the severity is increased. |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increase in average body weight, (+/-) increased non-motorized transport will result in a healthier population, but may also lead to more vulnerable road user fatalities |
| Influence on injury risk | (+/-) increased non-motorized transport will result in a healthier population, but may also lead to more vulnerable road user fatalities |
| Influence on mobility | (?) possible reduction in cars and shift to non-motorized modes |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Relation of obesity and collision severity has been explored, but not collision involvement. Obesity by mode unknown, and effects are possibly more significant for motorized modes due to higher energy released on impact. |
| | |
| Additional requirements | Confirmation of increased collision severity in the Netherlands. Research design, identification of best indicators, and data collection if weight by mode is desired. |
| | |
| Relation to other factors | Strongly related to mobility, social and cultural factors and spatial planning, possibly technology to a lesser extent. |
| Possible Indicator variables | Percentage of population who are overweight by age group (possibly by mode), and developments in mobility (shift to non-motorized modes from cars?) |

Table 2.3.4. *Healthy mobility relationships*

| | |
|---|---|
| **Public health, R-2005-16** | |
| **5.8** | **Alcohol and drug use** |
| **Application:** | National issue; 25% of fatal collisions involve alcohol impairment |
| **Measure type and description:** | Impairment by alcohol and drugs reduces the ability to safely operate a motor vehicle. Alcohol impairment is one of the most researched influencing factors on road safety, and as such a larger base of literature is available. Impairment among the non-motorized modes also increases the risk of collision involvement, and since these modes are vulnerable the outcomes are generally severe. |
| **Target group:** | Primarily young drivers, but also all motorists; all road users are potential victims |
| | |
| **Literature listed in SWOV document:** | |
| Valk (2005) | Alcohol use by Dutch youth, most frequent users in Europe, increased use 1992-2003 |
| SWOV (2009c) | Risk increase due to impairment larger for young drivers |
| Mathijssen & Houwing (2005) | Risk increased by 50% when drugs and alcohol are combined. |
| | |
| **Additional literature:** | |
| NHTSA (2000) | Relationship between driver age, gender and impairment. |
| Mathijssen et al. (2002) | Case control study, risk by BAC and age group. |
| Mathijssen & Houwing (2005) | Over representation of high offenders |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increased risk due to alcohol and drug impairment |
| Influence on injury risk | (+) increased risk due to alcohol and drug impairment |
| Influence on mobility | |
| Influence on mode choice | (?) possible shift to non-motorized modes |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | Relation of alcohol use and collision involvement and severity are well known. |
| Barriers / opportunities | Application of increased risk in models of road safety may be difficult due to actual offence levels by age group and varying impairment levels. Use of drugs in traffic is an emerging issue. |
| | |
| Additional requirements | Confirmation of increased collision severity in the Netherlands. Research design, identification of best indicators, and data collection if impairment by age and mode are desired. |
| | |
| Relation to other factors | Strongly related to economy and social and cultural factors, spatial planning may reduce car travel demand, technology may aid in detection / prevention (alcolock). |
| Possible Indicator variables | Percentage of population who are impaired (possibly by mode), and developments in mobility (shift to non-motorized modes from cars?), alcohol sales, better indicator of drug use? |

Table 2.3.5. *Alcohol and dugs use relationships*

| | |
|---|---|
| **Public health, R-2005-16** | |
| **6.2** | **Trauma care organization** |
| **Application:** | National, managed locally in safety regions; 25 regions, 10 trauma centres, 4 ambulance helicopters. |
| **Measure type and description:** | Trauma care organization includes many factors, from the first call, the response time of the ambulance, the distance to the nearest care facility and the level of care provided upon arrival. The trauma care process reduces the severity of crash outcomes, but is a purely reactive measure and does not influence collision frequency. Mobility may be influenced by the distance to trauma care centres of which there are fewer, and also by shorter distances to an increasing number of other care facilities. |
| **Target group:** | Direct benefit to road users involved in collisions |
| | |
| **Literature listed in SWOV document:** | |
| De Charro & Oppe (1998) | Trauma helicopters reduce fatal casualties by 11-17%, cost effective measure |
| Noland (2004) | International study of acute care found 5-25% reduction in fatalities over the last 40 years |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) Due to the organization of medical transport and the quality of care system |
| Influence on injury risk | (-) Due to the organization of medical transport and the quality of care system |
| Influence on mobility | (-) shorter trips due to increase in number of live in care facilities, (+) longer trips due to reduced number of hospitals |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | Medical cohort studies |
| Barriers / opportunities | Difficult to quantify the reduction in severity, and predict how this reduction varies as a result of changes in terms of response time trauma centre proximity and other indicator variables. |
| | |
| Additional requirements | Confirmation and quantification of decreased collision severity in the Netherlands. Research design, identification of best indicators, and data collection if effect by age or mode is desired. |
| | |
| Relation to other factors | Strong relation to technology (e-call, medical technology), spatial planning, and to a lesser extent mobility, economy and social and cultural factors. |
| Possible Indicator variables | Response time, distance from collision to trauma centre, possibly changes in survival rates by collision AIS or MAIS score. |

Table 2.3.6. *Trauma care and organization relationships*

## 2.4. **Economy**

The related SWOV report for the economy external influence is:
- *Economics and road safety*, Wijnen, W. (2008), SWOV report R-2006-30

The study of the economy is one area where a lot of numerical and statistical models have been developed to describe the influence of changes on road safety. The mathematical modelling of economics, commonly known as econometrics, has been the source of many of the statistical modelling methods in road safety such as time series analysis in its various forms. Although there is a large base of literature the assumptions made in the models or limitations of the data are often noted as limitations of the studies. Some uniformity has been obtained across models in terms of the directions of the relationships (e.g. increased employment leads to increased collisions) but the numerical relations, often expressed as elasticity, vary across models. As a result the literature is informative in terms of what the most promising factors are, but there is no consensus on what the size of the relationship is. To address this issue, and to obtain appropriate numerical values, a model of the impact of economic factors in the Netherlands may be needed.

Theory of the relationship between economic indicators and road safety is one of the departure points for future numerical research. Comprehensive summaries of variables and theoretical relations to safety outcomes are provided in Harry (1997) and Scuffham (1998); these literature reviews provide a solid starting point for the selection of desirable variables to include for Dutch calibration.

Of note from the Harry (1997) report is the note regarding the use of rates in econometric and statistical models. Firstly, the use of rates implies linearity of the relationships between variables, and this is rarely a true representation of the underlying relationship. Secondly, the use of the same variable, e.g. population, in several rate variables will create spurious relationships in three cases: variable as denominator in different rate variables, variable as denominator in one variable and numerator in another rate variable, and variable as numerator in more than one rate variable. These cautions, revealed through a strong history of various econometric models, should be kept in mind for all models.

From the report the relative relations are presented in *Table 2.4*. These relations are briefly described in the literature tables under the heading of qualitative relationships, but for a more thorough discussion of the relationship the reader is referred to the external influence report.

Table 2.4. *Qualitative relations of economic factors*

| Economy | | | | | | |
|---|---|---|---|---|---|---|
| External influencing factors | Influence on fatality risk | Influence on injury risk | Influence on mobility | Influence on mode choice | Influence on vehicle fleet | Influence on driving population |
| **PEOPLE TRANSPORT** | | | | | | |
| Income growth | +/–, +, – | | + | +, – | + | |
| Consumption increase | + | | + | | | |
| Vehicle ownership | | | + | | | |
| Cost of transport | +, – | | + | | | |
| Road pricing | + | | – | +, – | + | |
| Workforce participation | +, – | | + | | | |
| **GOODS TRANSPORT** | | | | | | |
| Economic growth | | | + | | | |
| Internationalization | + | | + | | | |
| Distribution of economic activities | – | | +, – | | | |
| Business and transport costs | +, – | | + | | | |
| ICT and e-commerce | –, + | | + | | + | |
| Quality of goods transport & specialization | +, – | | –, + | | | |

| **Economy, R-2006-30** | **People Transport** |
|---|---|
| **6.2.1** | **Income growth** |
| **Application:** | National, Income grew by 2.3% annually between 1980 and 2001 |
| **Measure type and description:** | Income growth is generally related to an increase in car ownership, but the literature regarding a direct relationship to collisions is weak |
| **Target group:** | Income earners, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No collision effect literature listed | |
| | |
| **Additional literature:** | |
| Dargay & Gately (1999) | Relation between income and vehicle ownership |
| Hakim et al. (1991) | Review of macro models of road safety, including income as a factor which increases collisions |
| Kopits & Cropper (2005) | Relation between GDP and traffic fatalities per capita using statistical models. Developed countries exhibit lower population fatality rates with larger GDP per capita. Focus of the paper is on the risk of developing countries |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+/-) increased supplementary cars, (-) more expensive and newer (safer) cars, (+) increased motorcycle ownership and earlier youth vehicle purchase |
| Influence on injury risk | |
| Influence on mobility | (+) increased car ownership and motorcycle ownership, also by youth |
| Influence on mode choice | (+) car and motorbike, (-) decreased use of public transport |
| Influence on vehicle fleet | (+) increased size of vehicle fleet due to increased vehicle ownership |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | The direct relationship is weak, but relations to vehicle ownership and national levels of income have been explored. |
| Barriers / opportunities | Difficult to directly link income changes and road safety due to confounders such as behaviour and vehicle choice differences between different income groups. |
| | |
| Additional requirements | Calibration of models to Dutch data. Research design, identification of best indicators, and data collection if effect by age or mode is desired. |
| | |
| Relation to other factors | Strongly related to mobility and social/cultural factors, possibly spatial planning and technology to a lesser extent. |
| Possible Indicator variables | Involvement in collisions by income group. |

Table 2.4.1. *Personal income growth relationships*

| **Economy, R-2006-30** | **People Transport** |
|---|---|
| **5.2.1** | **Consumption / disposable income** |
| **Application:** | National; increase in spending estimates at 1.4% to 2.4% to 2020. |
| **Measure type and description:** | The direct impact of disposable income is generally increased consumption, but collision effects have been mixed in the literature. |
| **Target group:** | All road users, higher income brackets may have more disposable income. |
| | |
| **Literature listed in SWOV document:** | |
| De Wit & Van Gent (1996) | Disposable income and vehicle price most important factors in vehicle ownership |
| | |
| **Additional literature:** | |
| Scuffham & Langley (2002) | Disposable income noted to have mixed effects on collisions in literature |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increased alcohol sales |
| Influence on injury risk | |
| Influence on mobility | (+) increased travel demand |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | Mixed effects found in literature |
| Barriers / opportunities | May be difficult to separate disposable income effect on collisions from other confounders such as income category and social/cultural factors. Vehicle ownership and influence on mobility are the most promising indicators of road safety |
| | |
| Additional requirements | Calibration of the effect on alcohol sales and mobility based on Dutch data. Research design, identification of best indicators, and data collection if collision effect by age or mode is desired. |
| | |
| Relation to other factors | Strongly related to mobility, to a lesser extent social / cultural and spatial planning also possible. |
| Possible Indicator variables | Consumption figures by income class, or age and gender |

Table 2.4.2. *Consumption / disposable income relationships*

| **Economy, R-2006-30** | **People Transport** |
|---|---|
| **6.2.3** | **Car ownership and cost of transportation** |
| **Application:** | National effect; car ownership cost increased from 29 to 36 eurocent per kilometre from 1980 to 2000. |
| **Measure type and description:** | The costs of transport modes influences their relative use, as costs become prohibitive alternate less expensive modes will become more attractive. |
| **Target group:** | Lower income drivers may change mode, all drivers may change behaviour, all road users. |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| Noland (2005) | Relationship between fuel economy and traffic fatalities, also by age category. Changes in vehicle efficiency are not related to changes in fatalities. |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) fuel cost increases will result in more and efficient cars(small, relatively vulnerable), (-) fuel cost increases will result in more efficient driving styles |
| Influence on injury risk | |
| Influence on mobility | (+) cost of transportation by car is lower than total cost (including time/inconvenience) of public transportation, increased vehicle ownership |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No strong effect studies on cost of transportation and collision effects found, weak relation of fuel prices to fatalities. |
| Barriers / opportunities | Effect is primarily on mode choice, and is therefore removed from collisions and affected by other confounders such as vehicle quality. Detailed choice of mode by age group based on cost may be difficult due to variety of socio-economic groups within age groups. |
| | |
| Additional requirements | Calibration of international models possible. Research design, identification of best indicators, and data collection if collision effect by age or mode is desired. |
| | |
| Relation to other factors | Strong relation to mobility, to lesser extent social / cultural and spatial planning factors. |
| Possible Indicator variables | Cost per kilometre by travel mode including measure of time value. Car ownership by age. |

Table 2.4.3. *Cost of transportation / car ownership relationships*

| **Economy, R-2006-30** | **People Transport** |
|---|---|
| **6.2.4** | **Road pricing** |
| **Application:** | National, will be applied first on some national roads, currently none, trials for trucks will begin in 2011. |
| **Measure type and description:** | To reduce traffic jams and congestion and to promote a reduction of unnecessary trips toll roads are planned in the Netherlands. The anticipated changes as a result of a rate per kilometre on the motorway system is a shift of mobility to the lower level, and relatively less safe secondary road network. |
| **Target group:** | Road users of the national network, beginning with motorway users; all road users on national and secondary road network. |
| | |
| **Literature listed in SWOV document:** | |
| Bakker et al. (2005) | Slower growth of motor vehicle kilometres |
| | |
| **Additional literature:** | |
| Albalate & Bel (2008) | Two way fixed effect semi-log model using European CARE data, estimated increase in collisions and model variants based on percentage toll roads in network. Discussion of pricing strategy variants. |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) shift of mobility to the secondary highway network, increased motorized two wheelers who are not charged, and increased youth vehicle purchase |
| Influence on injury risk | |
| Influence on mobility | (-) added cost of mobility, reduction of unnecessary trips |
| Influence on mode choice | (+) motorbike on the national system and increased use of public transport, (-) car use on national network |
| Influence on vehicle fleet | (+) motorbike ownership |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relations found |
| Barriers / opportunities | Most of the literature to date has focused on mobility effects. Recent road pricing in London may present some road safety relations. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if collision effect by age or mode is desired. |
| | |
| Relation to other factors | Strong relation to mobility and technology, spatial planning and social/cultural factors and population health to a lesser extent. |
| Possible Indicator variables | Changes in traffic volumes on toll roads, evaluation of spillover effect onto lower order roads, changes in collision rates on toll roads. |

Table 2.4.4. *Road pricing relationships*

| **Economy, R-2006-30** | **People Transport** |
|---|---|
| **6.2.5** | **Workforce participation** |
| **Application:** | National, increasing workforce and female participation in workforce increasing until 2020. |
| **Measure type and description:** | Employment is a source of income and also creates the demand for mobility to get to the workplace. One of the main drivers of change in this factor is the increasing participation of women in the workforce |
| **Target group:** | All drivers, increasingly female, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Scuffham (2003) | Effect of unemployment rate on collisions but not gender |
| Scuffham & Langley (2002) | Structural time series model including unemployment rate as an indicator variable, found to be inversely related to crashes. |
| | |
| **Additional literature:** | |
| Hakim et al. (1991) | Review of macro models of road safety, including unemployment as a factor which is negatively co-related to collisions |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) (lower unemployment, increased youth employment and increased lease cars), - (increased female workforce) |
| Influence on injury risk | |
| Influence on mobility | + (increased employment, increased workforce) |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | Possibility to see how marginal changes in gender distribution affect collisions |
| | |
| Additional requirements | Calibration of models to Dutch situation, quantification of gender difference. |
| | |
| Relation to other factors | Strongly related to social / cultural, mobility, spatial planning, and to a lesser extent technology and public health |
| Possible Indicator variables | Unemployment rate, gender distribution by age and mode. |

Table 2.4.5. *Workforce participation relationships*

| **Economy, R-2006-30** | **Goods Transport** |
|---|---|
| **5.2.1** | **Economic growth** |
| **Application:** | National effect, possible concentration of effect near economic centres, Dutch economy has grown 3.4% per year between 1950 and 2004, and is forecast as between 0.7 to 2.6% until 2040 |
| **Measure type and description:** | The economy is a major driver for mobility, particularly of goods. Indicators of economy are commonly included in econometric analyses of collisions. |
| **Target group:** | Focus on truck transport and to a lesser extent all drivers, all road users are potential victims |
| | |
| **Literature listed in SWOV document:** | |
| Kopits & Cropper (2005) | Relations between GDP and traffic fatalities per capita |
| Scuffham (2003) | Effect of GDP on collisions |
| | |
| **Additional literature:** | |
| No effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | |
| Influence on injury risk | |
| Influence on mobility | (+) increases in economy will result in increased goods transport, primarily by truck |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | Qualitative literature largely econometric factor analysis resulting in correlations and elasticities. |
| Barriers / opportunities | Economy is a logical driver of mobility, and therefore road safety, but the qualitative relation of economy, truck transport and road safety is still unknown. |
| | |
| Additional requirements | Calibration of econometric models to Dutch data, or translation to relevant relations. Research design, identification of best indicators, and data collection if transportation mode is desired. |
| | |
| Relation to other factors | Strongly related to mobility, also related to spatial planning, technology, and social / cultural. |
| Possible Indicator variables | Standard economic indicators. Spatial analysis by level of economic activity also possible. |

Table 2.4.6. *Economic growth and goods transport relationships*

| **Economy, R-2006-30** | **Goods Transport** |
|---|---|
| **5.2.2** | **Internationalization** |
| **Application:** | International truck traffic, primarily on national road network, penetration not reported |
| **Measure type and description:** | Internationalization results in an increased movement of goods, services, capital, and manpower between lands. Internationalization is anticipated to increase, and therefore mobility is also expected to increase. |
| **Target group:** | International drivers, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Methorst & Van Raamsdonk (2003) | Increased risk due to unfamiliarity of foreign drivers |
| Kuiken et al. (2007) | Increased risk due to unfamiliarity of foreign drivers, but also with increased exposure, so not a clear effect. |
| | |
| **Additional literature:** | |
| Beenstock & Gafni (2000) | Econometric model of internationalization at a trade level, may provide benefits in terms of upgrading the vehicle fleet and international road safety technology. May be less relevant to the Dutch situation due to higher levels of technological advancement. |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increased international competition will increase foreign driver proportion |
| Influence on injury risk | (+) increased international competition will increase foreign driver proportion |
| Influence on mobility | (+) increased foreign traffic in addition to national levels |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative literature relating to the Dutch situation increased risk not observed quantified in terms of increased collision involvement. |
| Barriers / opportunities | Collision involvement of foreign drivers and total number of foreign drivers by age group and mode are unknown |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if collision effect by age or mode is desired. |
| | |
| Relation to other factors | Related to mobility, technology, and to a lesser extent spatial planning |
| Possible Indicator variables | Proportion of foreign drivers, foreign driver collision involvement by age group and mode. |

Table 2.4.7. *Internationalization relationships*

| Economy, R-2006-30 | Goods Transport |
|---|---|
| **5.2.3** | **Distribution of economic activities** |
| **Application:** | Localized near economic centres, primarily Randstad and Flevoland, measures of penetration not reported |
| **Measure type and description:** | Economic centres attract businesses and create further concentration of economic activity, and therefore also the mobility. General development is at the edge of centre or near motorways. Mobility growth anticipated in areas with economic growth. |
| **Target group:** | Truck drivers, all road users but primarily on motorways. |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature reported | |
| | |
| **Additional literature:** | |
| No effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) shift toward evening transport to avoid congestion, location of distribution facilities along motorways may reduce urban truck transport, (-) if no separation in time or space for truck traffic |
| Influence on injury risk | |
| Influence on mobility | (+) increased transport distances, urban expansion, (-) business clustering along motorways |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found. |
| Barriers / opportunities | This is a factor which is very well suited to spatial analysis, location of collisions with truck involvement. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if collision effect by age or mode or location is desired. |
| | |
| Relation to other factors | Strongly related to spatial planning and mobility, and to a lesser extent technology |
| Possible Indicator variables | Density of economic activity |

Table 2.4.8. *Distribution of economic activities relationships*

| **Economy, R-2006-30** | **Goods Transport** |
|---|---|
| **5.2.4** | **Business and transport costs** |
| **Application:** | National, truck transport cost decreased on average 2% between 1977 and 1997 |
| **Measure type and description:** | The cost of transporting goods may impact the mode of transport. Vehicle improvements, lower speeds, and improved road network connectivity have all contributed to reduced operating costs, as well as logistical management improvements. |
| **Target group:** | Business choice of transport mode, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) longer truck trips and increased driver fatigue, (-) evening transport to separate truck traffic in time |
| Influence on injury risk | |
| Influence on mobility | (+) increased use of truck transport will result in longer trips |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found. |
| Barriers / opportunities | Exposure measures in terms of travel times and time of day are not available. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if collision effect by age or mode or time period is desired. |
| | |
| Relation to other factors | Related to mobility, technology, and to a lesser extent public health and social / cultural |
| Possible Indicator variables | Fuel and labour costs, changes in truck transport mode share |

Table 2.4.9. *Business and transport costs relationships*

| **Economy, R-2006-30** | **Goods Transport** |
|---|---|
| **5.2.5 & 5.2.6** | **ICT and e-commerce** |
| **Application:** | International; continuous expansion of ICT involvement, penetration measures not reported |
| **Measure type and description:** | Incorporation of ICT in truck transport and logistics management have created improvements in efficiency, and further advancements are anticipated. |
| **Target group:** | Transport companies, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Braimaister (2002) | Effects of e-commerce |
| | |
| **Additional literature:** | |
| No effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) increase use of delivery vans for small shipments, (+) increased urban traffic due to e-commerce, increase young delivery drivers |
| Influence on injury risk | |
| Influence on mobility | (+) better management resulting in more trips over longer distances, more small trips |
| Influence on mode choice | |
| Influence on vehicle fleet | (+) increased use of delivery vehicles |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found. |
| Barriers / opportunities | Changes in truck transport due to changes in may be difficult to quantify, but ICT itself may be a source of additional data in this area in terms of number of trips and efficiency in terms of monitoring unloaded trips and efficient network assignment. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if collision effect by age or mode or time period is desired. |
| | |
| Relation to other factors | Strongly related to technology and mobility, and to a lesser extent spatial planning |
| Possible Indicator variables | Changes to vehicle fleet, measures of efficiency in terms of goods moved per transport kilometre, spatial distribution of mobility by mode. |

Table 2.4.10. *ICT and e-commerce relationships*

| **Economy, R-2006-30** | **Goods Transport** |
|---|---|
| **5.2.7** | **Quality of goods transport & specialization** |
| **Application:** | National, increased concern for quality of transport, penetration not reported |
| **Measure type and description:** | Increased internationalization and ICT applications are creating efficiencies and therefore the competitive edge has now become the quality of goods transport. |
| **Target group:** | Transport companies, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) delivery time pressure, (-)load management, fewer trucks, professional management |
| Influence on injury risk | |
| Influence on mobility | (-) fewer trips due to increased load management, inter-modal transport and longer trucks, (+) intricate operations may result in undesired behaviours |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found. |
| Barriers / opportunities | Company quality control policies may be proprietary / trade secrets, may be difficult to quantify in terms of how quality of transport affects collisions. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if collision effect by age or mode or time period is desired. |
| | |
| Relation to other factors | Relationship to technology and mobility, possibly also spatial planning |
| Possible Indicator variables | Measures of transport efficiency |

Table 2.4.11. *Quality of transport and specialization relationships*

## 2.5. **Mobility**

The related SWOV report for the mobility external influence is:

- *The effects of mobility on road safety*, Wijnen, W. & Houwing, S. (2008), SWOV report R-2006-31

Developments in mobility are very strongly linked to developments in road safety. Traffic collisions are the direct result of mobility and are therefore very strongly linked to mobility, but the relationship remains uncertain due to several confounding factors. For example, the modal share of traffic has a strong impact on the type and severity of collisions. If there is an increase in cyclists and heavy vehicles then an increase in severe cyclist collisions is likely to result.

Changes in mobility itself, is a topic with which SWOV is not directly involved. Future mobility is provided to SWOV from DVS, and the results of these future traffic volumes, network distribution and modal splits on road safety are the concern of SWOV. Despite this arrangement influences among non-motorized road users, not considered by DVS, are also of particular interest to SWOV, and play an important role in road safety prediction.

The focus on the contribution of the other influencing factors is very well developed in this report; this type of interaction among the external influencing factors will play an important role in reducing the effect of confounders in the model residuals. The application of this approach to the other factors is also recommended.

From the report the relative relations are presented in *Table 2.5*. These relations are briefly described in the literature tables under the heading of qualitative relationships, but for a more thorough discussion of the relationship the reader is referred to the external influence report.

Table 2.5. *Qualitative relations of mobility factors*

| **Mobility** | | | | | | |
|---|---|---|---|---|---|---|
| External influencing factors | Influence on fatality risk | Influence on injury risk | Influence on mobility | Influence on mode choice | Influence on vehicle fleet | Influence on driving population |
| Mobility policy | | | +/– | +/– | | |
| Vehicle ownership | + | | + | | | |
| Traffic volumes and distribution | | | | | | |
| Mobility by gender | | | | | | |
| Mobility by age | + | | + | | | |
| Mobility by ethnicity | – | | | | | |

| **Mobility, R-2006-31** | **The summit conquered (5.1)** |
|---|---|
| **3.8** | **Mobility policy** |
| **Application:** | National, various possible directions for mobility policy |
| **Measure type and description:** | Mobility policy may be used to develop mobility in a desired way; the choice of policy may have predictable outcomes for road safety. Road pricing, for example, may result in risk migration to a lower level, and less safe road. |
| **Target group:** | All drivers, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Van Beek et al. (2007) | 60% of mobility growth is attributable to population growth, this mobility is largely (34%) due to increased travel distances. (possible mobility policy target: trip length reduction) |
| | |
| **Additional literature:** | |
| No effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) Road pricing may cause a shift to less safe lower level road network, (-) planning and policy directed at healthy non-motorized transport and public transport |
| Influence on injury risk | |
| Influence on mobility | (+/-) policy may increase or decrease mobility, pricing may reduce unnecessary trips, while improving the road network may induce more trips |
| Influence on mode choice | (+/-) road pricing may increase use of public transport or motorcycle, while decreasing car use. Policies aimed at expanding and improving the road network may result in increased car use |
| Influence on vehicle fleet | (+) motorcycles, (-) car |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | Policy effects are difficult to isolate due to the number of confounders, the time to initiate policy and the absence of control groups or cohorts. Evaluation of small scale implementations may provide a reasonable estimate of the effect |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if effect by age or mode is desired. |
| | |
| Relation to other factors | Strongly related to spatial planning, economy, and to a lesser extent technology and social and cultural factors. |
| Possible Indicator variables | Changes in mobility distribution, traffic volumes on road sections |

Table 2.5.1. *Mobility policy relationships*

| | |
|---|---|
| **Mobility, R-2006-31** | |
| **6.2.5** | **Vehicle ownership** |
| **Application:** | National; Vehicle ownership is increasing by ~2% per year, larger fluctuations in motorcycle ownership, stronger growth anticipated with growing economy and individualization. |
| **Measure type and description:** | Vehicle ownership allows greater mobility, but also increases exposure to risk. Motorcycle ownership has fluctuated more than car ownership, and resulting changes in motorcycle collisions have been linked to these developments |
| **Target group:** | All Drivers, including motorcyclists, All road users are potential victims |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) increased motorcycle ownership is related to increased collision involvement, increased fleet of delivery vans is also linked to increased risk |
| Influence on injury risk | |
| Influence on mobility | (+) increased vehicle ownership increases mobility by these modes |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | Forecasts of vehicle ownership not found, but may be useful for policy design to reduce undesired modes or improve safety for those modes (e.g. motorcycle) |
| | |
| Additional requirements | Forecast of vehicle ownership by vehicle type, increased knowledge of mobility of non-motorized modes |
| | |
| Relation to other factors | Strongly related to economy, social / cultural, and to a lesser extent spatial planning and technology |
| Possible Indicator variables | Existing measures of vehicle ownership |

Table 2.5.2. *Vehicle ownership relationships*

| | |
|---|---|
| **Mobility, R-2006-31** | |
| **6.2.5** | **Traffic volumes and distribution** |
| **Application:** | National; evaluation required at all levels, Growth on motorways has been larger than on provincial roads since the 1970's |
| **Measure type and description:** | Changes in traffic volumes and distribution have effects on the location and type of collision. Increases in traffic volumes in rural areas may result in relatively lower urban collisions, for example. As non-motorized modes increase with the aging population more attention will be required to understand developments |
| **Target group:** | All drivers, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Janssen et al. (2006) | Forecast of traffic volumes on motorway network based on development scenarios |
| | |
| **Additional literature:** | |
| No effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+/-) shift in traffic distribution may affect collision severity either positively or negatively |
| Influence on injury risk | (+/-) shift in traffic distribution may affect collision severity either positively or negatively |
| Influence on mobility | |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | Improved monitoring of traffic volumes, and therefore distribution over the road network, will require increased data collection and management, but will allow better forecasts of network distributions and mobility growth |
| | |
| Additional requirements | Forecast of network volumes and distribution, increased knowledge of mobility of non-motorized modes |
| | |
| Relation to other factors | Strongly linked to spatial planning, economy, and technology, and to a lesser extent social/cultural |
| Possible Indicator variables | Traffic volumes carried by road links, preferably also by vehicle type |

Table 2.5.3. *Traffic volumes and distribution relationships*

| | |
|---|---|
| **Mobility, R-2006-31** | |
| **5.3** | **Mobility by gender** |
| **Application:** | National, Mobility by women lower than by men, but mobility by women increasing, 2005 41% of travel kilometres by women, 70% of car victims were male between 1976 and 2005. |
| **Measure type and description:** | Gender differences are known to present differences in risk and also in travel mode choice and distance. As the share of women in traffic increases the aggregate risk may change |
| **Target group:** | All drivers, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | Distribution of risk by gender and mode discussed |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) possible reduced risk due to increased share of lower risk female drivers |
| Influence on injury risk | (-) possible reduced risk due to increased share of lower risk female drivers |
| Influence on mobility | |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | Due to changing proportion of genders the marginal effect on safety is unclear, best estimate is the most recent average effect |
| | |
| Additional requirements | Research regarding the forecast gender proportions and effect on road safety |
| | |
| Relation to other factors | Strong relation to social and cultural factors and economy, to a lesser extent spatial planning and technology also related |
| Possible Indicator variables | Percentage gender by mode and mobility |

Table 2.5.4. *Mobility by gender relationships*

| **Mobility, R-2006-31** | **The summit conquered (5.5)** |
|---|---|
| **5.4** | **Mobility by age category** |
| **Application:** | National, shifting of mobility from young to old, dominated by car mobility |
| **Measure type and description:** | Mobility by age distribution has been shifting to older drivers due to the dominance of the aging population. Lower risks of drivers older than 30 present the possibility of lower risks for the population in general, but as the percentage of licensed drivers over 60 and 75 increases this trend may reverse. |
| **Target group:** | All drivers, but a focus on drivers over 60 and 75, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) older drivers at increased risk of fatality due to increased physical vulnerability. High risk young drivers will continue to be an important issue for road safety. |
| Influence on injury risk | |
| Influence on mobility | (+) increased mobility anticipated due to larger proportion of licensed drivers in older age categories than previously |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative literature found |
| Barriers / opportunities | Difficult to estimate the marginal effect of increasing proportion of older age categories on collisions in advance. Mobility studies will continue to be the most important indicator to compare to collision and severity data |
| | |
| Additional requirements | Continued evaluation of effect of changes to proportions of age categories, both in terms of risk and mobility / mode choice. |
| | |
| Relation to other factors | Strongly related to social / cultural, spatial planning, and to a lesser extend public health and economy. |
| Possible Indicator variables | Percentage age category among licence holders, and mode choice / mobility within age categories. |

Table 2.5.5. *Mobility by age category relationships*

| | |
|---|---|
| **Mobility, R-2006-31** | |
| **5.5** | **Mobility by ethnicity** |
| **Application:** | National, penetration measures not reported |
| **Measure type and description:** | Mobility by ethnicity has been identified as being lower than Dutch nationals due to lower car ownership, and relatively higher use of non-motorized transport and public transport. The effects on collisions have not been evaluates. |
| **Target group:** | Immigrant Dutch licence holders, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+/-) effect of non-westerner mobility and mode choice effect on risk unknown |
| Influence on injury risk | (+/-) effect of non-westerner mobility and mode choice effect on risk unknown |
| Influence on mobility | (-) lower car use, (+) higher non-motorized transport and public transport |
| Influence on mode choice | |
| Influence on vehicle fleet | (-) relative decrease in size of fleet |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found. |
| Barriers / opportunities | Relative risks of Dutch nationals and Immigrant population unknown, study needed in order to develop this factor further |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection if effect of ethnicity is desired. |
| | |
| Relation to other factors | Strong relation to social/cultural factors, spatial development and economy |
| Possible Indicator variables | Mobility by ethnicity and spatial distribution, collision involvement by ethnicity |

Table 2.5.6. *Mobility by ethnicity relationships*

## 2.6. Technology and environmental care

The related SWOV report for the technology and environmental care external influence is:

- *Developments in technology and environmental care in the field of traffic and transport, with implications for road safety*, Schoon, C.C. (2008), SWOV report R-2008-4

Technology and innovation have a strong link to road safety, in many different ways. Technology has been the driver of mobility in terms of vehicle accessibility, lower costs and higher quality of vehicles. Changes in technology also have an effect on the environment in which we drive. In today's transportation system Information and Communication Technology (ICT) has become a tool for the dynamic management of traffic. Furthermore, technology has been applied toward enforcement efforts in the form of red light cameras, speed cameras and section speed control.

Vehicle technology has improved the handling characteristics of vehicles, through such measures as Electronic Stability Control and Anti-lock Braking Systems, and also the protection of occupants with energy absorbing structures, airbags, and pre-tensioning seatbelts. Vehicle measures are discussed ion more detail as road safety measures in *Chapter 4*, but other technologies are anticipated, such as road to vehicle communication and vehicle to vehicle communications, which will facilitate interactive systems for driver support systems and dynamic traffic management.

Technology in terms of infrastructure design was identified as having two main roles; separation of traffic modes, and quality assurance. Again, infrastructure developments are discussed in more detail in *Chapter 3*.

From the report the relative relations are presented in *Table 2.6*. These relations are briefly described in the literature tables under the heading of qualitative relationships, but for a more thorough discussion of the relationship the reader is referred to the external influence report.

Table 2.6. *Qualitative relations of technology and environmental care factors*

| Technology | | | | | | |
|---|---|---|---|---|---|---|
| External influencing factors | Influence on fatality risk | Influence on injury risk | Influence on mobility | Influence on mode choice | Influence on vehicle fleet | Influence on driving population |
| **Infrastructure design** | | | | | | |
| Separation of traffic modes | – | | +/– | | | |
| Quality assurance | – | | | | | |
| | | | | | | |
| **Vehicles** | | | | | | |
| Diversity of mass | + | | | | | |
| Diversity of vehicle types | + | | + | + | | |
| | | | | | | |
| **Transport** | | | | | | |
| **1. People transport** | | | | | | |
| Trip chains (multi-modal) | | | + | + | | |
| Public transport | –, +/– | | – | + | – | |
| **2. Goods transport** | | | | | | |
| Reduction of trips | – | | – | | | |
| Separation in time/space | – | | – | | | |
| | | | | | | |
| **Information and communication technology** | | | | | | |
| In-car systems | – | | | | | |
| Car-to-car systems | – | | | | | |
| Road pricing | –, + | | – | + | – | |
| | | | | | | |
| **Traffic management** | | | | | | |
| Mobility data | | | | | | |
| Speed data | – | | | | | |
| Network coverage (currently only major roads) | | | + | | | |
| Accessibility and safety | – | | + | | | |
| | | | | | | |
| **Environmental care (air quality)** | | | | | | |
| Vehicle | + | | ? | | | |
| Spatial planning | | | ? | + | | |
| Infrastructure | – | | ? | | | |

| | |
|---|---|
| **Technology, R-2008-4** | |
| **2.0** | **Infrastructure design** |
| **Application:** | National, with focus areas by mode, various penetration levels by technology |
| **Measure type and description:** | Technological advancements in infrastructural design takes many forms, but the most important of these have been measures focused on speed reduction and separation of incompatible modes. There are numerous technological advances and as effects are studies these will add to the list of road safety measures. |
| **Target group:** | All road users, a focus on vulnerable road users; all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | Description of measures as personal transport, public transport, or goods transport. Infrastructure innovations described have not been evaluated, or studies have been flawed methodologically. Several references to background reports for the measures. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) separation of traffic modes with focus on speed reduction for vulnerable road users, (-) implementation of a quality assurance system |
| Influence on injury risk | |
| Influence on mobility | (+/-) separation of traffic modes may generate changes in mode choice, (+) network analysis will allow optimization of the road network and increased mobility capacity |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative literature found |
| Barriers / opportunities | As new Infrastructure technology is introduced it will be very important to have an integrated evaluation so that the safety and mobility effects of these innovations can be quantified |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. Effect by location, mode and age. |
| | |
| Relation to other factors | Strongly related to spatial planning, mobility and economy, and to a lesser extent social / cultural factors |
| Possible Indicator variables | Effect of measures on various collision types, and eventually penetration measures. |

Table 2.6.1. *Infrastructure design relationships*

| | |
|---|---|
| **Technology, R-2008-4** | |
| **3.0** | **Vehicle technology** |
| **Application:** | National, changes in size of fleet, vehicle mass distribution(increasing) and safety technologies(increasing) |
| **Measure type and description:** | Technological advancements in vehicles can have several effects on road safety. Changes in mass distribution of the vehicle fleet reduce homogeneity of vehicles which is contrary to the aims of sustainable safety. Advancements to vehicle safety technology, both primary and secondary safety, are positive aspects in terms of safety. Increasing use of delivery vans also negative influence on safety. |
| **Target group:** | All drivers, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | Several background studies listed by vehicle type |
| | |
| **Additional literature:** | |
| Wenzel & Ross (2005) | Relations of risk to vehicle type and model in US, possible direction for Dutch research into vehicle diversity risks. Many non-conclusive findings, but some results based on aggressivity of crash opponent. |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) diversity of masses in the vehicle fleet decreases the homogeneity of the fleet, diversity of vehicle types also detracts from homogeneity of the fleet |
| Influence on injury risk | (+) diversity of masses in the vehicle fleet decreases the homogeneity of the fleet, diversity of vehicle types also detracts from homogeneity of the fleet |
| Influence on mobility | (+) increased mobility of non-car modes with increased light personal transport options such at scoot mobile and segway. |
| Influence on mode choice | (+) increased use of light transport modes |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No strong qualitative literature found |
| Barriers / opportunities | Technology and increased instrumentation of vehicle may provide new analysis possibilities. Difficult to predict the marginal effects of changing the fleet in advance. As effect studies become available changes may be included in vehicle road safety measures. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. Effect by vehicle type, crash opponent, and driver age. |
| | |
| Relation to other factors | Related to economy, social /cultural factors, and to a lesser extent mobility. |
| Possible Indicator variables | Vehicle mass, safety equipment presence and continued monitoring of fleet penetration. |

Table 2.6.2. *Vehicle technology relationships*

| | |
|---|---|
| **Technology, R-2008-4** | |
| **4.1** | **People transport technology** |
| **Application:** | National, Regional differences exist with higher intensity public transport in dense urban areas. |
| **Measure type and description:** | Personal transportation takes many forms including walking, cycling, car, and various forms of pay and public transport. An important development is the increase of 'trip chaining' or multi-modal travel. Use of walking, cycling and bus in a single trip can affect the trip risk. Public transportation cards have been shown to induce a modal shift to public transport. |
| **Target group:** | All road users of all modes, all road users are potential victims |
| | |
| **Literature listed in SWOV document:** | |
| Vlakveld et al. (2007) | Use of public transport card shown to affect mode choice, reduce car and motorized two wheeled vehicle use and increase public transport use. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) fewer car trips with increased public transport use, (+/-) mixed effect of non-motorized modes accessing public transport |
| Influence on injury risk | |
| Influence on mobility | (+) number of trips by mode due to trip chains, (-) reduced car mobility due to increased public transport use |
| Influence on mode choice | (+) trip chains results in more mode utility, (+) increased public transportation use may result in improved levels of service |
| Influence on vehicle fleet | (-) fewer cars in fleet as importance of public transport increases |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative literature found |
| Barriers / opportunities | Introduction of OV-chip card may permit detailed public transport mobility data. Difficult to study total trip characteristics, GIS may present analysis possibilities. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. Effect by mode choice, and road user age. Possible exploration of total risk trip for trip chains with multiple modes. |
| | |
| Relation to other factors | Strongly related to spatial planning, economy, and to a lesser extent social / cultural factors |
| Possible Indicator variables | Public transportation use and cost. Mode use by trip (more detailed travel survey?). |

Table 2.6.3. *People transport technology relationships*

| | |
|---|---|
| **Technology, R-2008-4** | |
| **4.2** | **Goods transport** |
| **Application:** | National, concentrated in economic centres and motorways |
| **Measure type and description:** | Technology regarding the management of truck transport of goods presents many possibilities for improving road safety, particularly in urban areas. Reduction of the number of trips, through more efficient loading and fewer empty return trips, and separation of goods trucks in time and space have been identified as the most promising areas of development for road safety. |
| **Target group:** | Truck transport companies, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Van der Heijden (2007) | 40% reduction in fatal and injured anticipated by separation of truck traffic in times when children are going to and coming from school |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) reduced risk with fewer truck trips, separation in time and space will also present fewer conflicts |
| Influence on injury risk | |
| Influence on mobility | (-) more efficient trips will result in fewer trips, and separation in time and space will reduce conflicts |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | Potential to increase the monitoring of truck routes and efficiencies with increased management tools and ICT applications. |
| | |
| Additional requirements | Continued evaluation of studies coupled with collision data, particularly in the urban setting |
| | |
| Relation to other factors | Strongly related to spatial planning, economy, and to a lesser extend social / cultural factors |
| Possible Indicator variables | Number of truck trips, spatial and temporal distribution of truck trips. |

Table 2.6.4. *Goods transport technology relationships*

| | |
|---|---|
| **Technology, R-2008-4** | |
| **5.0** | **Information and communications technology** |
| **Application:** | National, various penetration levels |
| **Measure type and description:** | Information and communications technology (ICT) introduced in vehicles is becoming common in many forms. Common platforms and standards for all in vehicle ICT systems will be important to ensure integration of all systems. Vehicle identification, on board computers, and the possibility of influencing driver behaviour have been identified as the key areas for ICT within vehicle technology. Vehicle identification will facilitate road pricing, and the use of GPS and event data recorders may be very useful for research purposes. In the more distant future on-board diagnostics may allow for communication between the vehicle and the road infrastructure |
| **Target group:** | Newer vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Wouters & Bos (2000) | Use of event data recorder may reduce collisions by 20%, based on fleet observations. |
| | Many other studies reported with intermediate results or estimates of effects. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) in-car enforcement and monitoring, trajectory speed control, driver assistance from car-to-car communications, reduced travel demand due to road pricing facilitated by vehicle identification, e-call likely to reduce severities (+) increased use of lower order roads or motorcycle mode in response to road pricing, increased driver dependence on advanced driver assistance systems, increased distraction from in-car systems. |
| Influence on injury risk | |
| Influence on mobility | (-) reduced car travel due to a shift to other modes including motorcycle and public transport |
| Influence on mode choice | (+) increased use of public transport |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | Vehicle monitoring using GPS positioning, and increasing presence of event data recorders are promising as technology innovations which will aid research. Due to the complexity of the systems and introduction in combination with other systems individual system effects may be difficult to isolate. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strong relation to economy, and to a lesser extent spatial planning, mobility, and public health. |
| Possible Indicator variables | Penetration of systems in fleet. Collision involvement of equipped models. |

Table 2.6.5. *Information and communications technology relationships*

| | |
|---|---|
| **Technology, R-2008-4** | |
| **6.0** | **Traffic management** |
| **Application:** | National, regional and local scope, Traffic management most advanced on motorway network and in major urban areas. By end of 2007, 65% of 10,000km main road network instrumented. |
| **Measure type and description:** | Traffic management is largely concerned with the collection and use of traffic data to optimize network operations. This management may take two forms, either adjusting the road network to road user behaviour (e.g. rush hour lanes) or influencing driver behaviour (e.g. suggestion of alternate routes). Speed data and network coverage are important issues, but do not impact safety or mobility directly, and rather facilitate other processes. |
| **Target group:** | Road authorities, all road users |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | Effect studies planned will mostly focus on mobility effects. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (-) risk will be reduced through increases traffic awareness and attention to safety, dynamic speed limits in response to congestion or traffic situations |
| Influence on injury risk | |
| Influence on mobility | (+) optimization of network will increase capacity, attention to access will improve connectivity and in turn mobility |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative effect literature found |
| Barriers / opportunities | As traffic management and micro simulation become more developed the opportunities for inclusion of road safety in the models will increase. The relationship between congestion and road safety is still an important research topic |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection, calibration and validation of future road safety functions with collision data. Collection and analysis of the shift from car to motorcycle and use of vulnerable modes by age group will be important, as well as changes in driver behaviour in response to traffic management techniques |
| | |
| Relation to other factors | Strongly related to spatial planning and social / cultural factors |
| Possible Indicator variables | Aggregate measures of speed (mean, % 10km/h over speed limit…) and following gap are the most likely measures, which are also commonly used in engineering literature. Micro simulation measures, such as time to collision, will become more important as modelling of road safety processes improves. |

Table 2.6.6. *Traffic management technology relationships*

| | |
|---|---|
| **Technology, R-2008-4** | |
| **7.0** | **Environmental care** |
| **Application:** | National/ global relevance, due to traffic growth in the Netherlands $CO_2$ has increased by an estimated 7% between 2000 and 2010. |
| **Measure type and description:** | Current engine technology is largely based on internal combustion of carbon based fuels. The resulting exhaust contains $CO_2$, $NO_X$ compounds and fine particulate matter, which are damaging to the environment and to public health. Strategic development of measures is underway and should include evaluation of safety and mobility effects. Noise is another environmental emission with consequences for public health. |
| **Target group:** | All vehicles; all road users, particularly in urban areas. |
| | |
| **Literature listed in SWOV document:** | |
| No effect literature listed | Effects of measures are largely evaluated in terms of changes of exhaust compound production, rather than behavioural or mobility changes. |
| | |
| **Additional literature:** | |
| No collision effect literature found | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | (+) efficiency improvement through the use of smaller vehicles will increase risk since the vehicle fleet has been found to be increasing in mass, (-) efficiency improvements achieved through infrastructure supported speed reductions will reduce risk |
| Influence on injury risk | |
| Influence on mobility | (?) changes to mobility are unclear, possible shift to non-motorized transport and public transport as a result of environmental care policies? |
| Influence on mode choice | (+) spatial planning can increase use of non-motorized transport and public transport. |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No qualitative literature found |
| Barriers / opportunities | Difficult to assess the influence of environmental care initiatives on road safety in particular and only slightly less difficult to evaluate changes to mobility. The effects of technical advancements, driver behaviour, education, enforcement and incentives on emissions are all potential research areas, but a step removed from road safety. Focus should be placed first on the relation between the pollutants and road safety as discussed in public health as an external influencing factor. |
| | |
| Additional requirements | Research design, identification of best indicators, and data collection. |
| | |
| Relation to other factors | Strongest relation to public health, and spatial planning, but also related to mobility, social cultural and economic factors. |
| Possible Indicator variables | Changes in exhaust compounds and noise concentrations. |

Table 2.6.7. *Environmental care relationships*

## 2.7. Other external factors

Some external factors which influence road safety do not fit into the classification as used so far. Examples of these are weather conditions, time of the day or month. We pick out only one of these since it is a very interesting factor and quite some information is available: the weather conditions. The others will not be discussed further in this report.

The weather condition actually falls apart in several variables, for example rainfall, fog, snow and black ice, hard wind and high temperatures. Each of these variables have to be studied separately. The weather conditions do influence the road safety, through mobility as well as risk. People may choose other traffic modes due to the present weather conditions or to the weather forecasts. On the other hand, also the risk is influenced by the weather conditions for example in case of slippery roads.

The relations and available literature are briefly described in *Table 2.7*, for a more thorough discussion we refer to Bijleveld & Churchill (2009) and SWOV (2009b).

| **Weather, R-2009-9** | |
|---|---|
| | **Weather** |
| **Application:** | National effect: influence may vary by traffic mode. |
| **Measure type and description:** | Weather conditions are measured in terms of several variables such as rainfall and temperature. Seasonal effect rather than time dependencies over the years. Effect on mobility as well as risk. |
| **Target group:** | All road users, partly depending on traffic mode and which weather condition is studied. |
| | |
| **Literature listed in SWOV document:** | |
| SWOV (2009b) | Short summary of influences of rainfall, fog, snow and black ice, low sun, hard wind, and high temperatures. Including many references. |
| | |
| **Additional literature:** | |
| See references in SWOV (2009b) | |
| | |
| **Qualitative relationships:** | |
| Influence on fatality risk | Risk not studied directly, only number of accidents and casualties, which is influenced by the mobility changes as well. |
| Influence on injury risk | Risk not studied directly, only number of accidents and casualties, which is influenced by the mobility changes as well. |
| Influence on mobility | In wet weather conditions the mobility of pedestrians and bicyclists decreases, especially for non-professional travel.<br>High average temperature is related to an increase of the use of bicycle and motorcycle. |
| Influence on mode choice | |
| Influence on vehicle fleet | |
| Influence on driving population | |
| | |
| **Quantitative relationships:** | |
| Relation to casualties / collisions | No quantitative relationships found. Since bad weather conditions usually only appear a limited number of days per year, it is difficult to determine the quantitative effect. For example, even in the Netherlands it is raining only about 7% of the time. |
| Barriers / opportunities | Information from other countries is difficult to apply for the Dutch situation. Since people are influenced by the general climate and because of the difference in mix of modes in the Netherlands as compared to other countries (role of pedestrians and bicyclists) this information cannot. Just be translated to the Netherlands. Possible interaction effects of different weather conditions should be taken into account as well. |
| | |
| Additional requirements | More research on the Dutch situation. In contrast to R-2009-9, it is probably useful to study the effect on mobility and risk separately and combine these effects to obtain the general effect. |
| | |
| Relation to other factors | Relation to mobility, especially choice of traffic mode. |
| Possible Indicator variables | Number of days per year/month of a certain weather condition and severity |

Table 2.7. *Weather relationships*

# 3. Road safety measures

The evaluation of knowledge gaps between road safety measures and the effects of these measures will begin in detail applying the literature review methodology outlined in *Section 1.2*. The main groupings of road safety measures listed in *The summit conquered* (SWOV, 2007) are:

- Infrastructural measures
  - Physical measures
  - Road rules
- Vehicle safety
  - Primary safety
  - Secondary safety
- Enforcement, promotion, and education

Where possible the measure should be the best indicator of casualty or collision involvement, but where not possible other appropriate measures which have been, and will continue to be, measured could be used as proxy variables (e.g. population belt wear rate as proxy for wear rate of occupants in collisions). The appropriateness of the data depends partially on what has been available, and also on what is reasonably available.

## 3.1. Infrastructure road safety measures

The most literature was available in regards to effects of road infrastructure safety measures. Despite the large availability of literature the majority of studies use intermediate measures as indicator variables, rather than collisions or severity of collisions. A lot of work has been done and can be translated into useful numerical values for road safety models, but there is a great deal of work to be done, and as more robust effects are obtained the road safety model can be updated and improved.

*Tables 3.1.1* to *3.1.12* summarize the infrastructure road safety measures and effects as listed in *The summit conquered* and the literature reviewed.

| | |
|---|---|
| **The summit conquered** | |
| **6.1.1** | **Motorway / Highway network** |
| **Application:** | National network; urban/rural; 11% growth in 70's, thereafter ~1% |
| **Measure type and description:** | Motorways are relatively safe due to access control, uniformity of direction, and although speeds are high risks are relatively low |
| **Target group** | Motorways, drivers of motorized vehicles, occupants of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| None listed in *The summit* | |
| | |
| **Additional literature:** | |
| Schoon (2000) | 50% reduction fatal and hosp - based on grade separation, clear zone, directional separation from VVR-GIS. |
| Van Geirt & Nuyts (2005) | Accident models for Flemish motorways |
| Bahar et al. (2007) | Literature review of crash reduction factors and functions for various features of freeways, ramps etc. with many references. |
| Elvik & Vaa (2004) | 40-80% lower risk on motorways than other roads, refers to Koornstra 1993 future developments of motorized traffic and fatalities |
| Bonneson et al. (2005) | Compilation of safety prediction models and accident modification factors |
| Caliendo et al. (2007) | Italian collision prediction models on freeways (length, curvature, AADT, sight distance…) |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** */ N* ) |
| Relation to casualties | Yes, as % value or Flemish models |

Table 3.1.1. *Motorway / Highway network relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.1.2** | **Parallel facilities** |
| **Application:** | local networks; urban/rural; penetration unknown |
| **Measure type and description:** | Separated facilities to allow separation of different vehicle types or masses Cycle paths or parallel roads |
| **Target group** | Primarily local roads, drivers of motorized vehicles and vulnerable road users. |
| | |
| **Literature listed in SWOV document:** | |
| SWOV (2008b) | 50% fewer injury accidents on cycle paths as compared to cycle lanes, and 50% fewer injury accidents on roads without cycle facilities as compared to cycle lanes (based on Welleman &Dijkstra, 1988) |
| | |
| **Additional literature:** | |
| Wijnen et al. (2010) | Bicycle paths - 25% reduction in cyclist casualties urban & rural distributors based on Welleman & Dijkstra (1988) |
| Schoon (2000) | parallel roads along distributor roads 25% reduction in fatal and serious injury, cycle facilities also 25% in KSI |
| Reekmans et al. (2004) | 68% reduction in collisions and 20% reduction in casualties for frontage roads for accesses along distributor roads |
| Elvik & Vaa (2004) | 4% reduction in injury accidents, also refer to Welleman & Dijkstra (1988) |
| Kallberg & Salusjarvi (1982) | 14% reduction in fatal and serious injury, and 40% in all collisions involving pedestrians and cyclists |
| Bahar et al. (2007) | Crash reduction factors for frontage road 40% all severities with references. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, as %reduction |
| Additional requirements | Dutch calibration, current penetration and geometry. |
| | |
| Relation to collisions | Yes, as % reduction in foreign literature |
| Additional requirements | Dutch calibration, current penetration and geometry. |

Table 3.1.2. *Parallel facility relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.1.3** | **Crossing facilities** |
| **Application:** | Local network; urban/rural; unknown penetration |
| **Measure type and description:** | Crossing facilities are intended to allow safe movements of vulnerable users across roads, applications are varied |
| **Target group** | Access roads and some distributor roads, vulnerable road users |
| | |
| **Literature listed in SWOV document:** | |
| SWOV (2010) | Variety of applications. Only 42 % of serious pedestrian injuries on crossing facilities, remainder are also crossing but not at these locations |
| Dijkstra (2000) | Sites with traffic lights and zebra crossings seem safer. |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Meta analysis, raised pedestrian crossings result in reductions in all severities of injury collisions: |
| | Pedestrian: reduction of 49% (-75to+3) |
| | Vehicle occupants: reduction of 33% (-58to+6) |
| | All injuries: reduction of 39% (-58to+10) |
| Proj.team prov.Overijssel & proj. team Goudappel Coffeng (2005) | Effect of raised pedestrian crossings to be a 35% reduction of fatal and injury accidents. |
| Reekmans et al. (2004) | Reported a range of 15-26% reduction in casualty collisions as a result of the introduction of raised pedestrian crossings. |
| Bahar et al. (2007) | Crash reduction factors for various features of crossing facilities with references. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, as % reduction in NL and BE |
| Additional requirements | Penetration and potential locations |
| | |
| Relation to collisions | Yes, as % reduction in NL and BE |
| Additional requirements | Penetration and potential locations |

Table 3.1.3. *Crossing facility relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.1.4** | **30 km/h zones** |
| **Application:** | Local network; urban; 2003 ~50% of residence streets developed as zone 30 |
| **Measure type and description:** | Speed of 30km/h has been shown to almost remove the possibility of fatalities. Design includes speed reduction measures, signage, and visual clues |
| **Target group** | Access roads, vulnerable road users and drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| SWOV (2009a) | Internationally 25% reduction in serious injuries |
| Vis & Kaal (1993) | For the Netherlands 22% +/- 13% |
| Wegman et al. (2006) | 2002 10% reduction in fatalities and 60% reduction in fatal and serious injuries combined |
| | |
| **Additional literature:** | |
| Wijnen et.al (2010) | 25% based on Vis & Kaal (1993) and Elvik (2001), partial conversions 15% based on Schoon (2000) |
| Reekmans et al. (2004) | 15-35% reduction in KSI |
| Elvik & Vaa (2004) | 15% reduction in Injury accidents, possibly a result of reduced traffic |
| Elvik (2001) | Meta analysis, accident reduction of 26% (38%; 11%) for the Netherlands |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes |
| Additional requirements | Data could be improved with a better inventory of full and partial conversions. |
| | |
| Relation to collisions | Yes |
| Additional requirements | Data could be improved with a better inventory of full and partial conversions. |

Table 3.1.4. *30 km.h zone relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.1.5** | **60 km/h zones** |
| **Application:** | Local network; rural; in 2003 there were 10,000km of zone 60 roads, 20% of these were sustainable safe |
| **Measure type and description:** | Speed of 60km/h reduces the possibility of fatalities. Design includes speed reduction measures, signage, and visual clues |
| **Target group** | Access roads, vulnerable road users and drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Beenker et al. (2004) | 18% reduction in fatal and serious injuries per converted kilometre, greatest effect at intersections, based on 20 areas evaluated for the water management board |
| Wegman et al. (2006) | 2002 70% reduction in fatal collisions and 30% reduction in seriously injured compared to 1997 |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | 5-12% reduction in injury accidents on main streets in area wide traffic calming. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes |
| Additional requirements | Data could be improved with a better inventory of full and partial conversions. |
| | |
| Relation to collisions | Yes |
| Additional requirements | Data could be improved with a better inventory of full and partial conversions. |

Table 3.1.5. *60 km/h zone relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.1.6** | **Roundabouts** |
| **Application:** | National and local network; urban/rural; ~3630 roundabouts in 2006, ~78% municipalities and ~20% provinces |
| **Measure type and description:** | Intersection treatment to reduce speed, reduce the number of conflict points and maintain traffic flow |
| **Target group** | Distributor and access roads, drivers of motorized vehicles vulnerable road users appear to be at increased risk |
| | |
| **Literature listed in SWOV document:** | |
| Elvik & Vaa (2004) | 10 to 40% reduction in casualties independent of before situation |
| Van Minnen (1990) | 73% reduction |
| | |
| **Additional literature:** | |
| Dijkstra (2005) | Priority cyclist: 11% reduction in-patients |
| | Without priority cyclist: 87% reduction inpatients |
| Van der Dussen (2002) | Non-casualty: 20% reduction |
| | Casualty: 70% reduction |
| Grontmij (2002) | All collisions: 53-60% reduction |
| | All casualties: 26-90% reduction |
| Van Minnen (1990) | Urban: 86% reduction casualties, 54% reduction collisions |
| | Rural: 90% reduction casualties, 60% reduction collisions |
| Schoon & Van Minnen (1993) | Urban: 69% reduction of casualties |
| | Rural: 86% reduction of casualties |
| | Reduction by user type: |
| | Occupant 95% |
| | Scooter 63% |
| | Cyclist 30% |
| | Pedestrian 89% |
| | Total casualties 70% |
| | All collisions: 50% reduction |
| Weijmans et al. (2002) | Priority intersection to roundabout: 80% reduction of casualties. Signalized to roundabout: 60% reduction of casualties |

| | |
|---|---|
| Persaud et al. (2000) | Urban Signalized to roundabout: |
| | 32% reduction collisions |
| | 68% reduction casualties |
| | Stop control to roundabout reductions: |
| | Urban: 61% collisions, 77% casualties |
| | 1 lane 61%, more lanes 15% |
| | Rural: 58% collisions, 82% casualties |
| | Urban and rural un-signalized to roundabout: |
| | 39% reduction collisions |
| | 76% reduction injury |
| | 89% reduction serious injury and fatal |
| Bahar et al. (2007) | Crash reduction factors for various features of roundabouts facilities and conversion situations with references. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes |
| Additional requirements | Development of roundabouts |
| | |
| Relation to collisions | Yes |
| Additional requirements | Development of roundabouts |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Change of effectiveness and shift of burden of harm |
| Barriers / opportunities | Before and after collision data, traffic control and geometry details, traffic volumes including cyclists. |
| | |
| Relation to collisions | Change of effectiveness and shift of burden of harm |
| Barriers / opportunities | Before and after collision data, traffic control and geometry details, traffic volumes including cyclists. |

Table 3.1.6. *Roundabout literature relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.1.7** | **Safe roadsides** |
| **Application:** | Provincial / National network; rural; Unknown penetration |
| **Measure type and description:** | Provision of clear zones and forgiving roadsides reduces the frequency and severity of run off road collisions |
| **Target group** | largely 80km/h distributor roads, drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Effect studies not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Schoon (2000) | 75% reduction in run off road fatalities and serious injuries on motorways, 20% for shoulder hardening and 55% for obstacle free zones on distributor roads |
| Reekmans et al. (2004) | 13-32% reduction in casualties for shoulder hardening and 51-55% for obstacle free zones |
| Elvik & Vaa (2004) | Obstacle free zone 1-5m 20-40% reduction in all accidents, 5-9m 43-46% reduction in all accidents (based on Zegeer et al., 1988) |
| Bahar et al. (2007) | Crash reduction factors for various shoulder widths and side slopes with references. |
| Ogden (1997) | Casualty reduction of 41% with shoulder paving of 600-1200mm |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reductions |
| Additional requirements | Data for hardened shoulder presence, clear zone presence required. |
| | |
| Relation to collisions | Yes, % reductions |
| Additional requirements | Data for hardened shoulder presence, clear zone presence required. May require Dutch study. |

Table 3.1.7. *Safe roadside relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.1.8** | **Recognizable roads** |
| **Application:** | All networks; urban/rural; unknown penetration |
| **Measure type and description:** | Recognizability of roads allows drivers to act in a uniform manner and know what speeds and road users to expect |
| **Target group** | All roads, drivers of motorized vehicles and vulnerable road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | Davidse et al. (2004) referred to, meta analysis of recognizability of road markings and road user behaviours. |
| | |
| **Additional literature:** | |
| None found | |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Degree of recognizability or variance from 'standard' for urban or rural |
| Barriers / opportunities | Difficult to link due to variety of road forms and other casualty factors. Relationship between recognizable roads and casualties may be determined best by in-depth study. Or before and after studies of conversions to 'recognizable road' layouts. |
| | |
| Relation to collisions | Degree of recognizability or variance from 'standard' for urban or rural |
| Barriers / opportunities | Difficult to link due to variety of road forms and other casualty factors. Relationship between recognizable roads and casualties may be determined best by in-depth study. Or before and after studies of conversions to 'recognizable road' layouts. |

Table 3.1.8. *Recognizable roads relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.2.1** | **Road rules** |
| **Application:** | National, provincial and local ; urban/rural; universal |
| **Measure type and description:** | Changes to road use rules and legislation such as right of way for all vehicles from the right |
| **Target group** | All roads, drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Noordzij & Vis (1994) | RVV 1990 not very different from 1966, many rules not known by drivers, importance placed on use of traffic plains, pedestrian crossings and mopeds free to turn right. |
| | No effects mentioned. |
| | |
| **Additional literature:** | |
| Elvik (1997) | Estimate of reduction for 100%compliance 27% injury, 48% fatality |
| Bahar et al. (2007) | Crash reduction factors for various turning movement legislations with references. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Change of road rule |
| Barriers / opportunities | Difficult to isolate due to confounding factors such as advertising and enforcement directed at same measure. Violation of rule may be traceable through in-depth studies. |
| | |
| Relation to collisions | Change of road rule |
| Barriers / opportunities | Difficult to isolate due to confounding factors such as advertising and enforcement directed at same measure. Violation of rule may be traceable through in-depth studies. |

Table 3.1.9. *Road rules relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.2.2** | **Establishing and altering speed limits** |
| **Application:** | National network; urban/rural; 11% growth in 70's, thereafter ~1% |
| **Measure type and description:** | Motorways are relatively safe due to access control, uniformity of direction, and although speeds are high risks are relatively low |
| **Target group** | Motorways, drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Wilmot & Khanal (1999) | 25-50% (5-10km/h) reduction in speeds as a result of 20km/h posted speed reduction |
| Aarts & Van Schagen (2006) | Larger speed reduction effect on access roads than motorways, and reductions in collisions and casualties, many models reviewed. |
| Aarts & Stipdonk (in prep.) | 60% reduction in fatalities, 45% severely injured. (20km/h lowering of speed limit with enforcement on motorways) |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Present linear relationship between % change in speed and % change in accidents (p.525), many changes discussed |
| Bahar et al. (2007) | Crash reduction factors for various speed limit changes with references. |
| Lee et al. (2006) | 5-17% reduction of collisions due to variable speed limit application in Toronto, as well as micro simulation model based on speed separation and lane changing behaviour |
| Johansson (1995) | Structural time series model of speed reduction on motorways. Speed reduction reduced all severities, but only significant for minor injury. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes |
| Additional requirements | Traffic speed characteristics by road segment, some models include traffic volumes |
| | |
| Relation to collisions | Yes |
| Additional requirements | May require calibration to Dutch situation |

Table 3.1.10. *Establishing and altering speed limits relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.2.3** | **Moped on the road** |
| **Application:** | Provincial and local network; urban/rural; universal road rule 70km/h or lower speed limit moped on roadway rather than cycle path |
| **Measure type and description:** | Separation of mopeds from other users based on relative vulnerability at higher or lower posted speeds |
| **Target group** | Distributor and local roads, moped riders and other vulnerable road users. |
| | |
| **Literature listed in SWOV document:** | |
| Van Loon (2003) | 15% of reduction in moped accidents in 2000 can be attributed to the Moped on the road measure |
| | |
| **Additional literature:** | |
| None found | |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | No |
| Additional requirements | Difficult to obtain since rule is now in effect, unless before and after volumes, location of potential roads affected and casualty data is available. |
| | |
| Relation to collisions | Yes |
| Additional requirements | Little use for application to prediction, since rule in effect. Useful as explanatory step in collisions. |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Rule / no rule |
| Barriers / opportunities | Possible to evaluate change if rule is ever repealed. |

Table 3.1.11. *Moped on the road relationships*

| | |
|---|---|
| **The summit conquered** | |
| **6.2.4** | **Right of way for slow vehicles from the right** |
| **Application:** | Provincial and municipal network; urban/rural; universal road rule |
| **Measure type and description:** | This measure is in effect at uncontrolled intersections where right of way must be extended to all road users from the right, including cyclists. |
| **Target group** | Uncontrolled intersections, vulnerable road users and drivers of motorized vehicles, vulnerable road users |
| | |
| **Literature listed in SWOV document:** | |
| Van Loon (2003) | Hardly any effect on road safety reported (7% increase in moped injury collisions, 3% increase cyclist injury collisions) |
| | |
| **Additional literature:** | |
| Räsänen et al. (1999) | Study of car bicycle interactions under different priority regulation, observed yield behaviour and cyclist head movement, no relation to collisions |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | No |
| Additional requirements | Difficult to obtain since rule is now in effect. |
| | |
| Relation to collisions | Yes |
| Additional requirements | Little use for application to prediction, since rule in effect. Useful as explanatory step in collisions. |

Table 3.1.12. *Right of way for slow vehicles on the right relationships*

## 3.2. **Vehicle road safety measures**

Vehicle road safety measures are generally divided into primary (preventative), or secondary (reactive) safety. Primary safety systems include measures that work to prevent a collision, while secondary safety systems aim to reduce the severity of casualties given that a collision has occurred.

Vehicle measures and technology are closely related, and the interaction of these factors will continue to have an influence on road safety. The incentive for vehicle manufacturers to produce safer vehicles is due in part to consumer demand for safer cars, and also to legislation and general initiatives to improve vehicle quality such as the EuroNCAP crash testing program. Although the contributions of the aforementioned factors are unclear, vehicle safety is continuing to improve with time.

*Tables 3.2.1* to *3.2.18* summarize the vehicle road safety measures and effects as listed in *The summit conquered* and the relevant literature reviewed. *Tables 3.2.1* to *3.2.8* cover primary safety vehicle measures, and *Tables 3.2.9* to *3.2.18* cover secondary safety vehicle measures.

| | |
|---|---|
| **The summit conquered** | |
| **7.1.1** | **Braking systems** |
| **Application:** | National network; urban/rural; ABS standard on new vehicles, EBA optional on some vehicles since 1997 |
| **Measure type and description:** | Use of systems such as Antilock Braking System to prevent wheel lockup and maintain vehicle control under severe braking conditions. Emergency Brake Assist senses emergency braking situations and apply a greater braking force. |
| **Target group** | Commercial and personal vehicles, drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Kahane (1994) | ABS little improvement in road safety, but a shift from multiple vehicle collisions to single vehicle collisions. |
| Farmer (2001) | ABS reduction in likelihood of fatal collision. |
| | Braking Assist or Emergency Brake Assist 20-40% shorter braking distances. |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Small reduction, 3-5%, in all collisions but large changes within collision types; increase in rollover, fixed object and single vehicle, reductions in pedestrian/cyclist/animal collisions. For trucks similar, 6-8%, reduction overall and increase single vehicle, reduced vulnerable users, but increase in all fatalities for crash opponents |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | No |
| Additional requirements | Of interest particularly for vulnerable road users and presence of ABS on both crash parties. |
| | |
| Relation to collisions | Yes |
| Additional requirements | Dutch investigation of effects possibly warranted, particularly shift of harm to vulnerable road users. ABS penetration data required. |
| | |
| **Unknown relationships:** | |
| Relation to casualties | ABS presence of both crash parties (or single party), and shift of harm to vulnerable road users. |
| Barriers / opportunities | Would require collection of vehicle data, or reduction from make/model/year and standard features. |

Table 3.2.1. *Braking systems relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.1.2** | **Stability control systems** |
| **Application:** | National network; urban/rural; ~25% of new vehicles |
| **Measure type and description:** | Electronic intervention to regain vehicle control after initiation of slide or tipping (Electronic Stability Control , ESC; or Electronic Stability Program, ESP) |
| **Target group** | Personal vehicles, drivers of motorized vehicles, occupants of equipped vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Green & Woodrooffe (2006) | 30% fewer fatal casualties of single vehicle casualties as compared to vehicles without ESC, greater effect for SUV's 50-60% |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Discussion of rollover mechanics and reference to Robertson & Kelley (1989), Risk of fatal rollover in utility vehicles. |
| Frampton & Thomas (2007) | Reduction of 7% all severities, serious 11%, fatal 25%, compared to non-ESC cars. Further rates for road conditions and collision types. |
| Dang (2007) | Overall reduction of 8% all casualties and 14% fatal. Comparison group is same vehicle, but those without ESC. Further rates by collision and vehicle types. |
| Lee et al. (2006) | 17% reduction in all collision types, further rates by surface type and severity. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes |
| Additional requirements | Dutch calibration requires vehicle equipment data linked to collision records. |
| | |
| Relation to collisions | No |
| Additional requirements | Work required for use in model, e.g. Dutch calibration, Data |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Presence of stability control systems in collisions related to penetration of systems in fleet. |
| Barriers / opportunities | Large data requirements; system penetration in fleet and collision involvement. |

Table 3.2.2. *Stability control systems relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.1.3** | **Visibility improvements** |
| **Application:** | National network; urban/rural; 11% growth in 70's, thereafter ~1% |
| **Measure type and description:** | Measures to improve the conspicuity of vehicles such as reflectors or daytime running lights |
| **Target group** | Motorized and non-motorized vehicles, drivers of motorized vehicles and non-motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Elvik et al. (2003) | Daytime running lights fatal collisions -15%, severe casualties -10%, light casualties -5%, no reduction in PDO collisions |
| Schoon & Roszbach (2000) | Reduction of 1-2% of rear end collisions. |
| Farmer (1996), Kahane & Hertz (1998) | In US reduction 5% in collisions due to third brake light |
| De Niet et al. (2002) | Retro reflective contour marking effect is estimated at -10 to 30% in collisions involving trucks. |
| Reflective marking on bicycles | No effect studies reported in *The summit* |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Daytime running lights result in a reduction of around 10-15% in multi party collisions (when DRL increased from 35-40% to 85-90% use). |
| Elvik & Vaa (2004) | Side marker lights decrease side impact collisions by 5-10% |
| Tromp & Noordzij (1991) | Small decrease in collisions with parked trucks with reflectors. |
| Bahar et al. (2007) | Crash reduction factors for various street lighting changes with references. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, but only for daytime running lights |
| Additional requirements | Fleet data regarding penetration of various visibility increasing measures. |
| | |
| Relation to collisions | Yes |
| Additional requirements | Fleet data regarding penetration of various visibility increasing measures. |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Effect of reflective marking on bicycles |
| Barriers / opportunities | Bicycle equipment data and collision involvement during periods of effectiveness (dark) are required. May explain cyclist casualty developments. |

Table 3.2.3. *Visibility improvements relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.1.4** | **Field of view improvements** |
| **Application:** | National network; urban/rural; blind spot mirror mandatory for trucks since January 2003 |
| **Measure type and description:** | Vehicle changes to increase field of view or clarity of view reduces the likelihood of not seeing another road user or increases reaction time |
| **Target group** | Commercial and personal vehicles, drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | Wipers, water repellant glass, Xenon lights |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Blind spot mirrors decrease right turn fatal but increase injury accidents (based on Behrensdorff & Hansen, 1994) |
| Langeveld & Schoon (2004) | Blind spot mirrors decrease fatal and injury accidents by 40% |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % Casualty reduction |
| Additional requirements | Continuing collection of penetration data required, better data collection regarding equipment of vehicles in collisions. |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Effects of wipers, water repellant glass, and Xenon lights not found |
| Barriers / opportunities | Presence in fleet required as well as collision involvement |
| | |
| Relation to collisions | Effects of Blind spot mirrors, wipers, water repellant glass, and Xenon lights not found |
| Barriers / opportunities | Presence in fleet required as well as collision involvement |

Table 3.2.4. *Field of view improvements relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.1.5** | **Speed limiting** |
| **Application:** | National network; urban/rural; 11% growth in 70's, thereafter ~1% |
| **Measure type and description:** | Limiting, or reducing, speed can reduce the frequency and severity of collisions, for heavy vehicles in particular. |
| **Target group** | Primarily heavy commercial vehicles but also personal motor vehicles, drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | Heavy vehicles |
| | |
| **Additional literature:** | |
| Mopeds / Motorcycles: | |
| Elvik & Vaa (2004) | Ban on tuning mopeds could reduce injury accidents by 4-21% |
| | Best controlled study noted is Ingebrigtsen (1990) including controls for gender, age, experience, risk taking and vehicle characteristics |
| | |
| Inteligent speed limitiation: | |
| Várhelyi & Maekinen (2001) | Larger effect on lower speed roads (30 & 60km/h) than on higher speed roads (70, 80, 110km/h), decreased following times possible negative consequences. Behavioural and stated preferences, no direct link to collisions or severity. |
| Regan et al. (2006) | 8% and 6% reduction in fatal and serious injury respectively. Based on observed reduction in mean speed of equipped vehicles. |
| OECD (2003) | Summarize estimates of collision reductions, but summarized studies are based on observed speed reductions. |
| Louwerse (2005) | 4-19% reduction in injury casualties based on 95% market penetration. |
| | |
| Adaptive cruise control: | |
| Elvik & Vaa (2004) | 49% reduction rear end collisions, and 6 % reduction in all accidents |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reduction |
| Additional requirements | Continuing collection of penetration data required, better data collection regarding equipment of vehicles in collisions. |
| | |
| Relation to collisions | Yes, % reduction |
| Additional requirements | Continuing collection of penetration data required, better data collection regarding equipment of vehicles in collisions. |

Table 3.2.5. *Speed limiting relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.1.6** | **Combined safety systems** |
| **Application:** | National network; urban/rural; 11% growth in 70's, thereafter ~1% |
| **Measure type and description:** | Pre-crash sensing can lead to the activation of several systems such as electronic brake assist (EBA), seatbelt pretensioning or other preventative measures. Collision avoidance systems (CAS) are another example of a combination of ABS and ESC. |
| **Target group** | Some personal vehicles, drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Lu (2006) | Model developed to allow comparison of ADAS to infrastructural measures reductions estimated for several systems and situations. Reported reductions: speed assistance (46% fatal, 33% hospital), Anti-collision (3% fatal, 2% hospital), Intersection support (64% fatal ,46% Hospital) |
| OECD (2003) | In combination with an instrumented intersection reductions of 17-50% have been found, more research necessary. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reductions |
| Additional requirements | Collection of penetration data required, better data collection regarding equipment of vehicles in collisions. |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Effects of systems for various collision types |
| barriers / opportunities | Collection of penetration data required, better data collection regarding equipment of vehicles in collisions. |

Table 3.2.6. *Combined safety systems relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.1.7** | **Child door lock** |
| **Application:** | Optional; urban/rural; unknown introduced in 1972 |
| **Measure type and description:** | Physical deactivation of the interior door handle to prevent children opening the door while the vehicle is in motion |
| **Target group** | Personal vehicle, Child passengers in motorized vehicles, Child passengers in motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| None found | |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Effect of child door lock on reducing child fatalities |
| Barriers / opportunities | Market penetration of measure is unknown, as is the number of children who open the door and fall out of vehicle, estimated as few. |
| | |
| Relation to collisions | Effect of child door lock on reducing child collisions |
| Barriers / opportunities | Market penetration of measure is unknown, as is the number of children who open the door and fall out of vehicle, estimated as few. |

Table 3.2.7. *Child door lock relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.1.8** | **Vehicle quality** |
| **Application:** | International; all vehicles; Universal requirement with variable timeframes |
| **Measure type and description:** | General periodic inspection is an international initiative to reduce the presence of mechanical failure as a cause of traffic collisions |
| **Target group** | All motor vehicles, drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Tromp (1985) | From 70s and 80s 2-6% of collisions had mechanical failure as a cause. |
| CITA (2007) | 60% reduction as a contributor to collisions |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Best study noted as (Fosser 1991, 1992) with 204,000 passenger cars in three groups followed over three years (decrease injury accidents of 10% to an increase of 7%) |
| | Heavy vehicle inspection (Moses & Savange, 1992). Injury accident decrease 8%, limits decrease 13% to increase 3%. |
| Christensen & Elvik (2007) | Small (stat. insignificant) decrease in accident rates if defects present, repaired vehicles slight increase in accident rate, overall no effect quoted. |
| John A. Volpe National Transportation Systems Center (2007) | Intervention model based on difference in risk associated with various truck safety factors (including driver) 334 fatal and 6418 injuries claimed to be saved in 2005. |
| SWOV (2009d) | 20-30% reduction of 2-6% total collisions (1 % of all collisions). Increased inspections estimated at 60% reduction. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to collisions | Yes, as % reduction |
| Additional requirements | More detailed data regarding vehicle condition at collision and last inspection |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Effect of vehicle quality inspection |
| Barriers / opportunities | More detailed data regarding vehicle condition at collision and last inspection, in-depth study detail, casualty involvement |

Table 3.2.8. *Vehicle quality relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.1** | **Helmets and protective clothing for mopeds and motorbikes** |
| **Application:** | All networks; urban/rural; helmets required but wear rate uncertain (nearly all) |
| **Measure type and description:** | Two wheeled motor vehicle drivers and passengers are vulnerable road users due to speed and lack of protection, helmets and protective clothing increase the likelihood of survival. |
| **Target group** | Two wheeled motor vehicles, drivers of two wheeled motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Huijbers & Van Kampen (1985) | Reduction of 40% fatal and 30% injured moped riders. |
| Huijbers & Van Kampen (1985) | Use of helmets and protective clothing 5% fewer deaths and 10% fewer injuries for two wheeled motor vehicles. |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Introducing mandatory helmet wearing; fatal decrease 26% (19 to 33), all injury decrease 27% (25 to 28) |
| | Motorcycle protective clothing effect is between 33 and 50% reduction in number of injuries |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reduction |
| Additional requirements | Helmet wearing rates and casualty involvement with or without helmet. |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Helmet and protective equipment wearing causation of collisions |
| Barriers / opportunities | Helmet wearing rates and collision involvement with or without helmet. |

Table 3.2.9. *Helmets and protective clothing for moped and bicycle relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.2** | **Seatbelts** |
| **Application:** | All networks; urban/rural; wear rate in the 90% range |
| **Measure type and description:** | Seatbelts are a supplementary restraint to prevent secondary collisions of the occupant with the vehicle, and also to prevent ejection from the vehicle. Seatbelts do not reduce the risk of collision only the resulting severity. Most effective in head on or rollover collisions. |
| **Target group** | Personal and commercial vehicles, drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Evans (1986; 1991) | 25% reduction in hospital injuries, 40% fatal for front seat occupants; 20% in-patients, and 30% fatal for rear seat occupants. |
| Kullgren et al. (2006) | Seatbelt reminder system resulted in near 100% wear rates. |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Fatal injuries reduced by 45-50% (35-55) for front and 25% (15-35) for rear occupants. Serious injury similar with 45% and 25% for front and rear respectively |
| | Log relationship presented for % change in fatalities and injuries as a function of % change wear rate. p. 679 & 680. |
| Derrig et al. (2002) | Little or no effect on reducing fatality rates based on 14 models, Primary law (ability to stop for seatbelt offence) weakly significant. Better to target efforts at high risk groups than overall wear rates. Fixed effects models with several demographic and social factors for all 50 states in the US. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, as % reduction for front or rear positions |
| Additional requirements | Belt wearing rates continued collection |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Seatbelt wearing and changes in collision involvement (risk compensation) |
| Barriers / opportunities | Difficult to link seatbelt wearing to change in behaviour and resulting collision involvement, possibly in-depth detail. |

Table 3.2.10. *Seatbelts relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.3** | **Crumple zones** |
| **Application:** | National network; urban/rural; introduced in 50's, widespread today. |
| **Measure type and description:** | Crumple zones are designed to absorb the impact energy and increase the time over which impact occurs thereby reducing deceleration rates |
| **Target group** | Personal vehicles, occupants of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| None found | |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Crumple zone effect on casualties |
| Barriers / opportunities | Different crumple zone properties by vehicle (e.g. resulting Delta V) and severity distributions by crash involvement. Difficult to determine historical penetration for explanatory purposes. |
| | |
| Relation to collisions | Crumple zone effect on collisions |
| Barriers / opportunities | Numerous confounders to show link between presence and collision involvement. Risk compensation possible, but unlikely. |

Table 3.2.11. *Crumple zones relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.4** | **Headrests** |
| **Application:** | National network; urban/rural; present in nearly all vehicles rates of proper use unclear |
| **Measure type and description:** | Headrests reduce backward head movements and whiplash |
| **Target group** | Personal vehicles, passengers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Reduction of neck injuries of 14% (11-17) for adjustable and 25% (17-34) for fixed headrests |
| Walz (2001) | Reduction of neck injuries of 6% (3-8) for pickup trucks in rear end collisions |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, % reduction neck injuries |
| Additional requirements | Headrest penetration in fleet |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Headrest presence or absence unlikely to effect collision involvement |
| Barriers / opportunities | Numerous confounders to show link between presence and collision involvement. Risk compensation possible, but unlikely. |

Table 3.2.12. *Headrests relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.5** | **Child seats and placement** |
| **Application:** | National network; urban/rural; rate of proper restraint use unclear, but generally high |
| **Measure type and description:** | Secondary restraint system to prevent secondary collisions of children with the interior of the vehicle and to reduce likelihood of ejection |
| **Target group** | Personal vehicles, child passengers of motorized vehicles |
| | |
| | |
| **Literature listed in SWOV document:** | |
| Schoon & Van Kampen (1992) | Reductions of 30% serious injury and 50% fatalities based on foreign studies |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Reduction of 25% in all injuries for babies (-75 to +120) |
| | 0-4 years old child seat and belt use 50% (30-70) reduction forward facing, 80% (70-90) rear facing, 32% (29-35) for belted only (no seat) |
| | 5-9 years old child seat and belt use 52% (27-69) reduction forward facing, 19% (7-29) reduction for belted only |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reduction based on foreign studies |
| Additional requirements | Correct use rates and placement type |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Child seat presence or absence unlikely to effect collision involvement |
| Barriers / opportunities | Numerous confounders to show link between presence and collision involvement. Risk compensation possible, but unlikely. |

Table 3.2.13. *Child seats and placement relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.6** | **Airbags** |
| **Application:** | National network; urban/rural; 100% driver, 90% passenger, 75% side, 65% curtain in new vehicles as of 2005 |
| **Measure type and description:** | Supplementary secondary restraint to increase deceleration times prior to colliding with the interior of the vehicle |
| **Target group** | Personal and commercial vehicles, occupants of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Evans (1991); Polak & Schoon (1994) | Reduction by 8% fatalities when seat belt used (in addition to seat belt reduction of 40%) or 12% alone |
| McCartt & Kyrychenko 2006 | 30% reduction in fatalities as a result of side impact collisions |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Airbags reduce the probability of fatal injury in head on collisions by 20-25%, effect slightly larger for unbelted than belted occupants. Various reductions are provided for seating position, belted or unbelted, collision types and adult or child |
| Langeveld & Schoon (2004) | Reduction in fatal and hospital injuries of 20% |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reductions |
| Additional requirements | Fleet penetration and casualty involvement |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Airbag presence or absence unlikely to effect collision involvement |
| Barriers / opportunities | Numerous confounders to show link between presence and collision involvement. Risk compensation possible, but unlikely. |

Table 3.2.14. *Airbags relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.7** | **Truck closed side protection, Under-run guard rails** |
| **Application:** | National network; urban/rural; 11% growth in 70's, thereafter ~1% |
| **Measure type and description:** | Closing the sides of trucks prevents two wheeled motor vehicles and cyclists from falling under open wheels |
| **Target group** | Trucks, vulnerable road users |
| | |
| **Literature listed in SWOV document:** | |
| Goudswaard & Janssen (1990) | 35 to 50% reduction in serious injury, fatal and in/patient |
| Van Kampen & Schoon (1999) | 35% reduction using closed sides, and 25% when using partially closed sides |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | 29% casualty reduction listed as best estimate of effect (based on Robinson & Riley, 1991) |
| | No effects for cyclists or pedestrians listed |
| Langeveld & Schoon (2004) | Reduction in fatal and hospital injuries of 25 or 30%, for open or closed side protection respectively |
| | Reduction in fatal and hospital injuries of 15%, for front and rear under-run protection |
| Schoon (2000) | Closed sides 35% casualty reduction, open side protection 25%. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reduction |
| Additional requirements | Fleet penetration and collision involvement |
| | |
| **Unknown relationships:** | |
| Relation to collisions | Presence or absence unlikely to effect collision involvement |
| barriers / opportunities | Numerous confounders to show link between presence and collision involvement. Risk compensation possible, but unlikely. |

Table 3.2.15. *Truck side protection and under-run guardrails relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.2.8** | **General promotion of crash safety (Crash testing)** |
| **Application:** | European network; urban/rural; increasing participation in crash testing |
| **Measure type and description:** | Collision testing programs such as NCAP and EURONCAP promote improvement of crash performance of personal vehicles |
| **Target group** | Personal vehicles, passengers of motorized vehicles and vulnerable road users |
| | |
| **Literature listed in SWOV document:** | |
| Kahane (1994); Lie & Tingvall (2000); Newstead & Cameron (1999) | Correlations between NCAP stars and reduced fatalities and injuries have been reported, but whether the number of stars is influenced by NCAP is unclear |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Cars that performed well in crash tests(good rating) 20% (10-29) lower probability of fatal injury than cars which performed poorly(poor rating), based on Kahane (1994) |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, as % reduction (possible) |
| Additional requirements | linking vehicles to EuroNCAP ratings and collision types |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Reduction of casualties as a function of NCAP stars preferred |
| Barriers / opportunities | Calibration to Dutch setting, in-depth analysis and linking vehicles to EuroNCAP ratings and collision types |
| | |
| Relation to collisions | Star rating unknown effect on collision involvement |
| Barriers / opportunities | Numerous confounders to show link between star rating and collision involvement. Risk compensation possible, but unlikely. |

Table 3.2.16. *General promotion of crash testing relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.3** | **Vehicle mass** |
| **Application:** | National network; urban/rural; Distribution of vehicle masses unclear but generally mass increasing |
| **Measure type and description:** | Motorways are relatively safe due to access control, uniformity of direction, and although speeds are high risks are relatively low |
| **Target group** | Personal and commercial vehicles, passengers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | See: Van Kampen (2003) |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Relationship of risk for risk by vehicle weight and external risk, heavier vehicles are safer and shift risk to lighter opponents. |
| | Reference to Broughton (1995) effect of 5% decrease in weight of all cars in UK to 3.8% decrease in urban serious injuries and 2.9% in rural serious injuries. |
| Wood (1997) | Risk as a function of energy dispersion and vehicle dimensions. Theory based on Newtonian physics and related to field results in US and Europe. Good summary of previous studies. |
| Buzeman et al. (1998) | Injury and fatality rates as functions of vehicle masses, and change in velocity (delta V) |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, rough % reduction |
| Additional requirements | Collision opponent vehicle masses (or proxy) and speed (or proxy, e.g. speed limit) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Vehicle fleet mass and collision severity based on own and opposing vehicle mass |
| Barriers / opportunities | Masses of collision opponents and changes in velocity, in-depth study detail |
| | |
| Relation to collisions | Vehicle mass unknown effect on collision involvement |
| Barriers / opportunities | Numerous confounders to show link between mass and collision involvement. Risk compensation possible, but unlikely. |

Table 3.2.17. *Vehicle mass relationships*

| | |
|---|---|
| **The summit conquered** | |
| **7.4** | **Traffic laws, insurance and licence plates** |
| **Application:** | National network; urban/rural; Universal, rates of uninsured unclear |
| **Measure type and description:** | General penalties or incentives related to vehicles which may affect driver intentions |
| **Target group** | Personal vehicles, drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Insurance | |
| Elvik & Vaa (2004) | Generally effect of insurance on road safety is not well known, increase in fatal and injury accidents with increased insurance (2-26%) reported. |
| | Cash bonus payouts may reduce accidents involving young drivers by 20% (Vaaje, 1992). |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, % changes for insurance increases and payout schemes |
| Additional requirements | Dutch calibration, insurance data |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Traffic laws, licence plates |
| Barriers / opportunities | Difficult to determine alone due to confounders such as enforcement (complementary). In-depth study of these factors and casualty involvement or behavioural changes possible. |
| | |
| Relation to collisions | Traffic laws, Insurance, licence plates |
| Barriers / opportunities | In-depth study of these factors and casualty involvement or behavioural change (risk compensation) possible. |

Table 3.2.18. *Other vehicle related measures relationships*

## 3.3. Enforcement, education, and road safety promotion measures

Promotion of safety through the use of enforcement and education is important to influence the behaviour of drivers; driver behaviour is commonly credited as having the largest influence on road safety, and at the same time noted as being one of the hardest factors to change. The measures discussed in this section represent the main areas of focus in *The summit conquered*.

*Tables 3.3.1* to *3.3.16* summarize the enforcement, education and safety promotion road safety measures and effects as listed in *The summit conquered* and the literature reviewed.

In general, effects of enforcement and education initiatives have been difficult to quantify due to the number of confounders and moderators. None the less, a great wealth of literature is available, and progress continues to be made in these areas.

| | |
|---|---|
| **The summit conquered** | |
| **8.1.1** | **Driving tests, licences and certificates** |
| **Application:** | National network; urban/rural; Universal requirement, proportion unlicensed unclear |
| **Measure type and description:** | The regulation of driver proficiency of minimum skills sets acceptable standard, and licences and certificates allow accountability |
| **Target group** | All roads, drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Driving tests | |
| Elvik & Vaa (2004) | Discussion of methodological difficulties, self selection bias for advanced training, results cannot be taken for granted |
| | Hoinville, Berthoud & Mackie (1972) studied groups of drivers based on passing test, fail then pass, fail and drive well, fail drive poorly, larger accident rate differences between passing groups are related to larger initial test failing rates. |
| Congdon (1999) | Found relation between hazard perception test scores and collision involvement, but with low predictive power. |
| | |
| Licences | |
| Elvik & Vaa (2004) | Graduated driver's licence reduction of injury accidents by 9% (7-10) |
| | Provisional driving licence 3% reduction in injury accidents (1-5) |
| Hagge & Romanowicz (1996) | California, more strict test for commercial drivers - no effect on fatal or serious injury collisions |
| | |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, for drivers' licences |
| Additional requirements | Dutch calibration for potential licence changes, requires monitoring of licence type penetration and collision involvement |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Driving tests and driving certificate effect on road safety |
| Barriers / opportunities | Effect of variation of test difficulty, driver behaviour and casualty involvement. |
| | |
| Relation to collisions | Driving tests and driving certificate effect on road safety |
| Barriers / opportunities | Effect of variation of test difficulty, driver behaviour and collision involvement. |

Table 3.3.1. *Driving tests, licences and certificates relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.1.2** | **Driver training / education** |
| **Application:** | National network; urban/rural; optional |
| **Measure type and description:** | Driver training teaches driving skills, knowledge or attitudes, |
| **Target group** | All roads, new drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | Questions as to the self selection bias raised, that those who chose to apply may be in a different category |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Best studies (experimental design with distribution among treatment and no treatments) show no difference between formal training and none (0 +/-4%) |
| Conner & Lai (2005) | National driver Improvement Scheme in UK for offending drivers - no effect |
| Henderson (1991) | Discusses difficulties of evaluation of effect on fatalities and serious injuries, and importance of link to laws and enforcement |
| Senserrick & Haworth (2005) | Literature review of several driver training evaluation studies, mixed results, with more favourable results for attitude training. Most protective feature was found to be many and varied hours of supervised driving as a learner. |
| Engström et al. (2003) | Literature review of effects of many programs, and various effects on young novice driver safety, no reported reductions in collisions or casualties. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Driver training / education |
| Barriers / opportunities | Many confounding variables, but (best) studies show little or no effect |
| | |
| Relation to casualties | Driver training / education |
| Barriers / opportunities | Many confounding variables, but (best) studies show little or no effect |

Table 3.3.2. *Driver training and education relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.1.3** | **School projects and other educational activities** |
| **Application:** | National; urban/rural; penetration / uniformity unclear |
| **Measure type and description:** | Educational programs targeting children aim to improve traffic participation in terms of behaviour near trucks or on bicycles |
| **Target group** | Local roads, children as pedestrians or cyclists |
| | |
| **Literature listed in SWOV document:** | |
| Twisk et al. (2007) | no behaviour change observed |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Mixed results; 30% lower or 67% higher collision involvement |
| Henderson (1991) | Discusses difficulties of evaluation of effect on fatalities and serious injuries |
| Delaney et al. (2004) | Safe routes to school combined with engineering measures 17% reduction in casualty crashes during peak. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reduction (in Australia) |
| Additional requirements | Identification of equivalent Dutch programs and related casualty outcomes |
| | |
| Relation to collisions | % Relations present in literature but uncertain |
| Additional requirements | Identification of equivalent Dutch programs and related collision outcomes |

Table 3.3.3. *School projects and other educational activities relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.1** | **Road rules and developments in enforcement in general** |
| **Application:** | National; urban/rural; universal |
| **Measure type and description:** | Changes to road rules and enforcement methods and levels are expected to have an effect on road safety |
| **Target group** | All roads, drivers of motorized vehicles, all casualties |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | 90's saw the introduction of regional traffic enforcement teams to focus on: helmet use, belts, red light running, alcohol and speed offences |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Police patrols associated with 16% reduction in injury accidents |
| | Drink driving enforcement reduces fatal and injury accidents by 9% and 7% respectively |
| DG-TREN (2003) | Listing of European road rules and enforcement |
| Hakkert et al. (2001) | Increased police enforcement (national traffic police) quantification of behaviour and attitude changes, and collision reduction (one area significant) |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, % reduction for traffic patrol increase |
| Additional requirements | Confirmation of Dutch validity, enforcement hours and related collisions |
| | |
| Relation to collisions | Yes, little change or small reductions |
| Additional requirements | Confirmation of Dutch validity |
| | |
| **Unknown relationships:** | |
| Relation to casualties | General enforcement and road rules |
| Barriers / opportunities | Difficult to relate enforcement to casualties, requires enforcement measures, behaviour measures and casualty outcomes related to enforcement actions. |
| | |
| Relation to collisions | General enforcement and road rules |
| Barriers / opportunities | Difficult to relate enforcement to collisions, requires enforcement measures, behaviour measures and collision outcomes related to enforcement actions. |

Table 3.3.4. *Road rules and general enforcement relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.2** | **Alcohol offences** |
| **Application:** | National; urban/rural; ~4% offence rate since 1990 |
| **Measure type and description:** | Alcohol impairs the ability to operate a motor vehicle. The enforcement of alcohol limits aims to reduce the number and magnitude of offences |
| **Target group** | All roads, impaired drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Nagele & Vissers (2000) | Educational measure alcohol and traffic |
| Bovens (1991); Kuiken & Oostlander (2004) | Educational measures for offenders provides a positive effect on reduction of repeat offences |
| effects not reported in *The summit* for collisions or casualties | |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Reductions for introduction of BAC laws as well as changes to limits and drinking age reported. New program reduction 26% fatal, increasing age reduction 18% fatal within affected age group, reducing age increase 18% fatal within affected age group. |
| Yannis et al. (2007) | Negative binomial regression of enforcement and number of accidents. Statistically significant relationship to collisions for all regions. |
| Mathijssen (2005) | Doubling of the number of random breath tests in the Netherlands, decreased drink driving offenders by approximately 25% |
| Erke et al. (2009) | Meta analysis of effect of alcohol enforcement by type of alcohol control, time halo, country, various reductions estimated. |
| Voas et al. (2003) | Reduction in alcohol related collision involvement after the introduction of underage and general alcohol laws. Reductions of 18-24% reported based on US data. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, % reduction for lowering limit and age |
| Additional requirements | May require Dutch calibration study |
| | |
| Relation to collisions | Yes, Yannis et al. (2007) |
| Additional requirements | Will require Dutch study |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Alcohol impairment |
| Barriers / opportunities | Enforcement level monitoring, prevalence of impaired driving (offence rate), alcohol casualty involvement. All at the regional level |
| | |
| Relation to collisions | Alcohol impairment |
| Barriers / opportunities | Enforcement level monitoring, prevalence of impaired driving (offence rate), alcohol collision involvement. All at the regional level |

Table 3.3.5. *Alcohol offences relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.3** | **Use of safety devices** |
| **Application:** | National; urban/rural; enforcement levels have nearly doubled from 2001 to 2005, offence rates nearly halved |
| **Measure type and description:** | Enforcing belt use can reduce the severity of collisions for occupants and prevent ejection from the vehicle |
| **Target group** | All roads, drivers of motorized vehicles, all vehicle occupants |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in the summit for belts on collisions or casualties | |
| effects not reported in the summit for helmet use on collisions or casualties | |
| Goldenbeld (1996 ) | 40% correct headrest use in 1995, 60% in 1996 after campaign, 21% of 1996 respondents reported changing due to the campaign effect on casualties not reported. |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Risk 45-50% reduction in KSI if belts are worn |
| | 20 % increase in wear rate in urban areas, 16% rural, fatal accidents reduced by 6%, injury by 8% |
| | Based on included studies of wear rate before and after enforcement is presented (p. 988) |
| | Refers to Hagenzieker & Davidse (1997), incentive programs increase (12%) belt use short term, and long term (10%) |
| Mathijssen & De Craen (2004) | 4-5% decrease in fatalities (regional enforcement teams) |
| Derrig et al. (2002) | Model of relation of belt wear rates to fatality rates in the US. Model includes many demographic characteristics (age, education, income) as well as |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reductions |
| Additional requirements | Wear rates among all drivers and casualties. |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Relationship of enforcement effort and casualty reduction. |
| Barriers / opportunities | Enforcement level connection to casualties difficult to link since there are so many other influencing factors, social acceptance for example. Regional enforcement levels, and resulting wear rates and casualty data required. |
| | |
| Relation to collisions | Safety devices unknown effect on collision involvement |
| Barriers / opportunities | Numerous confounders to show relation between safety devices collision involvement. Risk compensation possible. |

Table 3.3.6. *Use of safety devices relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.4** | **Speeding offences** |
| **Application:** | All networks; urban/rural; enforcement on all roads some automated some manual |
| **Measure type and description:** | Speed enforcement is intended to reduce speeds, and thereby frequency and severity of collisions, through deterrence by threat of fines |
| **Target group** | All roads, drivers of motorized vehicles, all casualties |
| | |
| **Literature listed in SWOV document:** | |
| Elvik (1997); Gains et al. (2005); Goldenbeld & Van Schagen (2005); Keall et al. (2002) | Various speed reductions fixed: 18% urban, 10% rural; mobile 10% urban, <5% rural. |
| Nilsson (2004) | Casualty reduction by speed reduction applied to above: fixed 18-33% urban, 10-19% rural; Mobile 10-19% urban, 3-10% rural |
| | |
| **Additional literature:** | |
| Goldenbeld & Van Schagen (2005) | Reduction of serious casualties of 21% |
| Reekmans et al. (2004) | 5-26% reduction in injury casualties for fixed speed cameras |
| Elvik & Vaa (2004) | Stationary: 14% (8-20) reduction in fatal accidents, 6% (4-9) in injury accidents Automatic: Refers to Oei (1994), Makinen & Oei (1992) from NL; 17% (16-19) reduction in injury accidents, urban 28% (26-31), rural 4% (2-6) |
| Aarts & Van Schagen (2005) | Literature review of relation of speed to casualties |
| Lynam & Hummel (2002) | Literature review of relation of speed to casualties |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to casualties | Yes, % reduction by enforcement type and location |
| Additional requirements | Presence (time and place) of speed enforcement, speed related casualties. |
| | |
| Relation to collisions | Yes, % reduction by accident type and location |
| Additional requirements | Presence (time and place) of speed enforcement, speed related casualties. |

Table 3.3.7. *Speeding offences relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.5** | **Red light offences** |
| **Application:** | Provincial and lower networks; urban/rural; Both mobile and fixed enforcement have increased nearly five fold between 1999 and 2005 |
| **Measure type and description:** | The enforcement of red light compliance at intersections reduces the likelihood of severe right angle collisions but increased rear end collisions |
| **Target group** | Intersections, drivers of motorized vehicles, occupants of motor vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Retting et al. (2003), Aeron-Thomas & Hess (2005) | Reduction of 25-30% of injury collisions |
| Dobbenberg (2006) | 21% reduction of injury collisions |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | 12% (2-21) reduction in injury accidents at intersection, 31%(2 increase to 53 decrease) for rear end, and 15% (24% increase to 42 decrease) in rear end. |
| Council et al. (2005) | Red light camera installation - reduction 16% in injuries (55 injuries) and 24% increase in rear end (32 injuries) |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, % reduction in right-angle and increase in rear-end |
| Additional requirements | Historical presence and future developments red light enforcement locations |
| | |
| Relation to collisions | Yes, % reduction in right-angle and increase in rear-end |
| Additional requirements | Historical presence and future developments red light enforcement locations |

Table 3.3.8. *Red light offences relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.6** | **Lights for mopeds and bicycles** |
| **Application:** | Local network; urban/rural; use rates about 60% as of 2005/2006 |
| **Measure type and description:** | Increasing the conspicuity of vulnerable transport modes increases the likelihood of driver response to avoid collision. |
| **Target group** | Distributor and local roads, cyclists and moped riders, vulnerable road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Daytime running lights for mopeds 7% (+/- 3) reduction in multi party collisions. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to collisions | Yes, general % reduction |
| Additional requirements | Dutch calibration |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Change in light use rates effect on casualties |
| Barriers / opportunities | Penetration of measure, change in rates, and presence by casualty involvement |
| | |
| Relation to collisions | Change in light use rates effect on collisions |
| Barriers / opportunities | Penetration of measure, changes in rates, and presence by collision involvement |

Table 3.3.9. *Lights for mopeds and bicycles relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.7** | **Aggression in traffic** |
| **Application:** | All networks; urban/rural; |
| **Measure type and description:** | Aggression in traffic may increase risk in terms of undesirable behaviours such as tailgating or abrupt acceleration/deceleration |
| **Target group** | All roads, drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | studies which are quoted report the self reported behaviour of drivers rather than observed behaviour or casualty effects |
| | |
| **Additional literature:** | |
| Wells-Parker et al. (2002) | Questionnaire study of reported road rage behaviours and crash involvement |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Aggressive behaviour and casualty involvement |
| Barriers / opportunities | In-depth study of behaviours and casualty involvement or behavioural change (risk compensation) possible. |
| | |
| Relation to collisions | Aggressive behaviour and collision involvement |
| Barriers / opportunities | In-depth study of behaviours and collision involvement or behavioural change (risk compensation) possible. |

Table 3.3.10. *Aggression in traffic relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.8** | **Phone use while driving** |
| **Application:** | All networks; urban/rural; More cell phones in the Netherlands than people |
| **Measure type and description:** | Cellular phone use while driving has been identified as a distraction which increases the risk of collision |
| **Target group** | All roads, drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | Shift to hands free calling, but this has been shown not to reduce increased risk (Dragutinovic & Twisk, 2005) |
| | |
| **Additional literature:** | |
| McEvoy et al. (2005) | Linking hospitalization crashes to cell phone records, increase of crash risk by 4 times for handheld and hands free. |
| Caird et al. (2008) | Meta analysis of cell phone driver performance effects. Age only demographic indicator; performance indicators include, headway, speed, positioning, largest effects in reaction times, many references cited. |
| Neyens & Ng Boyle (2008) | Ordered logit model of young driver distraction, driver and passenger at increased crash risk when driver distracted by cell phone |
| Redelmeier & Tibshirani (1997) | Linking hospitalization crashes to cell phone records, risk increase by about 4 times, separate values by age, gender, education, more. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, increased risk of hospitalization (4 times) |
| Additional requirements | Offence rates, casualty involvement with phone use. |
| | |
| Relation to collisions | Yes, increased risk of collision risk (4 times) |
| Additional requirements | Offence rates, casualty involvement with phone use. |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Phone use and casualty involvement |
| Barriers / opportunities | In-depth study of phone use and casualty involvement possible, headway, speed, positioning. Relation of offence rates to casualties desirable. |
| | |
| Relation to collisions | Phone use and collision involvement |
| Barriers / opportunities | In-depth study of phone use and collision involvement possible, headway, speed, positioning. Relation of offence rates to collisions desirable. |

Table 3.3.11. *Phone use while driving relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.9** | **Driving time professional drivers** |
| **Application:** | National network; urban/rural; 11% growth in 70's, thereafter ~1% |
| **Measure type and description:** | Logging of driving hours of professional drivers helps to ensure that drivers of heavy vehicles are not at increased risk of collision |
| **Target group** | Motorways, drivers of motorized vehicles |
| | |
| **Literature listed in SWOV document:** | |
| Van Schagen (2003) | Drivers with sleep disorders or acute sleep deficits have a 3-8 times higher risk of collision when driving |
| | |
| **Additional literature:** | |
| Elvik & Vaa (2004) | Injury risk increases by 1.3 times relative to first 4.5 hours of driving, and 3.12 times compared to first 9 hours (p. 901 & 903). Factors mentioned are Longest continuous periods of driving, length of breaks or rest (longer rest-lower risk, unbroken rest lower risk), weekly hours, monthly overtime, fixed hours or shift work (shift work ~2x risk). |
| Williamson et al. (2000) | Comparison of sleep depravation to BAC effect on performance, hours of wakefulness and different sleep management practices. No direct link to crashes. |
| | |
| **Known relationships:** | (Dutch literature available? ***Y*** / *N* ) |
| Relation to collisions | Yes, increased risk |
| Additional requirements | Indicator variable for sleep disorders or deficits |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Driving time or sleep shortage impairment |
| Barriers / opportunities | In-depth study possible time log offences and casualty involvement. |
| | |
| Relation to collisions | Driving time or sleep shortage impairment |
| Barriers / opportunities | In-depth study possible, time log offences and collision involvement. |

Table 3.3.12. *Driving time for professional drivers relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.10** | **Beginners' drivers licence / demerit points** |
| **Application:** | All networks; urban/rural; All new drivers |
| **Measure type and description:** | Beginners' drivers licences allow the opportunity of more stringent regulations and monitoring of offences by new drivers. |
| **Target group** | All roads, new drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| Vlakveld (2004) | Literature study of demerit points, no quoted effects for the Netherlands. |
| | |
| **Additional literature:** | |
| Lam (2003) | Differences in risk between learner licence, provisional (Graduated), and full licence. Stratified by gender, age, and crash characteristics. |
| Elvik & Vaa (2004) | The effect of a demerit point system to the number of crashes is a reduction of 5% according to a meta analysis. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, relative to full licence |
| Additional requirements | Stratified by gender, age, contributing factor presence, calibration for Dutch situation required |
| | |
| Relation to collisions | Yes, relative to full licence |
| Additional requirements | Stratified by gender, age, contributing factor presence, calibration for Dutch situation required. |

Table 3.1.13. *Beginners' drivers licence relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.11** | **Campaigns regarding safety of children** |
| **Application:** | All networks; urban/rural; children primarily in urban areas |
| **Measure type and description:** | Measures reminding drivers to be aware of children returning to school |
| **Target group** | Local roads, drivers of motorized vehicles, child traffic participants |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Bötticher & Van der Molen (1986) | Positive to no effect from publicity campaigns in the Netherlands, qualitative, influence of behaviour not proven. |
| AVV (2007) | Summary of campaigns aimed at bicycle lights, seatbelts and child seats. No effects on collisions reported. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Effect of child safety campaigns |
| Barriers / opportunities | Self reported recall of campaign, self reported behaviour change, and observed speed and collisions in school zones. |
| | |
| Relation to collisions | Effect of child safety campaigns |
| Barriers / opportunities | Self reported recall of campaign, self reported behaviour change, and observed speed and collisions in school zones. |

Table 3.3.14. *Campaigns regarding child safety relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.2.12** | **Actions relating to truck traffic** |
| **Application:** | All networks; urban/rural; Universal program |
| **Measure type and description:** | Prevention of loose loads and vehicle deficiencies to prevent vehicular damage |
| **Target group** | All roads, Trucking companies and drivers of trucks motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | Programs include the Safety Scan program in 2004 |
| | |
| **Additional literature:** | |
| Naveh & Marcus (2007) | Company certification with ISO9000 standard resulted in (small) reduction of collisions (company initiative) |
| Gregersen et al. (1996) | Company safety training program and group discussion resulted in reduced collision involvement. |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| | |
| **Unknown relationships:** | |
| Relation to casualties | Enforcement of loose loads |
| Barriers / opportunities | Loose load collisions, enforcement effort, resulting loose load collisions |
| | |
| Relation to collisions | Enforcement of loose loads |
| Barriers / opportunities | Loose load collisions, enforcement effort, resulting loose load collisions |

Table 3.3.15. *Actions relating to truck traffic relationships*

| | |
|---|---|
| **The summit conquered** | |
| **8.3.1** | **Other education and enforcement initiatives** |
| **Application:** | All networks; urban/rural; Universal programs |
| **Measure type and description:** | Various processes and goals |
| **Target group** | All roads, all drivers of motorized vehicles, all road users |
| | |
| **Literature listed in SWOV document:** | |
| effects not reported in *The summit* | |
| | |
| **Additional literature:** | |
| Delaney et al. (2004) | 5-8,7% reduction in collisions due to speed and concentration advertising, 6,7-10,2% for drink driving campaigns |
| Elvik & Vaa (2004) | Safety belt info campaigns 23% (13-31) reduction injuries to occupants, Drink-driving 49% (35-60) reduction impaired collisions |
| | |
| **Known relationships:** | (Dutch literature available? *Y / **N*** ) |
| Relation to casualties | Yes, % reductions for various efforts |
| Additional requirements | Dutch calibration / study possible |
| | |
| Relation to collisions | Yes, % reductions for various efforts |
| Additional requirements | Dutch calibration / study possible |

Table 3.3.16. *Other education and enforcement initiatives relationships*

# 4. General summary of literature

In *Chapter 2* and *3* the current literature has been summarized; during the literature review several trends of note were evident:

- Much of the literature was too specific or limited in study size to be applied in the Netherlands. Often causal links in reports were vague, or intermediate indicators were applied which provide a less clear impact on collision outcomes.
- Theory of the relationship between the external effects or road safety measures was often weak, and the resulting (fitted) models although explaining what the relationship is (in part) they often provide few clues as to why; post analysis theories were often postulated to explain the model results rather than the other way around. Surprisingly few 'physical' or fundamental relationships were found in the road safety literature.
- Methodologies of road safety research have progressed dramatically in the last 20 years; many confounders which were previously uncontrolled can now be addressed. Application of state of the art methods should be applied to previous topics in conjunction with the continuation of advances in methodology development.
- Data availability, quality, and management capability is increasing with technological advances and this will also contribute to advances in road safety.
- Road safety is a complex system, a fact which becomes clear with many of the same research questions posed in the oldest literature reviewed (Smeed, 1949) still lingering in the current literature, and the same barriers to knowledge still quoted. As technology and evaluation methods are developed reduction of these barriers should be an area of special focus.
- There is an enormous volume of road safety literature on which to build, and this is promising for future road safety research.

The results of the literature review tables are summarized in *Table 4.1* and *Table 4.2*, for the external influences and the road safety measures respectively. The four main summary points for each sub topic are:

- Casualty/collision literature available
  - Literature was found, either Dutch or international, which relates the factor to casualties, collisions, or strongly to risk.
    - √ - indicates literature available
    - **~** - indicates that weak relationship literature found
- Ready for inclusion in model
  - The literature and data is available to enable inclusion of the factor in the model
    - √ - indicates that factor is ready for inclusion
    - ~ - indicates that minor work required
- Additional work required
  - Some or no literature is available, but additional research is required prior to inclusion of factor in the model
    - √ - indicates additional (Dutch) research needed
    - ~ - indicates that some work needed

- Additional data required
  - Data is required to allow proper inclusion of the factor in the model
    - √ - indicates data identification / collection needed
    - ~ - indicates that some data or continued data collection is required

Various combinations of the above points are evident in the tables, the result of various different levels of research or data availability; for example, there are several cases where international literature and data for the Netherlands are available, but calibration is required prior to use in the model.

Table 4.1. *Summary of results of the external influence literature review*

| External influence | Casualty/ collision literature available | Ready for inclusion in model | Additional work required | Additional data required |
|---|---|---|---|---|
| **Social and cultural** | | | | |
| Aging population | √ | ~ | √ | |
| Age category (including young driver) | | ~ | √ | |
| Individualization | | | √ | √ |
| Informalization | | | √ | √ |
| Internationalization | | | √ | √ |
| Intensification | | | √ | √ |
| Ethnicity | | | √ | √ |
| **Spatial planning and policy** | | | | |
| Vicinity | | | √ | √ |
| Concentration on one or more centres | | | √ | √ |
| Size and type of urbanization | | | √ | √ |
| Connection to the main arteries of public transport | | | √ | √ |
| Function mixture and facility level | | | √ | √ |
| Design at street and neighbourhood level | | | √ | √ |
| **Public health** | | | | |
| Emissions & noise | | | √ | √ |
| Aggression & fatigue | | | √ | √ |
| Fitness to drive / medical disorders | | | √ | √ |
| Healthy mobility | | | √ | √ |
| Alcohol and drug use | √ | | √ | √ |
| Trauma care organization | √ | | √ | |

| External influence | Casualty/ collision literature available | Ready for inclusion in model | Additional work required | Additional data required |
|---|---|---|---|---|
| **Economy** | | | | |
| **PEOPLE TRANSPORT** | | | | |
| Income growth | √ | | √ | |
| Consumption / disposable income | | | √ | |
| Car ownership and cost of transportation | ~ | | √ | √ |
| Road pricing | | | √ | √ |
| Workforce participation | ~ | | √ | |
| **GOODS TRANSPORT** | | | | |
| Economic growth | √ | | √ | |
| Internationalization | ~ | | √ | √ |
| Distribution of economic activities | | | √ | √ |
| Business and transport costs | | | √ | √ |
| ICT and e-commerce | ~ | | √ | √ |
| Quality of goods transport & specialization | | | √ | √ |
| **Mobility** | | | | |
| Mobility policy | | | √ | √ |
| Vehicle ownership | | | √ | |
| Traffic volumes and distribution | | ~ | √ | |
| Mobility by gender | | ~ | √ | √ |
| Mobility by age | | ~ | √ | √ |
| Mobility by ethnicity | | | √ | √ |
| **Technology** | | | | |
| Infrastructure design | (see measures) | ~ | √ | √ |
| Vehicles | (see measures) | ~ | √ | √ |
| People transport | | | √ | √ |
| Goods transport | √ | | √ | √ |
| Information and communication technology | | | √ | √ |
| Traffic management | | | √ | √ |
| Environmental care (air quality) | | | √ | √ |
| **Other** | | | | |
| Weather | √ | | √ | ~ |

Table 4.1 (continued). *Summary of results of the external influence literature review*

Table 4.2. *Summary of results of the road safety measure literature review*

| Road safety measure | Literature available | Appropriate for model | Additional work required | Additional data required |
|---|---|---|---|---|
| **Infrastructure** | | | | |
| Motorway /Highway network | √ | √ | | ~ |
| Parallel facilities | √ | ~ | √ | √ |
| Crossing facilities | √ | ~ | √ | √ |
| 30 km/h zones | √ | √ | ~ | ~ |
| 60 km/h zones | √ | √ | ~ | ~ |
| Roundabouts | √ | √ | √ | ~ |
| Safe roadsides | √ | ~ | √ | √ |
| Recognizable roads | | | √ | √ |
| Road rules | | | √ | √ |
| Establishing and altering speed limits | √ | | √ | ~ |
| Moped on the road | √ | ~ | | |
| Right of way for slow vehicles from the right | √ | ~ | | |
| **Vehicle** | | | | |
| Braking systems | √ | ~ | √ | √ |
| Stability control systems | √ | ~ | √ | √ |
| Visibility improvements | √ | ~ | √ | √ |
| Field of view improvements | √ | ~ | | √ |
| Speed limiting | √ | √ | | √ |
| Combined safety systems | √ | | √ | √ |
| Child door lock | | | √ | √ |
| Vehicle quality | √ | ~ | √ | ~ |
| Helmets & protective clothing for mopeds and motorbikes | √ | √ | | √ |
| Seatbelts | √ | √ | | ~ |
| Crumple zones | | | √ | √ |
| Headrests | √ | | √ | √ |
| Child seats and placement | √ | ~ | | √ |
| Airbags | √ | ~ | | √ |
| Truck closed side protection | √ | ~ | | √ |
| General promotion of crash safety (Crash testing) | √ | | √ | |
| Vehicle mass | √ | ~ | √ | |
| Vehicle laws, insurance and licence plates | √ | | √ | √ |

| Road safety measure | Literature available | Appropriate for model | Additional work required | Additional data required |
|---|---|---|---|---|
| **Enforcement / Education** | | | | |
| Driving tests, licences and certificates | √ | | √ | |
| Driver training / education | √ | | √ | |
| School projects and other educational activities | √ | | √ | |
| Road rules and developments in enforcement in general | √ | | √ | √ |
| Alcohol offences | √ | ~ | √ | √ |
| Use of safety devices | √ | | √ | √ |
| Speeding offences | √ | | √ | √ |
| Red light offences | √ | | √ | ~ |
| Lights for mopeds and bicycles | √ | | √ | √ |
| Aggression in traffic | | | √ | √ |
| Phone use while driving | √ | | √ | √ |
| Driving time professional drivers | √ | ~ | | √ |
| Beginners' drivers licence / demerit points | | | √ | √ |
| Campaigns regarding safety of children | √ | | √ | √ |
| Actions relating to truck traffic | √ | | √ | √ |

Table 4.2 (continued). *Summary of results of the road safety measure literature review*

Physical relationships are few and there is a lot of work to be done. The initial development of the model can be achieved by starting with the most available and reliable data sets which have a known relationship with road safety, then proceed to fill these is with additional relationships as the become available. In the next chapter future research and the interesting and/or promising factors are discussed.

# 5. Model development and future research

In the previous chapter a short overview of the scan of literature on the relationship between road safety and external influences and road safety measures is given. The possibilities of including these factors into a road safety model is shown in *Table 4.1* and *4.2* respectively. The two main aspects for inclusion of these factors in a model are the availability of data and the state of knowledge about the relationship with collisions/casualties. Subsequent literature reviews in conjunction with further work are recommended before a factor can really be included in a road safety model.

The SWOV model of road safety is conceptualized as having mobility by traffic mode as the basic explanatory factor and the number of fatalities or serious injuries as dependent variables. The mobility is in some sense the necessary input of the model to get from number of collisions or casualties to risk figures. The conceptualization of the road safety system as a highly stratified factors permits inclusion of the multitude of considerations presented in this report. However, the stratification (also called disaggregation) has to be applied for mobility as well as road safety.

Critical to the identification of how external influences and road safety measures affect road safety outcomes (collisions and casualties) will be dependent on the main model criteria – mobility by traffic mode and demographics of drivers and victims. Each of the measures should therefore incorporate stratification by these measures and then provide additional explanatory power based on the relations which have been presented in the literature, possibly requiring adaptation to the Dutch traffic system. Any of the key criteria for which no effects have been documented will then need to be established and these will form the target research areas. Road safety measures with the largest effect or largest penetration will likely be targeted first as these will likely provide the largest explanatory power in the model and best reduce confounders.

Although not fully developed, one of the necessary next steps is to improve the way that SWOV selects research projects. Selection of research topics for the development of the road safety model will be influenced by the estimated contribution of the external influence or the effect of the road safety measure in terms of the number of fatal or seriously injured casualties, as well as the barriers to including the effect in terms of either data requirements or quantification of the effect. A possible general research topic ranking tool is presented in *Table 5.1*.

The framework for the selection of the most promising research projects should also consider the potential impact of the measure,
- Potential casualty reductions
- Presence of alternative literature
- Development of research framework (barriers?)
- Cost / time of data collection for new studies

Table 5.1. *Proposed general framework for research selection*

| Ease of inclusion | Effect in model | | |
|---|---|---|---|
| | Large | Medium | Small |
| Easy | High | High | Medium |
| Medium | Medium | Medium | Low |
| Difficult | Low | Low | Low |

If the effects of a measure are estimated to be higher than another, due to higher exposure or higher risk, then available funds could be directed to a project with higher potential impact on road casualties. Where international studies are present the analysis method may be applied to the Dutch situation in a relatively short time period, provided the required data is available.

There may be interesting relationships between road safety measures and casualties, but if the related data is unavailable and not likely to become available then there is little need, in the short term, to focus research on these areas. As technology changes, acquisition management and processing of these data may become feasible, but until such time research efforts can better be focused where positive outcomes are achievable. In order to judge the importance of integration in the model it is important to know the impact of all the variables in the model and the effort required to obtain and maintain the required data. There have been a lot of numerical models developed to describe road safety; the development of a new model should then increase the level of detail of the predictions such that the additional data required is justified.

In addition to the mathematical relationships some of the measures and external factors are not well understood from a theoretical point of view. Underpinning the relationships with theory of the causal chains and effects on other measures and external factors will be essential in achieving the goal of creating a realistic road safety model.

## 5.1. External influences

External influences are highly inter-related and many of the studies found to date focus on intermediate effects, rather than direct effects on mobility, collisions or collision severity. As a result, inclusion of these factors will require considerable effort, and focusing on the factors for which the most literature is present is recommended as a starting point. Although the exploration of external factors has revealed numerous relations among the external factors and also on road safety, a lack of quantification of direct relations has been noted in general. The reasons for the lack of information are numerous, but chiefly among these is the complexity of the system and the near inability to control for the other influences in a study. In terms of statistical modelling any terms not included in the model become a part of the error term. This issue may be further aggravated by the fact that there is a significant interaction among factors, and in many cases the size of the interaction is unclear. Accounting for fluctuations with time will be critical to revealing the interaction of external influencing factors.

## 5.2. Road safety measures

Road safety measures in general have more commonly been analyzed in the literature using quantitative analysis. In spite of this, the majority of studies are not immediately useful to the SWOV model in its intended form. Many studies on the effect of road safety measures are carried out on the local level. So, the effects have to translated to a national level and to the road safety situation in the Netherlands in particular. As an initial step, the inclusion of percentage collision reductions as factors in the model can be attempted, and as more robust statistical and mathematical relationships become available, for sub-stratifications, or are calibrated to the Dutch setting these factors can be replaced.

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