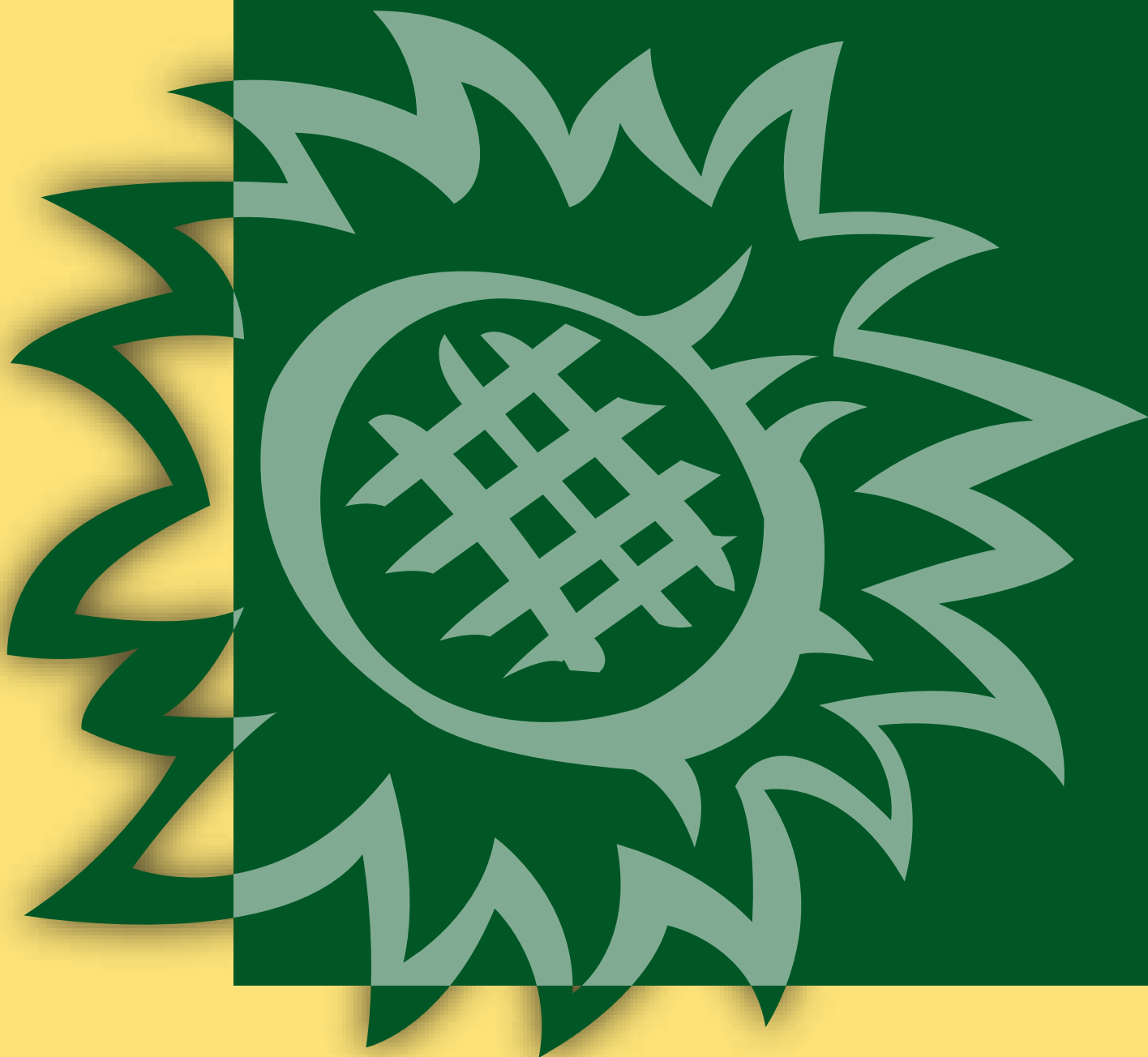# SUNflowerNext

Towards a composite road safety performance index

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SUNflowerNext:
Towards a composite road safety performance index

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Report documentation

Foreword

You can't manage what you can't measure
Robert Kaplan, Harvard Business School

Measuring the way to knowledge ("Door meten tot weten")
Heike Kamerlingh Onnes, Dutch Nobel Prize winner, 1913

In 2002, the first SUNflower report was published. This report compared the road safety in three countries: Sweden, the United Kingdom, and the Netherlands. The comparison was made as an attempt to identify the similarities and differences between these countries, not just with respect to the numbers of crashes and victims. Particularly the factors, circumstances, developments that have an influence on the risk of a crash and the severity of its outcome were investigated. The underlying thought was that the findings could be helpful in the possibility to learn from each other. Although the mortality and the risks are approximately equal in the three countries, large differences were found in the ways road safety improvements were tackled. Furthermore, although the mortality was approximately equally high (or, rather, equally low), various large differences were found between the explanations: in the United Kingdom, for example, the fatality risks for motorcyclists and pedestrians showed to be high as opposed to that in Sweden and the Netherlands, as it did for car occupants in Sweden compared to the other two countries, and for moped riders in the Netherlands. The long list of recommendations showed that with the analysis method used it was indeed possible for countries to learn from each other.

Understandably, this result was reason to enlarge the SUNflower range and to attempt a further deepening: the SUNflower+6 study was initiated and reported on in 2005. Nine European countries participated in this study: the original three countries, three countries in Southern Europe (Greece, Portugal and Spain, with a special position for Catalonia), and three Central European countries (Hungary, Slovenia and the Czech Republic). This study also resulted in very interesting insights and useful recommendations. However, this study also showed that the more the countries differ between themselves, the harder it becomes to interpret the comparisons. A tendency arose to make three comparisons of three countries and not so much compare all nine countries.

The study also resulted in a first design of a road safety footprint. A footprint was defined as a representation of the road safety status of a country. A footprint contains a combination of indicators, measured as a snapshot in time or a time series. This footprint was found to be an interesting concept deserving further elaboration. The present SUNflowerNext study has carried out this task.

This elaboration was done as part of the SafetyNet project. This project aims to build the framework of a European Road Safety Observatory, which will be the primary focus for road safety data and knowledge, as specified in the Road Safety Action Programme (EC, 2003).

SUNflowerNext is aimed at the development of a knowledge-based framework for comprehensive benchmarking of road safety performances and developments for a country or other sub-national jurisdictions. An explorative method was used to accomplish this. In this project we limited ourselves to the use of readily available data; no additional data was collected.

The SUNflower approach and its proven benefits (data driven, comprehensiveness through the road safety pyramid, science-based understanding of differences between benchmark values, identification of potential improvements of performances) aims at presenting the best relevant knowledge and available data, and introduces best practices for benchmarking of countries or sub-national jurisdictions.

Over time, this study has explored different directions. They address different aspects of ranking or benchmarking of safety performances of countries and regions/cities in countries. The explorative character of the work and the immaturity of the different developments so far make a conclusion about obvious dissimilarities between the different chapters unavoidable. If this approach is to continue, and we will certainly support this decision, we will certainly pay more attention to this issue.

Three groups worked on this report. One group consists of Shalom Hakkert, Victoria Gitelman and Etti Doveh of Technion in Haifa, Israel. This group mainly investigated the possibilities for the development of a composite index in Chapter 3. A second group focused at the sub-national level and consisted of David Lynam (UK) and Vojtech Eksler (Czech Republic). Their contribution can be found in Chapter 6. Finally, the Dutch group, formed by Jacques Commandeur, Siem Oppe and Fred Wegman worked on the remaining chapters. But I would wrong everyone involved by only linking the researchers to individual chapters. This explorative study's quest for ways that enable a good comparison between countries did not follow an easy path. No appropriate examples were available, although similar efforts were undertaken in other social disciplines (see also Chapter 2). However, the specific character of the road safety issue required the exploration of many new paths. Together we explored this *terra incognita*. And I can tell you a secret: that path was not always straight, but was often bendy; it sometimes was hard to even find a path at all; we were not always a tight-knit group and did not always immediately agree at each fork of the path which branch would be the shortest and fastest one to our destination. But together we reached the finishing line. Our process brought a quote to our minds: "If you want to go quickly, go alone. If you want to go far, go together". Al Gore quoted here an African proverb in his Nobel Lecture in Oslo, 2007.

This is my third foreword to a SUNflower report. Each time the same emotions rise up when I see a group of eminent researchers driven to excellent performance on the basis of their thorough knowledge of road safety and their research in this field. This is the place to express my gratitude to the entire team. My gratitude also goes to two SWOV employees whose efforts ensured that an excellent version of the report could be published in print. As on many other occasions, Marijke Tros and Hansje Weijer have significantly contributed to the quality of the final product. I also extend my gratitude to the SafetyNet consortium for welcoming us within their ranks, and to the 'reviewers' who made a useful contribution to utmost quality.

I very much hope that the set-up for benchmarking the safety performance of countries (or sub-national jurisdictions) and the idea of defining a composite road safety performance index (*SUNflower index*) will be realized, will be measured and published annually, and will hence provide a firm basis for road safety improvements in the EU Member States and a possibility to continue to learn from one another.

Fred Wegman

Content

Executive summary

Background and aim

One of the aims of international cooperation in the field of road safety is to make oneself familiar with performances and progress in other countries and to understand if and how these can be of guidance to policymaking, in an adapted form if appropriate. Comparisons can be a starting point to learn from each other.

The learning includes subjects such as monitoring and explaining road safety developments, and gaining good insights in the impacts of interventions as a basis for speeding up road safety improvements in one's country or jurisdiction.

Benchmarking is a process in which countries or sub-national jurisdictions evaluate various aspects of their performance in relation to that of other counties or jurisdictions, including the so-called 'best-in-class'. The benchmark results provide countries or sub-national jurisdictions with information about others that can be used as a basis for developing measures and programmes to increase their own performance.

Two important tasks can be identified in this process:
1. defining the key components of a road safety performance and investigating if and how these key components can be combined in a composite index;
2. finding a meaningful reference (best-in-class) and defining procedures for identifying such a meaningful reference.

Comparing performances and, one step further, benchmarking performances seems to be an appropriate approach for road safety. This approach should help us to go beyond the rather traditional methods of comparing performances by only using mortality rates or fatality rates or risks. Ranking countries by using only these rates is a useful first step, but not very meaningful as a start to learn from each other.

The SafetyNet project aims to build the framework of a European Road Safety Observatory, which will be the primary focus for road safety data and knowledge, as was specified in the Road Safety Action Programme 2003. In the SafetyNet project it was decided to develop a method of benchmarking road safety by using road safety indicators. To this end, the SUNflower approach was used, more precisely the information captured in the SUNflower pyramid and earlier attempts to elaborate on this in developing the SUNflower footprint, as well as other SUNflower studies. We gave this project the name SUNflowerNext.

Hence, the aim of the SUNflowerNext project is to develop a knowledge-based framework for comprehensive benchmarking of road safety performances and developments of a country or of sub-national jurisdictions.

SUNflowerNext has made use of existing data that was relatively easily available. This ensured that the study could be carried out in a relatively short time. However, one important concession needed to be made. Because this study used an innovative approach with only existing data that was not always available, it was decided to set up the research in such a way that all the steps required for benchmarking a country's performance are taken, but to refrain from presenting the actual results of the benchmark as they are of insufficient quality. The experiences

gained from this study are such that SUNflowerNext's ambition – benchmarking the safety performance of countries - is realistic once reliable data is available. Therefore, it is recommended to carry out this benchmarking in Europe in the near future, to widely disseminate the results, and to consequently use them for policy making in the European Member States.

Benchmarking of road safety performances

Benchmarking is a process in which actors evaluate various aspects of their performance in relation to others, and to the so-called 'best in class'. In the SUNflowerNext study we researched whether countries in the European Union could all be placed in one class, or whether we should consider working with two or more classes. Three procedures were used to find out whether meaningful groups could be made: safety experts were asked to group countries, secondly, countries were grouped based on road safety outcome indicators (grouping obtained with a Singular Value Decomposition (SVD) of the annual fatality risks in the years 1980-2003 of countries), and, thirdly, countries were grouped using general statistical data from a Multiple Correspondence Analysis (MCA) about a country in the most recent years.

In the SUNflowerNext project we concluded that it is better not to make comparisons between all European countries as one group, but to attempt grouping comparable countries and to then compare the countries within a specific group or class. The results of the three methods have many points of agreement. The grouping results have a preliminary character and it is recommended to elaborate on this topic before coming to a final decision on the grouping. The approach explored in SUNflowerNext could be used for this purpose.

Towards a composite road safety performance index

SUNflowerNext decided to develop an integral and comprehensive set of indicators to measure the road safety performance of a country while including all information in the SUNflower pyramid. SUNflowerNext distinguishes three types of indicator: *the road safety performance indicator, the implementation performance indicator, and the policy performance indicator*.

The first type of indicator captures a country's road safety quality. It has been named the **Road safety performance indicator**. Other names such as outcome indicator and product indicator are also used. In SUNflower the three top layers of the SUNflower-pyramid are included: final outcomes (numbers of killed and injured), intermediate outcomes (such as the safety performance indicator), and social costs.

The second type of indicator specifies the quality of the implementation of road safety policies: the **Implementation performance indicator**. For this implemen-tation quality indicator the term process indicator can also be used. Basically, this indicator follows a vertical line in the pyramid linking 'safety measures and pro-grammes', safety performance indicators and numbers of killed and injured people.

The third type of indicator deals with the quality of policy to improve road safety: the **Policy performance indicato**r. Here SUNflowerNext distinguishes two compo-nents: the quality of conditions (strategies, programmes, resources, coordination,

institutional settings, etc.) and the quality of action plans and individual (counter)measures) in the perspective of the ambitions expressed in road safety targets.

There are several reasons why it is attractive to combine all information in one indicator, a so-called composite index. A composite index includes all components of the SUNflower pyramid, more specifically the three types of indicator. The pros and cons of working with composite indices are rather well known and are presented in the report. Three words can summarize the main characteristics: 'simplification, quantification and communication'. Road safety will not be the first policy field to successfully attempt to capture performance in one single value. To mention a few: the Human Development Index, the Environmental Sustainability Index, and the Overall Health System Index. Based on these examples it was decided to also explore the opportunities for a composite index for road safety performance.

Weights based on statistical models were used to combine the basic indicators into a composite index. Both Principal Component Analysis (PCA) and Common Factor Analysis (FA) weighting were examined. Both methods group collinear indices to form a composite index that captures as much as possible of the information that is common among sub-indicators. The analysis was made on the data collected for 27 European countries. The composite index enables us to rank the countries in accordance with their safety performance.

The analysis revealed that the countries' ranking based on the combination of indicators is not necessarily similar to the traditional ranking of countries based only on mortality rates or fatality rates. We believe that adding information on policy performance and implementation performance to the ranking and grouping process improves the results beyond the established methods and makes them more comprehensible. Furthermore, it was observed that the indicators belonging to the final outcomes and intermediate outcomes, both part of the road safety performance indicator, are not uniform in their behaviour. The indicators that were found to be more consistent and termed 'core set of basic indicators' are recommended for future uses.

The general conclusion is that the design of a composite road safety performance index, for example the SUNflower index in which relevant information from the different components of the road safety pyramid has been captured and weighted, is realistic and meaningful. In addition, such an index gives a more enriched picture of road safety than a ranking only based on data on mortality or fatality rates, which is common practice at present. Grouping countries using this process is promising and seems to be preferable to simply ranking countries. Before defining the *SUNflower index* and actually applying the results to policy making, two improvements should be made: indicators must be developed for the Implementation performance indicator and procedures must be developed to make available high quality and comparable data for EU Member States.

Time series analysis

Safety developments are interesting because they may give us a better insight in underlying forces and, hopefully, also in the effectiveness of road safety interventions. Different approaches were used in this part of the study, among which state space modelling. The first attempt to compare developments in fatality rates

(fatalities per 10,000 motorized vehicles) and mortality rates (fatalities per 100,000 inhabitants) was made at a macroscopic level. Although European countries do have a remarkably different history when it comes to the development of fatality rate vs. mortality rate, our data suggests that all countries seem to be moving to the same road safety position, although not at the same pace. Leading countries in the field of road safety generally keep ahead of the other countries, albeit with decreasing advantage.

Three types of disaggregate developments were compared (age, transport mode and road type). In this comparison countries were grouped. Looking at the results of the analyses, we may conclude that, although all European countries tend towards the same aggregated or macroscopic level of road safety, there are important differences between the individual countries as well as between groups of similar countries. These differences relate to how they reach this level of road safety when considering their focus on avoiding special types of accidents. In other words, the general policies of improving road safety in different countries ultimately seem to move towards the same safety level, but for different countries that level of road safety is achieved at a different pace and in different ways.

Sub-national comparisons

There are two basic reasons for comparing the safety performance of sub-national jurisdictions. In the first place, a ranking of relative performance of each area will be very useful for comparison within countries. In the second place, it will provide better understanding of the factors affecting safety improvement, so that safety practitioners can achieve more effective programmes. This requires greater focus on understanding how the effects of programmes are modified by the nature of the safety problems faced by each area. Lessons can not only be learned from comparison of areas within countries, but also from comparison of similar areas in different countries.

The study clearly identifies factors which have effects on risks at a regional and local level. Based on a literature review it was concluded that structural and cultural differences, the bottom layer of the pyramid, can considerably affect road safety at a regional and local level. The results of this part of the study are considered sufficiently interesting for recommending continuation of this work in an international/ European project. In addition, it is recommended to use different approaches for studies at both the regional and the urban level.

1. Integration of SafetyNet and SUNflower

1.1. Introduction

We can observe a growing interest and a growing number of activities in the field of road safety internationally, more specifically in Europe. Activities supported by the European Commission like, for example, including road safety research in the European framework programmes, are instrumental in this process. European road safety policies, as expressed for example in the EC's White Paper on European transport policy (EC, 2001) and in the European Road Safety Action Programme (EC, 2003) also encourage international cooperation. One of the more visible activities is the recent establishment of a European Road Safety Observatory (ERSO). This Observatory has different aims, among which monitoring progress towards road safety targets and identifying best practices.

The SafetyNet project was initiated with the aim to build up the ERSO, paying attention to three different areas: collecting and analysing data at a *macroscopic level* (CARE, risk exposure data, and safety performance indicators), *in-depth-data* (independent accident investigation and in-depth accident causation data) and *knowledge on road safety topics* (www.erso.eu).

During the course of the SafetyNet project it was decided to incorporate the SUNflower approach in SafetyNet in order to integrate different components of the SafetyNet activities. This report reflects the work that was done to accomplish this task.

The first SUNflower report (Koornstra et al., 2002), comparing road safety in Sweden, the United Kingdom and the Netherlands, formulates the basic idea behind the SUNflower approach: "A better insight into the development of policies and programmes in these countries might conceivably identify key factors, which could further improve current safety practice in each of them". From analysis and diagnostic point of view, the SUNflower approach aims to identify strong and weak points in the road safety performance of different European countries. The aim of this approach is to determine underlying elements in the current policies and programmes in EU Member States, to learn which of these elements make them particularly effective in coping with the traffic safety problem, and thereby identify policy improvements most likely to result in further casualty reductions. Of course, it is also possible to use the opposite approach. From an intervention point of view (how can road safety effectively be improved) the SUPREME project, for example, identified and published best practices in road safety in the EU Member States (KfV, 2007).

Comparing three countries was found to shed very interesting light on the performances of the countries. In many senses the countries differ a lot, but they are the three countries with the highest road safety level in the world. We found that these similar levels of safety were achieved through continuing planned improvements over recent decades, that the targeted policy areas had been similar, but implemented policies differed at a detailed level. In the second study, called SUNflower+6, the number of countries was increased to nine (Wegman et al., 2005). The positive outcome from the initial SUNflower study was more or less repeated in the SUNflower+6 study, although the final conclusions were not as easy to interpret as those in the SUNflower study. But comparing performances and

safety developments in three groups of countries with similar road traffic backgrounds resulted in interesting and meaningful recommendations for all nine countries.

The comparisons of nine countries made clear that just the comparison of countries did not sufficiently generate the interest of the researchers and policymakers. It was evident that learning from each other, and especially from the best performing countries added an extra dimension to this approach. For that reason we introduced the concept of benchmarking. Benchmarking is an action aimed to improve your performance by learning from others through 1) identifying and 2) understanding, and by 3) adapting outstanding practices from the countries which are considered to be 'best-in-class'. This concept originates from business/the private sector, but can also be applied, for example in comparing road safety performances between countries.

Comparing or benchmarking countries in the field of road safety presupposes a set of indicators, which together paint the whole picture. This set of indicators is called a benchmark. A frequently used word as indicator needs some clarification to reach a common understanding. In general terms, an indicator is a quantitative or a qualitative measure derived form a series of observed facts that can reveal relative positions (e.g. of a country) in a given area (Nardo et al., 2005). According to these authors a composite indicator is formed when individual indicators are compiled into a single index on the basis of an underlying model. The composite indicator should ideally measure multi-dimensional concepts which cannot be captured by just a single indicator, e.g. competitiveness, industrialization, sustainability, single market integration, knowledge-based society, etc.

The road safety target hierarchy in the SUNflower approach (see also Figure 1.1) was introduced to compare road safety performances of countries. This hierarchy acknowledges the different aspects of road safety and road safety interventions. These aspects can be measured when they are properly defined and can be correctly measured by using different indicators. To make matters even more complicated, the indicators at all levels of this hierarchy are also multi-dimensional. To illustrate this point, final outcome indicators are expressed in terms of 'Number of killed and injured'. However, Elvik (2008) suggests that this number (magnitude) is only one of the nine possible characteristics. The other eight that are identified by Elvik are: severity, externality, inequity, complexity, spatial dispersion, temporal stability, perceived urgency and amenability to treatment. If we have five layers in our road safety target hierarchy, and we have different indicators for each layer, it is obvious that we need to combine and simplify information in order to help us interpret. This is a good reason for the wish to capture all relevant pieces of information in a composite index.

When benchmarking the safety performance of countries we have interests in monitoring and understanding, if not explaining, progress in road safety. Furthermore, we would also like to answer questions about how to adapt these findings for other countries in order to enable countries to learn from each other. And one step further: how to learn from outstanding practices in those countries that are considered to be 'best-in-class'. When benchmarking, it is not necessary to compare many countries, but it is a prerequisite to identify a 'best-in-class'. To this end the countries must be grouped into classes, which gives rise to the question how this must be done for this purpose. Can the grouping be carried out based on

road safety outcome indicators (final or intermediate), on policy output or policy input indicators, or on the structural and cultural background of countries?

1.2.   Aim of the study

It is obvious that there is not much history and experience in using indicators for road safety. This is even more so the case for using a composite index. We somewhat lag behind other fields. Examples of such indicators are known in other domains such as the Human Development Index, which reflects life expectancy, education level and living standards in a country, and is used by the United Nations for the estimation of progress and annual country comparisons; the Environmental Sustainability Index which is used by the World Economic Forum; or the Overall Health System Index used by the World Health Organisation (WHO).

So far, we have used simple indicators in road safety like the number of people killed in a road crash as the one single indicator. Sometimes (serious) injuries are analysed additionally. When comparing countries we went one step further by making indicators comparable by normalising or standardizing them, for example by taking into account the size of a country, the number of inhabitants, motorization, etc. In order to achieve a generally accepted way of normalization or standard-ization, such as proposed by Trinca (Trinca et al., 1988), in SUNflower we used the indicators personal safety (number of fatalities divided by the number of inhabitants) and traffic safety (fatalities divided by the number of motorized vehicles). These indicators, however, also raised some questions: which indicator is the best one, can they be replaced by one another, etc. It is considered worthwhile to proceed with this discussion and to investigate whether a composite index serves our goals of making a more comprehensive comparison and of benchmarking road safety performances between countries, more than simple indicators would.

Another interesting question deals with comparing programmes and performances at a sub-national level, as was demonstrated in the SUNflower+6 study. In this study we not only compared Greece, Portugal and Spain (Hayes et al., 2005), but we could also compare a Spanish region (Catalonia) with Spain, and both other countries. Sub-national comparisons open the possibility to take 'structure and culture' (e.g. spatial and demographic factors, organizational and cultural factors) into account to a larger extent.

Although it can be stated that working with indicators has not only advantages, the anticipated benefits are considered appealing enough to study road safety indicators in more detail. Based on the experiences with practical applications, this study discusses the pros and cons of using indicators for road safety and policy making, both at a national and a sub-national level.

The aim of this study is to develop a knowledge-based framework for comprehensive benchmarking of road safety performances and developments of a country or of other sub-national jurisdictions.

1.3.   The SUNflower approach

As an introduction to the SUNflower approach we will refer to earlier studies and publications (Koornstra et al., 2002; and Wegman et al., 2005). This study can be

seen as a logical follow-up of earlier work. Some of the SUNflower+6 study's recommendations for further research can be used to illustrate this.

"We recommend the Commission to focus specifically on three major data issues, exposure data, information on safety performance indicators and information on severely injured road users.

In addition, we recommend to develop standards for the definition of such indicators and for data collection procedures, in order to achieve unambiguous European data that can be compared at the European level. Another challenging task is to soundly quantify the relationships between particular levels of the road safety pyramid, especially between the levels of indicators and outcomes, and to introduce the methods on how to use this knowledge for the prediction and monitoring of road safety outcomes at the country level.

Further knowledge development should be stimulated in order to assure that the footprint gives a valid and reliable representation of countries' road safety performances, now and in the future.

Finally, a prototype of a benchmark system has been developed; the data template used in this project should be improved. We recommend that a European standard will be developed of such a safety template, to be used in all European (Union) countries. We further recommend to develop the existing and already working prototype of a benchmark system into a user friendly final format for use with the safety template."

The so-called footprint study discusses these recommendations in somewhat more detail (Morsink et al., 2005).

After consultation with the European Commission and the SafetyNet Steering Group, it was decided to explore possibilities to integrate these recommendations in the SafetyNet project. In 2007, a SafetyNet-SUNflower workshop discussed how this could be done.

The main conclusions from this workshop can be summarized as follows:

It was concluded that SUNflower can be of great added value to SafetyNet as a valuable tool for benchmarking of the safety performance of countries. Although the focus during the workshop was on the pyramid structure, SUNflower entails a lot more than just the pyramid: it is more than a benchmarking instrument; it improves our understanding of developments and consequently contributes to better policymaking.

The pyramid shape gives the model a stable basis. The costs are at the top: after all, we want to reduce the costs of crashes to society. However, there are some important issues concerning the pyramid structure that need our attention on the short term. Definitions are needed for mobility and exposure. When are they internal in the pyramid and when are they external factors? What disaggregation levels for the third dimension of the pyramid are most appropriate? Last but not least, it was remarked, there is more work to be done in describing or developing clear indicators for the different levels of the pyramid and for the links between them.

Finally, while ERSO is growing in importance, we need to establish its position in the world, and providing a sound methodological framework can help in reaching this.

We can use the experiences and the results in the several SUNflower projects until now as a solid basis for further enhancing our methodological framework for benchmarking road safety performances. In addition, we can use certain results of the SafetyNet project, especially those from WP1 (accident data and analysis), WP2 (exposure), and WP3 (safety performance indicators). The SUNflower approach uses a so-called target hierarchy as presented in Figure 1.1.
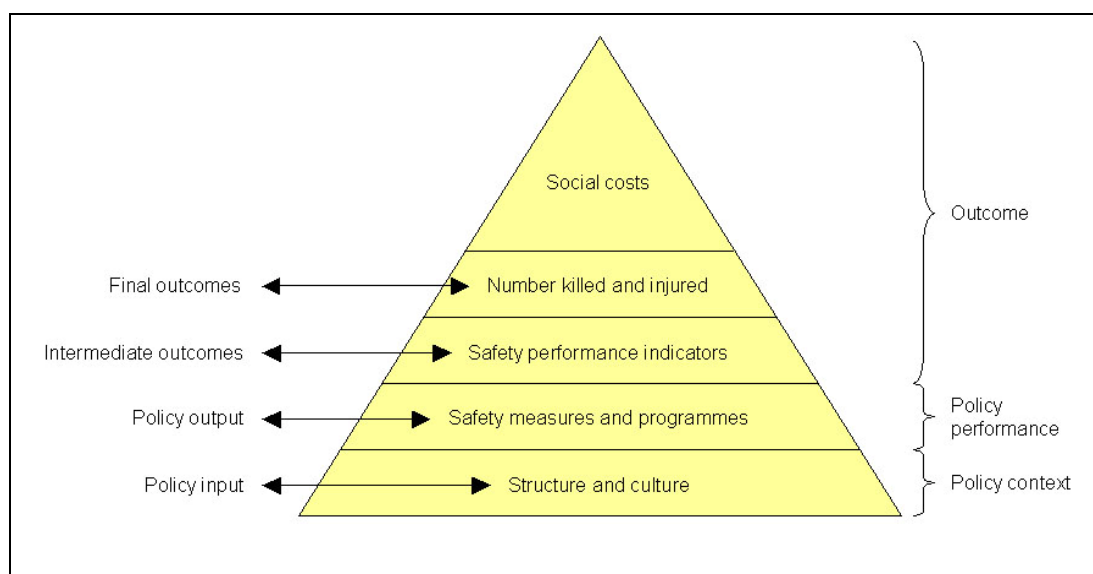
Figure 1.1. *A target hierarchy for road safety (Koornstra et al., 2002; LTSA, 2000).*

Using this target hierarchy generated quite some support over the years and has many followers. But this approach also raised discussion. First of all, the pyramid was considered to be a too simplistic model of a far more complex reality. This may be the case for all models. But if we do not start with a simple model to deepen our understanding of this complex reality, we will most probably never be able to take further steps.

Four items were subjects of discussion in the past:
- the system boundaries of the pyramid and the definition and characteristics of the external factors influencing the processes in the pyramid (Section 1.3.1);
- how to define both bottom layers of the pyramid: Safety measures and programmes and Structure and culture (Sections 1.3.2 and 1.3.3);
- the vertical relationships between the different layers (Section 1.3.4);
- the appropriateness of the top level of the pyramid: social costs (Section 1.3.5).

1.3.1. System boundaries and external influences

The first question that needs to be answered is which boundaries must be used in the target hierarchy, which factors are part of the road safety system, and which factors must be considered as separate from that system an why. Human activities like traffic participation, vehicle choice and route choice are considered to be part of the road safety system. This is the case even although these choices are hardly or not at all made from a road safety perspective but are much more based on the

availability of a vehicle or a road, and an assessment of the cost and time a journey will take. The reason is that the exposure to risk is a crucial factor within road safety, like, for example, human activities are part of the Pressure-State-Response model in the field of Environmental Performance Indicators; see Adriaanse (1993). The same argumentation holds true for the (safety quality of the) design and the lay-out of our road infrastructure and also for vehicles. It needs not be said that neither the road design nor the use of road and vehicle can only be understood and influenced from a road safety perspective, but also from a contribution to economic developments, spatial planning, environmental effects etc.

In many countries a discussion has arisen about the road safety benefits that can still be achieved being only relatively small, and why only specific road safety measures should be applied. After all, there is a good driver training, there is a fair amount of enforcement, road safety is included in the guidelines for road design to a satisfactory extent, etc. This makes an answer interesting to the question if 'win-win' situations can be achieved by strategic alliances with other social issues. Examples could be health care, developments in giving society a more sustainable character, social developments, etc. The search for win-win situations could have as a result that the system boundaries for road safety become wider, but this needs to be judged for each individual case.

For a full and correct picture of indicators at all levels of the pyramid we need to pay attention to developments which affect the quality of measuring these indicators. As an example, underreporting of crashes is a major problem in almost all countries. The less severe the consequence of a crash, the higher the chance of not reporting the crash to end by the police (Derriks & Mak, 2007). Also when it comes to measuring safety performance indicators (Hakkert et al., 2007) large steps are still needed to arrive at high quality comparable results.

The conclusion seems to be that there are no correct or incorrect system boundaries, but that these boundaries are somewhat flexible. But it must be recommended to investigate how to set the system boundaries for each problem definition.

1.3.2. Road safety management: safety measures and programmes

The layer called *Safety measures and programmes* is an essential layer in the pyramid, because it is by implementing effective (and efficient) measures and programmes that we try to reduce the negative consequences of road crashes for society, the so-called outcomes. All our efforts for a better understanding of road safety and a better insight in measures and programmes are irrelevant if it cannot be used to design and implement more and better measures and programmes.

So far, road safety activities studied in SUNflower have covered a long period of time (from 1970 onward). However, it turned out that these interventions were seldom a well-documented. This may be part of the explanation why road safety developments could not be described and explained very well. Later we added more general information to the evaluation items for policy documents and for effective policy implementation (Wegman, 2004). This general checklist has not yet been translated for road safety management purposes. However, the World Bank took the first steps with its so-called country capacity reviews, which have in the meantime been carried out for several countries, and the results of which serve as a basis for further investments in improving road safety.

Recently it has been argued that it would be better to divide this layer of 'safety measures and programmes' into two components: institutional road safety management functions, a number of generic characteristics that allow for the proper design and implementation of effective interventions, and the interventions themselves (Bliss & Breen, to be published). This concept of 'managing for results' will be further discussed as part of Section 2.4.

1.3.3. Structure and culture

The lowest layer/level of the pyramid, called *Structure and culture* has not yet been very well defined in the SUNflower approach. SUNflower added an extra layer to the model as developed in New Zealand (LTSA, 2000). The reasons were twofold:
- It gives an essential background for all the observations and indicators at a higher level of the pyramid. Progress in road safety could perhaps not be fully understood or even be misinterpreted by not knowing or ignoring these backgrounds.
- It is not easy to transfer findings of benchmarking and to learn from experiences and results abroad without having a clear picture of the setting in which these results have been made or the changes were measured.

The SUNflower approach has been criticized for not fully recognizing the role of spatial and demographic factors (IIHS, 2006) and organizational and cultural factors (Delorme & Lassarre, 2005) in influencing casualty trends. In fact, the SUNflower approach, and the pyramid on which it is based, include both these groups of factors. However, it is fair to say that the influence of these factors on the work to date has been explored to a much lesser extent than the data on more directly safety related policies, such as accident outcomes, safety performance indicators and policy inputs. Analyses at sub-national level provide one opportunity to explore some aspects of these issues further (see Figure 1.2).

In the **Structure** part of the bottom layer two dimensions are distinguished: physical structure and operational (functional) structure.

The *physical structure* of a country can be described by numerous factors that can be defined as specific long-term conditions contributing to different road safety outcomes. They are typically not, or at least not only, amenable to interventions by conventional road safety policies. Moreover, they are typically modifiable by more general policies, in a long term only. The two groups of structural factors can be distinguished by their amenability to interventions in time: 1) Stationary factors – not changing in time (e.g. geographic and climate conditions) and 2) Tractable (dynamic) factors – subject to evolutions or changes in time (e.g. demography, road topology, and urbanization).
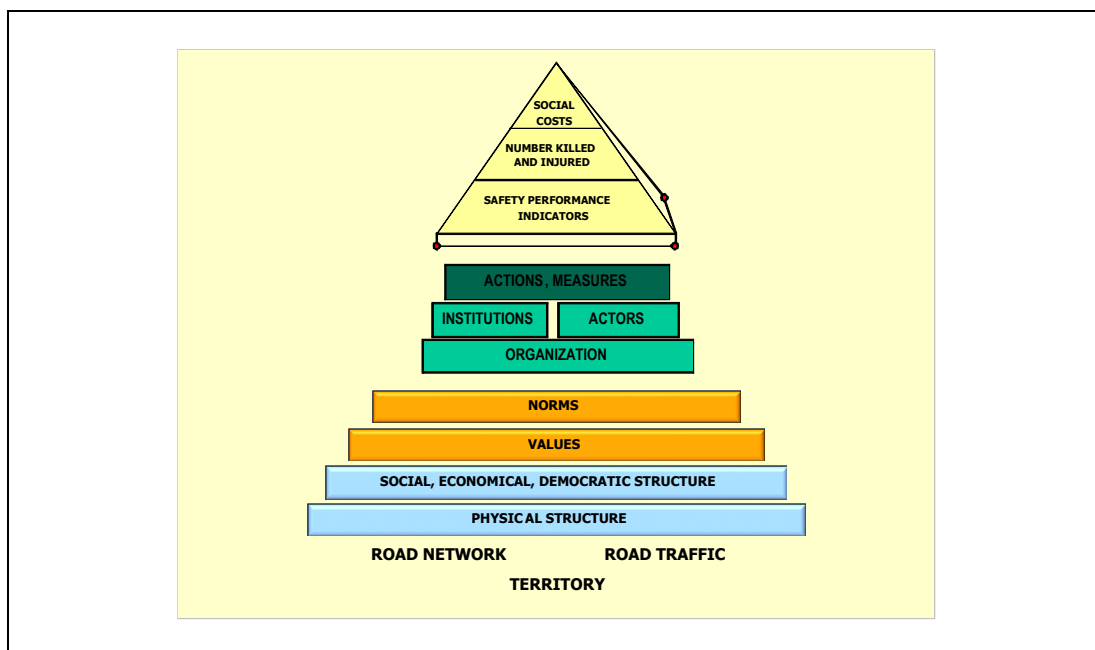
Figure 1.2. *Aggregated road safety pyramid (adapted from Eksler, to be published).*

Stationary factors are of a physical nature and are beyond the influence of any policy interventions, while tractable factors often have socio-demographical-economical character and in a longer term can be influenced by targeted measures.

Stationary factors	Tractable factors
Relief Climate Settlement geography	Demography Urbanization Road network topology Social deprivation Economical performance Modal split

Table 1.1. *Overview of some structural factors in road safety.*

The list of structural factors presented in Table 1.1 is not exhaustive and many other structural factors could be added. Also, it can be argued that many of the structural factors are subject to adaptation processes, such as climate conditions, implying different road infrastructures, and vehicle properties, but also different driving skills. Therefore, these differences tend to have no real impact on compared road safety outcomes indicators. However, there are other factors that indirectly have such a strong impact on road safety outcomes, that they should not be omitted in any relevant comparison of road safety performance. Structural factors describing the settlement (and road network) structure have been identified as the strongest determinative factors of road safety outcomes at a regional level (Eksler et al., 2008a). They have such a strong impact on the speed driven by motorized vehicles that they have a direct relation with road safety outcomes. Both qualified and quantified indicators, i.e. typological or empirical indicators, could be considered.

The *operational* structure refers to the organization of and arrangements between all potential actors involved in policy making. Therefore, this is where the manner is

8

discussed in which society uses institutions to try and solve social problems; road safety in this case. The *World report on road traffic injury prevention* (Peden et al., 2004) gives a good illustration of the numbers and variety of the different actors (Figure 1.3).
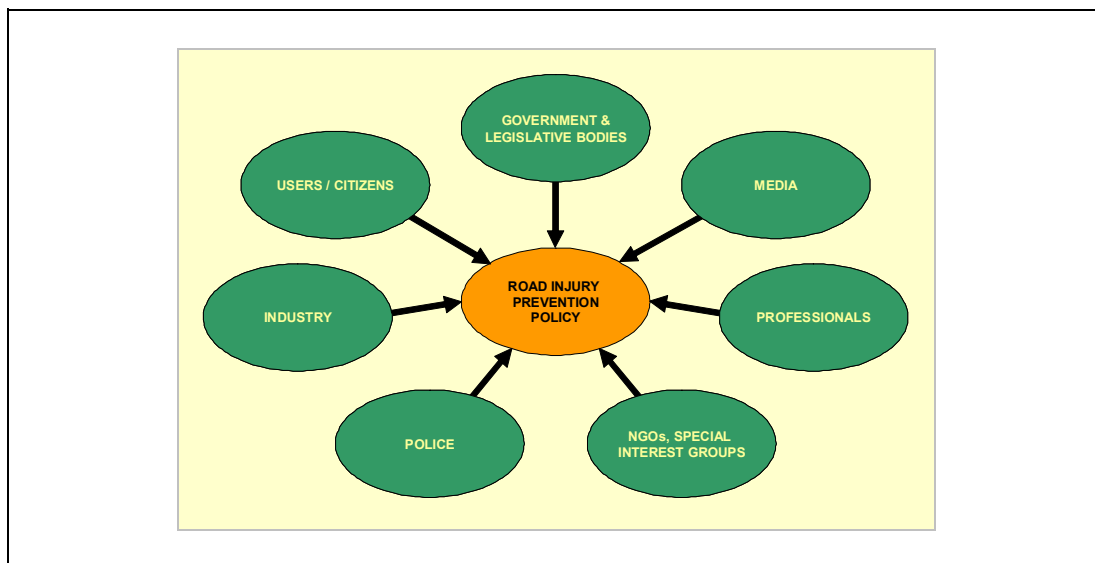
Figure 1.3. *Overview of different key stakeholders in road safety policy (source: Peden et al., 2004)*.

Somehow, agreements will have to be made between the various actors about their contribution to road safety improvement. If this cooperation is not well coordinated, loss of both quality and efficiency will be the result. An added complication is that such losses are not easily indicated. The solution to this problem could be to ask organizations to commit themselves to verifiable performances and next to create a system that makes them accountable for these performances. If different actors are expected to produce policy performances at the same time and if the joint total of these performances is more than the sum of it parts, inadequate cooperation results in (unnecessary) loss of effectiveness.

The government's role is especially important in this, or rather the roles of the different layers of government. It must be said here that the government is not only committed to keep to its own agreements and to deliver a good product at the lowest possible cost. The government has to 'deliver' in a political context where political rationalities are important and play a serious part alongside the scientific rationalities.

As we remarked earlier, it is not yet customary to thoroughly document the policy efforts for road safety improvements in terms of deliveries, products and costs. This complicates the scientific evaluation of implemented policies that was pursued and hence also the giving a proper answer to the question if the delivery has been adequate for achieving the target that was set.

Culture consists of values and norms in their social sense. *Values* can be regarded as assumptions upon which implementation can be based. Sets of consistent values and measures together form the value system, which is subjective and varies across people. Types of value include ethical/moral values, ideological, social and aesthetic

values and it may be argued that all of them have an influence on behavioural attitudes of road users, which in turn will manifest itself in different road safety outcomes. Values such as the value of a human life, respect for each other's rights, etc., are directly reflected in road safety provisions, such as those related to reduction targets. *Norms* refer to the rules that are socially enforced. Social sanctioning is what distinguishes them from values. They can be viewed as reference standards, or statements that regulate behaviour and act as informal social control. The most typical example is society's attitude towards drink-driving, which differs significantly between countries.

For road safety this is reflected in the way society deals with the consequences of the lack of road safety, to what extent these consequences are considered to be unavoidable, and the degree of social and political interest in eliminating or at least modifying these consequences. This is about road safety culture and this culture partly decides the political, governmental and social reactions to traffic risks (see also AAA, 2007). What role does a government see for itself in reducing risks in society, and where is the boundary between citizens', respectively road users', responsibility and collective responsibility? And how do political priorities translate this collective responsibility? And to which extent will road safety measures be accepted, especially if they limit individual freedom? But the cultural element can also be seen as the way in which a society, and politics in particular, deals with setting concrete goals (a quantitative road safety target) and the reaching or failing to reach such a target. Undoubtedly countries differ, but previously a European study of drivers' attitudes has taught us that there is also a reasonable amount of similarity between countries, as has been illustrated in several SARTRE studies (1991,1996, 2004).

However, it is certain that when comparing countries differences in 'structure and culture' have an effect on the size and nature of road safety problems, but also influence the possibilities to reduce the problem effectively and efficiently. This presents an important theme for future research.

1.3.4. Vertical relationships between the different layers

The presentation in the shape of a pyramid with different layers could give the impression that the layers are relatively unconnected. Nothing is further from the truth, as has been made clear in earlier SUNflower publications. In fact, the pyramid has three, if not four, dimensions. Two of these dimensions are not visible in Figures 1.1 and 1.2. The first is the dimension *time*. The pyramid's indicators can be read periodically and this way trends can be studied. The second dimension is that indicators can be read not only for a country in its entirity, but also for (parts of the problem): regions, modes of transport, road types, age groups, etc. This can be visualized by not using a triangle like in Figures 1.1 and 1.2, but by adding a third dimension, thus creating a pyramid.

The two remaining dimensions can also be made visible in the two-dimensional plane, the triangle. The horizontal dimension indicates that the number of observations decreases for the top three layers while approaching the top. The pyramid's layers are stacked logically. This enables a top-down approach: understanding developments at the top and explaining them using developments at the bottom. It is also possible to make changes at the bottom and investigate to what extent they cause changes at the top.

The relations between indicators at different layers are very important and must be, conceptually seen, causal for the top four layers. Without these causal relations the pyramid is even meaningless. We will use one example as an illustration. Policy interventions will first need to have an effect at the level of the intermediate variables (SPIs) before it can be made credible that the interventions have an effect on crashes and risks. Alcohol legislation will first have to result in fewer alcohol-related crashes and fewer alcohol-related casualties.

It goes without saying that our knowledge is not good enough to link indicators of the different layers in a causal way. Although we lack for evidence-based information, we may use the judgement of road safety experts to overcome this drawback. This lack of 'evidence-based' information can be considered as a good incentive to guide further research.

It can be observed that interventions are increasingly composite interventions: it is not just new legislation, but they also include the public information about the new legislation and its enforcement. It can become even more complicated when it is attempted to discourage the use of alcohol in a society, one of the reasons being to reduce traffic participation under the influence of alcohol. In addition, determining the effects of interventions becomes increasingly difficult if they are more widely spread over time and place. This presents a heavy task for the methodology of evaluation research.

Summarizing, the idea behind the pyramid's layers is the continuous attempt to define a causal relation between the top four layers which can be seen as the core of the SUNflower approach.

1.3.5. Social costs

Until now, SUNflower has paid hardly any attention to the social consequences of road crashes, more in particular to those consequences that can be expressed in monetary units. There are good reasons to initiate this (SWOV Fact sheet Road crash costs, 2007) and therefore *Social costs* have been added to the pyramid as its top layer. In the first place, this information is useful for comparing road safety policy with other policy areas. These can be other sectors within traffic and transport or outside, for instance environmental care, public health or other safety issues. Secondly, information about the costs of road crashes is used in cost-benefit analyses (SWOV Fact sheet Cost-benefit analyses of road safety measures, 2008). Social costs estimates can be used for setting policy priorities.

There is another good reason for adding Social costs as a top layer to the pyramid, rather than ending with 'Numbers of killed and injured'. This will be illustrated with an example. Assuming that the development of the number of fatalities is not exactly equal to the development of the number of injuries, which conclusion is to be drawn? This is not a hypothetical question, but a reality in many countries. This situation requires a method of adding up fatalities and injuries. However, fatalities are considered to be more severe than injuries, and, moreover, there are major differences between the severity of injuries: from lifelong disability to a bleeding thumb. To take this into account the health sector has developed indicators such as QALY (Quality Adjusted Life Years) and DALY (Disability Adjusted Life Years) (Sassi, 2006). Injuries scales such as the Injury Severity Scale and the Abbreviated Injury Scale have also been developed. All these scales help us attaching a value to different consequences of road crashes. The SafetyNet project made a major

contribution to the comparability of road crash injury data between European countries.

SUNflower uses the term Social costs, sometimes the term Road crash costs is used, or the term socio-economic costs. All three terms cover five main categories:
- medical costs;
- production loss;
- quality of life loss;
- material costs;
- settlement costs.

Estimates of these costs have been made for several European countries (Elvik, 2000). They vary form 1.3% to 3.2% of the Gross Domestic Product (an average of 2.1%). This type of information allows us to make comparisons with other sectors in society. It also enables rational prioritization of policy actions based on cost-benefit analyses.

Therefore, we have every reason to place the consequences of road crashes at the top of our pyramid and we have to develop procedures/methods to use these estimates properly in benchmarking the safety performance of countries.

1.4.   Structure of the report

Chapter 2 discusses the concept of road safety benchmarking and the use of road safety indicators for that purpose. It is argued that it might be an excellent idea to capture the complex phenomenon of road safety in some simple indicators, if not in one single composite index. Simplification, quantification and communication are the key words here. However, indicators should be accepted by road safety researchers and professionals, as well as by policy makers. This chapter hopes to gain that support. Different types of benchmarking are distinguished and introduced.

Chapter 3 makes a first proposal for a composite index for road safety performance. It is our ambition to include the different layers of the road safety pyramid in such a composite index. The proposed layers are policy performance indicators (safety programmes), road safety performance indicators (killed and injured) and implementation performance indicators (limited to a set of measurable safety performance indicators). The aim of this composite index is to enable ranking countries in accordance with their safety performance.

The concept of benchmarking not only addresses ranking the safety performances of countries; this ranking is only a step towards 'identifying, understanding and adapting outstanding practices from the countries which are considered to be 'best-in-class'. Therefore, this concept requires defining classes and identifying criteria that can be used to form different classes. Therefore Chapter 4 is dedicated to the problem of how to group European countries and it answers the question whether it is wise to form different classes or whether to consider all European countries to be pupils in the same class.

Chapter 5 deals with road safety developments and seeks how to describe and analyse these developments best. Trends for fatality risks and rates are presented for individual countries and the results are compared. For example, the results of the grouping of countries from Chapter 4 are used to illustrate the potential conclusions

that can be based on the modern techniques of time series analyses. The same techniques are applied to studying disaggregate data for age groups, traffic modes and road types.

Chapter 6 starts with the observation that SUNflower analyses to date have focussed on national comparisons. These analyses can also be made for the comparison of programmes and performances at a sub-national level. This allows us to take into account structural (spatial, demographical, economical, political) and cultural differences/variation and to gain better understanding of their importance. Sub-national analysis can be made at a regional level and to compare the safety programmes and performances of cities. Avenues for further work are presented.

The final chapter, Chapter 7, contains conclusions and recommendations. It summarizes the main findings and uses them as a basis to draw conclusions and make recommendations for next steps.

2. Benchmarking by using road safety indicators

2.1. Benchmarking road safety performances

Basically, the essence of (international) cooperation is learning from each other. This learning should be targeted at a better understanding of the subject involved, in our case road safety. The learning includes subjects such as monitoring and explaining road safety developments, and gaining good insights in the impacts of interventions (in the causal relationships between interventions and impacts on road safety, in the active ingredients of interventions and in the dose-response relationship) as a basis to speed up improvements in road safety in one's own country or jurisdiction.

Benchmarking is a process in which countries or jurisdictions (states, provinces, 'länder', etc.) evaluate various aspects of their performance in relation to other, and so-called 'best-in-class' practices. The benchmark results provide countries or jurisdictions with information from others that can be used as a basis for developing measures and programmes to increase their own performance. From here on we will only mention country or countries in this chapter, but the sub-national level, consisting of regions and jurisdictions, is also included.

Benchmarking consists of the following core activities: identifying the key components of a road safety performance, identifying with whom to compare (other countries/jurisdictions and 'best-in-class'), constructing indicators for meaningful comparisons, determining and understanding gaps in performances, and, finally, establishing future attainable performances. It is attractive to speak about a benchmark cycle (Figure 2.1) and to carry out benchmarking at regular intervals, to monitor progress made and to evaluate the results of interventions.
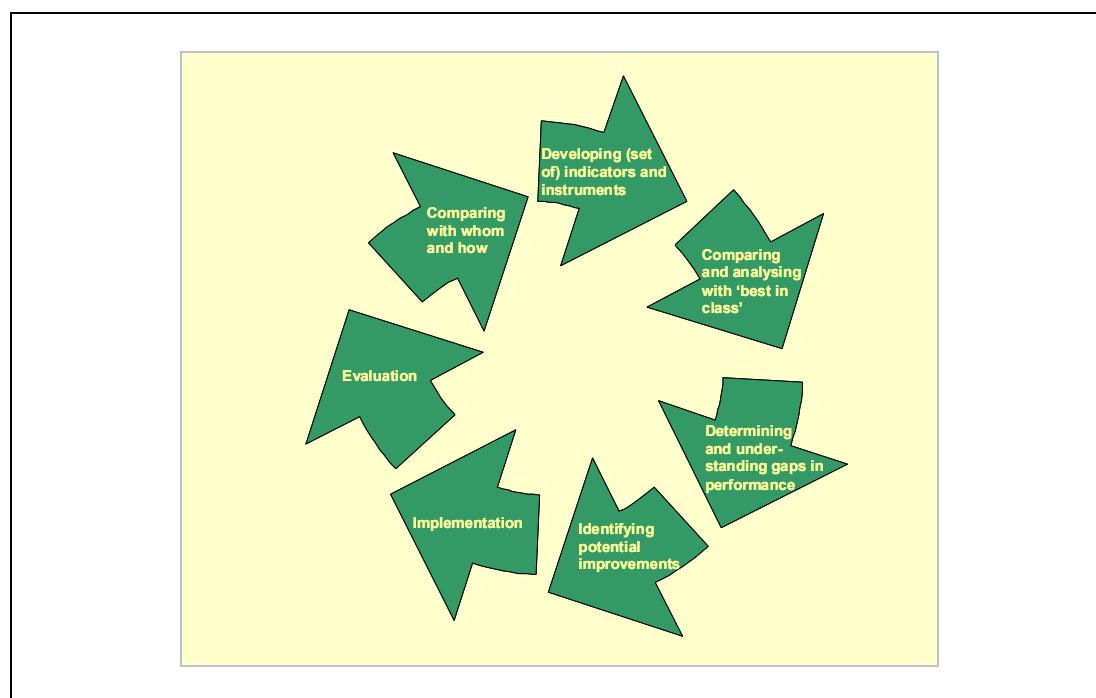
Figure 2.1. *The benchmarking process in seven steps*.

Benchmarking is based on learning from others, rather than developing new and improved approaches. Although helpful, benchmarking should never be the primary strategy for improvement. However, it can lay an important basis for a good strategy.

Two important tasks can be identified for this process:
- defining the key components of a road safety performance and investigating if and how these key components can be brought together in a composite index, a road safety performance index;
- finding a meaningful 'reference' (best-in-class) and defining procedures for identifying such a meaningful reference.

In the literature and in practice two words are regularly used for ranking performances: an *index* (e.g. Dow Jones Index, Human Development Index) and an *indicator.*

The number of indicators which is suggested for use in the field of road safety has been growing rapidly, especially over the last decade (e.g. ETSC, 2001; Wegman et al., 2005; Hakkert et al., 2007). Today, recognizing the complex character of the road safety phenomenon, more and more indicators are used with the intention of measuring the factors leading to accidents, identifying conditions which are associated with increased accident/injury risks, and detailing the structure of traffic injury patterns, whereas the traditional approach considered the safety outcomes mostly in terms of fatalities per head of population, vehicle fleet or exposure.

Because the word 'indicator' is so heavily used in road safety already, we decided to work with the word 'index': a road safety performance index. Because this index is a combination of several performance indicators, we introduce the term composite index in this study. Perhaps it will be helpful, for reasons of easy communication, to call this performance index the SUNflower index.

2.2. Performance indicators for road safety

Road safety is steadily developing into a major policy area (Peden et al., 2004), in which safety performance indicators should serve as supportive tools for policymakers. In comparing the safety achievements of countries there is a need to reduce the dimensions of the problem and to be able to work with a composite index that can express all the relevant components in a concise and comprehensive way. Examples of such indicators are known in other domains such as the Human Development Index, which reflects life expectancy, education level and living standards in each country, and is used by the United Nations for the estimation of progress and annual country comparisons, the Environmental Sustainability Index which is used by the World Economic Forum, the Overall Health System Index used by the World Health Organisation (WHO), and others (Nardo et al., 2005).

In SUNflower+6 the concept of road safety footprints was developed. A road safety footprint of a country was described by Morsink (2005) as a representation of the road safety status of a country. Three components of this footprint were considered to be essential:
- The footprint gives a multiple score of standardized key indicators.
- The indicators can be compared with meaningful references.

- The indicators are expressed as a snapshot in time, and as a past picture over time.

A road safety footprint draws a full picture of all impacts of road safety and their most relevant underlying elements and processes for which causal relationships exist.

The SUNflower+6 final report suggested that the road safety footprint of a country ideally is a composition of suitable indictors at all levels of the so-called SUNflower pyramid and for all components of the traffic system. Morsink et al. (2005) developed two schemes: a detailed footprint scheme and a summary footprint scheme. Both schemes intend to give an overview of indicators at all layers of the pyramid and make proposals how to compare indicators with a reference. It was experienced that even the summary schemes carry too many pieces of information to be understood easily and were not considered as attractive enough to be helpful for policy makers.

The concept *footprint* received a boost a decade ago when the ecological footprint concept was introduced. Ecological footprint analysis compares human demand on nature with the biosphere's ability, or it regenerates resources and provide services (Wackernagel & Rees, 1996). This ecological footprint approach tries to include environmental externalities in decision-making. For products and services the assessment of the environmental impact of a given product or service throughout its lifespan can be expressed by using the concept of life cycle assessment; see for example ISO 14040 (ISO, 2006).

The (ecological) footprint concept is basically a comparison of demand and supply, as the Pressure-state-response model developed by Adriaanse (1993). Demand should be less than supply in order to create a sustainable situation. For road safety this is not the case. We cannot identify a safe supply level other than zero fatalities/injuries, and we understand well that reaching zero is unachievable under prevailing conditions. Perhaps the lack of a clear-cut and acceptable supply level in road safety complicates an easy acceptance of this metaphor too much and seems to support the association with footprint as not very helpful for road safety.

The concept of comparing performances and, one step further, that of benchmarking performances seems to be a more appropriate approach for road safety. Benchmarking was originally developed and used in the private sector to compare the performances of individual companies as a tool for improving their operations. Benchmarking tries to provide an objective way of measuring performances against a meaningful reference (in the private sector: the competitor). This meaningful reference is sometimes described as the performance of the 'best-in-class'. This comparison is usually made with the aim of increasing some aspects of its own performance, in other words to learn from each other.

The first chapter already introduced the main aim of this study as to develop a benchmark cycle for international comparisons for road safety performances. In order to prevent misunderstandings we propose to work with the concept of benchmarking, and to leave out the concept of footprint, although both approaches are rather similar and work in the same direction.

Three main functions of indicators have been made clear by Adriaanse (1993) in his attempts to build indicators to be used in environmental policies: *simplification, quantification* and *communication.* This implies that defining indicators should be

directed by which intentions must be satisfied when using indicators. Basically, by using indicators we try to capture complex phenomena in relative simple terms and in doing this, we run the risk of losing relevant information or insights. Nevertheless, according to Adriaanse, indicators generally use simplification to make complex phenomena quantifiable in such a manner that communication is either enabled or promoted. Furthermore, these indicators can be used to compare countries, to rank them and to benchmark them.

In SUNflowerNext three types of indicators are distinguished. These three indicators together could, and in our view should be combined to form one composite index (see Section 2.3).

The first indicator captures the quality of road safety in a country and has been named **Road safety performance indicator**. The terms 'outcome indicator' and 'product indicator' are also used. In SUNflower we distinguish final outcomes (numbers of killed and injured), intermediate outcomes (such as the safety performance indicator), and social costs. In this we follow the line chosen in the New Zealand model (LTSA, 2000) and later in SUNflower (Koornstra et al., 2002). Therefore, we use the top three layers of the pyramid (see Figure 1.1) to indicate a country's road safety performance.

For a meaningful comparison of countries, numbers of people killed or injured are typically 'normalized', which results in fatality rates, e.g. fatalities per inhabitant, vehicle, or kilometre travelled. In addition, more vulnerable groups of road users like pedestrians, cyclists, and motorized two-wheelers may specifically be considered. Based on the number of people killed and injured and the consequences of road accidents it is possible to express the socio-economic burden imposed on societies by road accidents. These costs enable a comparison of the consequences of road crashes with other threats to public health (Peden et al., 2004) or with other investment priorities in a country or jurisdiction (Elvik & Veisten, 2005).

The second type of indicator indicates the quality of the implementation of road safety policies and has therefore been named **Implementation performance indicator.** For this implementation quality indicator the term 'process indicator' can also be used. Basically, this indicator follows a vertical line in the pyramid linking 'safety measures and programmes', safety performance indicators, and the numbers of people killed and injured.

Implementation performance, in general, can deal with different components of causal relationships between the different layers of the safety pyramid, such as between the policy context ('structure and culture') and the road safety policies; between the policy changes ('safety measures and programmes') and the changes in performance indicators; between the changes in safety performance indicators and changes in the number of casualties, et cetera. In this context, quite some progress was attained in the development of safety performance indicators within the SafetyNet project. However, the possibilities for systematic measurement of all these relationships are still limited and need further research.

The third type of indicator indicates the quality of response in policy documents to improve road safety and has been named **Policy performance indicator.** It has two components: the quality of conditions (strategies, programmes, resources, coordination, institutional settings, etc.) and the quality of action plans and individual

(counter)measures in the perspective of ambitions of countries as expressed in road safety targets

Policy performance deals with the quality of road safety strategy, more specifically with the quality of road safety plans and with the conditions introduced for the actual implementation of road safety measures and programmes, e.g. institutional arrangements, budget, quality of professionals, application of evidence-based knowledge, sound analysis and diagnosis of road safety problems, vertical cooperation between different tiers of government, etc. Reports by OECD (2002), ETSC (2006), Bliss & Breen (to be published) summarize the demands for the effective development and implementation of national road safety policies.

Hence, three types of indicator, *Road safety performance indicator*, *Implementation performance indicator* and *Policy performances indicator* can be included in the target hierarchy of the pyramid (Figure 2.2).
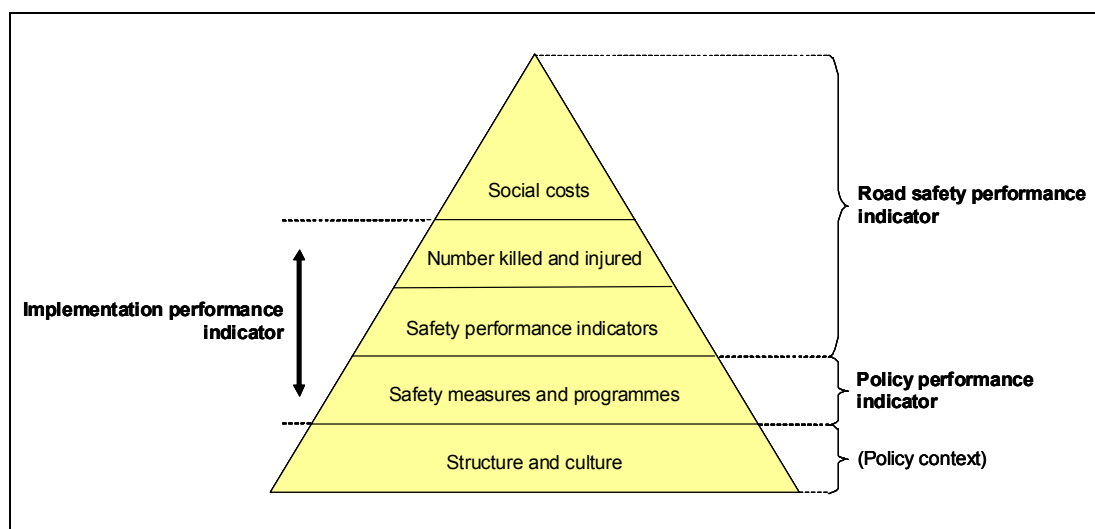
Figure 2.2. *Three types of indicator combined, forming the performance index for road safety*.

2.3.   Road safety: towards a composite performance index

The target hierarchy for road safety, as presented and used in earlier SUNflower studies, and in the SafetyNet project, contains several building blocks to be used in benchmarking. For several reasons, it is attractive to combine all information in one indicator, a so-called composite index.

The main pros and cons of using composite indices are adapted from Saisana & Tarantola (2002) by OECD/JRC (2008).

Pros
Composite indices:
* can summarize complex, multi-dimensional realities with a view to supporting decision-makers;
* are easier to interpret than a battery of many separate indicators;
* can assess progress of countries over time;

- reduce the visible size of a set of indicators without dropping the underlying information base;
- thus make it possible to include more information within the existing size limit;
- place issues of country performance and progress at the centre of the policy arena;
- facilitate communication with general public (i.e. citizens, media, etc.) and promote accountability;
- enable users to compare complex dimensions effectively.

Cons

Composite indices:

- may send misleading policy messages if they are poorly constructed or misinterpreted;
- may invite simplistic policy conclusions;
- may be misused, e.g., to support a desired policy, if the construction process is not transparent and/or lacks sound statistical or conceptual principles;
- the selection of indicators and weights could be the subject of political dispute;
- may disguise serious failings in some dimensions and increase the difficulty of identifying proper remedial action, if the construction process is not transparent;
- may lead to inappropriate policies if dimensions of performance that are difficult to measure are ignored.

Nardo et al. (2005) quote two statements on the pros and cons of using composite indices and these quotations illustrate these pros and cons rather well.

"The aggregators believe there are two major reasons that there is value in combining indicators in some manner to produce a bottom line. They believe that such a summary statistic can indeed capture reality and is meaningful, and that stressing the bottom line is extremely useful in garnering media interest and hence the attention of policy makers. The second school, the non-aggregators, believes one should stop once an appropriate set of indicators has been created and not go the further step of producing a composite index. Their key objection to aggregation is what they see as the arbitrary nature of the weighting process by which the variables are combined." (Sharpe, 2004, in Nardo, 2005.)

According to other commentators:

"[…] it is hard to imagine that debate on the use of composite indicators will ever be settled. […] official statisticians may tend to resent composite indicators, whereby a lot of work in data collection and editing is 'wasted' or 'hidden' behind a single number of dubious significance. On the other hand, the temptation of stakeholders and practitioners to summarize complex and sometime elusive processes (e.g. sustainability, single market policy, etc.) into a single figure to benchmark country performance for policy consumption seems likewise irresistible." (Saisana et al., 2005, in Nardo, 2005)

The OECD (Nardo et al., 2005) prepared a *Handbook on constructing composite indicators* with the aim to provide a guide for constructing and using composite indices for policy-makers, academics, the media and other interested parties. The handbook is concerned with indicators which compare and rank country performance in areas such as industrial competitiveness, sustainable development, globalization and innovation. The handbook contains a set of technical guidelines

that can help constructors of composite indices to improve the quality of their outputs.

The handbook distinguishes the following steps in the construction of composite indices, which are of relevance for a road safety composite index:
- Theoretical framework - to provide a basis for selection and combination of single indicators;
- Data collection – on the basis of their analytical soundness, measurability, country coverage, relevance of the phenomenon being measured;
- Multivariate analysis – assess the suitability of the data set;
- Imputation of missing data – consideration should be given to different approaches for imputing missing values;
- Normalization – indicators should be normalized to render them comparable;
- Weighting and aggregation – indicators should be aggregated and weighted according to the underlying theoretical framework;
- Robustness and sensitivity – analysis should be undertaken to assess robustness of the composite index;
- Links to other variables – correlate the composite index with other published indicators as well as to identify linkages through regressions;
- Visualization – composite indices can be visualized or presented in a number of different ways, which can influence their interpretation;
- Back to the real data – composite indices should be transparent and be able to be decomposed.

Although it is evident that to construct and work with composite indices has not only advantages, this fits the SUNflower approach rather well. There is a generous amount of information and even the summary footprint scheme as developed by Morsink et al. (2005) requires a thorough comprehension of road safety and its mutual relationships to understand this information in its full depth. This led to the conclusion that a composite index for road safety needed to be developed in which all components of the SUNflower pyramid should have a position. In addition, attention was to be paid to the cons that are presented in this section.

2.4. Performance indicators for road safety policies and their implementation

In recent years, there has been increasing attention for rational decision-making about road safety; not in the last place caused by the fact that many countries use quantitative targets. This indicates a policy and research based interest in the road safety developments (will we or won't we make the target?) as well as in the factors that can be an explanation for those developments (did the implemented policy make a contribution to the developments that were observed?).

It is barely possible to give a coherent explanation for the road safety developments. This is partly due to the complexity of the problem and the limitedness of our knowledge. Many factors and developments are important and have an influence, but at the same time we must establish that there still is insufficient knowledge to obtain a clear picture of all the relations. In addition, much important information is still lacking. But the growing attention for this area can be seen to lead to real improvements.

From this perspective there are two areas that require our specific attention if we wish to develop a *SUNflower road safety performance index* that allows all layers of the pyramid to be visible: in the first place the quality of the intended road safety policy (in Section 2.4.1), as can be found in the policy documents (Policy performance indicators). But it is also important that we can measure the quality of the policy implementation (in Section 2.4.2), which is indicated by the extent to which the intended policy is implemented, and to what extent this policy implementation affects the safety quality of vehicles, roads and human behaviour (the safety performance indicators) and to what extent changes can affect the numbers of crashes and victims. This means that here the quality of the causal chain is under discussion. This quality was previously called the Implementation performance indicator. Both these performances will briefly be discussed in this chapter, and will be elaborated in the following chapter.

In the past few years much work has already been done on Road safety performance indicators. This includes setting the numbers of fatalities (and sometimes also the numbers injured) as the standards for international comparison. This is often done by dividing these numbers by the size of the population (mortality and morbidity), and/or by the number of vehicle kilometres, or, if that data is not available, by the number of motorized vehicles. Following Trinca (1988), SUNflower has also chosen this approach. In the discussion about the best standard SUNflower has chosen to present the possibilities as different, independent measures that are all valuable. There is, however, increasing interest in detailing these general measures. Examples are the idea of valuing injury severity or to find a way to combine killed and seriously injured by taking the injury severity into account without simply adding the numbers. A second refinement can be made by taking vulnerable road users into account. The United Kingdom, for example, has decided to formulate a separate target for the safety of children.

During the last few years, the second part of the Road safety performance indicators, the intermediate outcomes, has been detailed by SPIs (safety performance indicators). Here, the SafetyNet project has made a very important contribution.

The last part of the pyramid that must be mentioned is the bottom layer: structure and culture. This is the foundation for road safety on which policy making and implementation is based. But this bottom layer also indicates the possibilities and limitations for policy. This layer also needs to be detailed further.

The remainder of the present chapter will discuss two indicators: de policy performance indicator (Section 2.4.1) and the implementation performance indicator (Section 2.4.2).

2.4.1. Benchmarking policy performance

For Policy performance indicators four key points are identified as crucial by Adriaanse (1993):
1. Quality aspects;
2. Sensitivity in time;
3. Policy relevance;
4. Recognizability and clarity.

The first point concerns not only the quality of data but also the methodology used. This methodology must be clearly defined, accurately described, socially and scientifically acceptable and, consequently, easy to reproduce. The indicators should enable composing temporal trends and identifying effects of medium-term and long-term policy interventions. The developed methodology must be derived from the main policy structure, paying attention to major policy themes and target groups, not only for a country as a whole, but also at a sub-national level. Finally, recognizability and clarity require carefully designed indicators with an easy appeal in order for them to be accepted by policy makers and scientists.

Policy performance deals with the quality of a road safety strategy. Table 2.1 lists the items that are required for the evaluation of policy documents (Wegman, 2004). At this stage, the assessment of policy documents, resulting in a score, is based on expert opinions. However, it is recommended to develop a standardized methodology for this purpose and to collect data for these indicators at a regular basis.

Evaluation items for policy documents
The political support of the document
The precision of the definition of goals/objects/targets
The use of valid causal theory (problem – solution)
The available means (implementation + monitoring)
The reduced necessity of inter-organizational decisions
The sanctions/incentives for co-producers and target audience
The implementation priority for all stakeholders
The active support of stakeholders

Table 2.1. *Evaluations items to measure the quality of policy documents (Wegman, 2004)*.

2.4.2. Benchmarking implementation performances

Benchmarking implementation performance mainly involves the causal relations between the different layers in the pyramid:
- if and how policy changes (safety measures and programmes) affect safety performance indicators;
- if and how changes in safety performance indicators affect changes in the number of casualties (killed and injured) and casualty rates;

The initial SUNflower study (Koornstra et al., 2002) introduced the causal chain between the policy performances of specific road safety interventions and their impact on Road safety performance indicators and final outcomes, such as people killed in a road crash. The study was based on activities in New Zealand (LTSA, 2000), but we decided to add a basic layer to this model, titled *Structure and culture*. It was argued that such a basic layer was needed as a policy context for understanding (impacts) of road safety policy. The Structure-component addresses topics such as how responsibilities between governmental layers are divided, and in relation with this, how governmental budgets are organized, what is considered to be a role for the private sector in road safety, what role NGO's play, etc. The culture element concentrates on how a society and its citizens perceive the road safety

problem compared with, for example, the role of (motorized) traffic in our society and its contribution to economical growth, welfare, environmental consequences, etc. Also questions on how responsibilities are defined for individuals and the government are relevant. We can also use the word 'safety culture' here (AAA, 2007).

Based on international literature on public policies Wegman (2004) lists the circumstances that affect the implementation quality of the policy documents and that are useful for the monitoring progress:
- the economic/social/political environment;
- the public support;
- the progress of the implementation of policy documents;
- the support of key stakeholders;
- the quality of the 'delivery mechanisms'.

However, it must be conceded that this is really a new area within road safety; an area, moreover, that is not yet very well-documented in many countries. If initially we were almost exclusively working on understanding road safety from a further and increasingly more in depth analysis of road traffic accidents, since only a few years the interest for road safety performance indicators (SPIs) came into being. It was mainly initiated by the Swedish professor Kare Rumar and was later developed by ETSC (2001). SafetyNet (Workpackage 3) has further elaborated this concept (Hakkert et al., 2007). Now a following step needs to be taken along this path: investigating and documenting systematically if and to what extent intended policy has been implemented, what relevant changes affecting road safety have occurred, and, finally, whether these influences indeed resulted in changes in safety performance indicators and the numbers of casualties.

In this context, the World Bank report (Bliss & Breen, to be published) is interesting. This report is based on six recommendations in the WHO/World Bank report on road safety (Peden et al., 2004). In the chapter entitled 'Managing for results' Bliss & Breen discuss two layers that are important for effective policy implementation: first a number of 'institutional management functions' need to be well organized and to be embedded and operational. Within this bedding, effective and efficient measures can then be implemented. The Bliss & Breen report can be regarded as a further elaboration and detailing of the list that was formulated by Wegman in 2004.

The institutional management functions could also be fitted in the pyramid's bottom layer (Structure and culture). But as we wish to reserve this layer for conditions and developments that are suitable for wider application and can hardly be influenced from the road safety perspective, the choice has been made to split the layer 'Safety measures and programmes' in two parts: the management functions and the concrete measures and actions.

In addition, the layer 'Structure and culture' also requires detailing in indicators. A first attempt at a more detailed definition is made in Chapter 6. Continuing this effort in the sequel to this study is recommended. Chapter 3 offers a first elaboration; these indicators fit within 'Structure'.

It has been clearly illustrated above that a good understanding of the effect of an actual road safety measure is only possible if the bedding of such a measure is sufficiently well-known. This has two major consequences. If it is important to know whether a measure has been implemented well or whether there is room for improvement, it is sensible to not only consider the actual measure, but to pay

special attention to its bedding. Making explicit advance statements about a measure's expected output (and about its expected contribution to the improvement of an SPI or the numbers of fatalities and injured) increases the possibilities of getting a thorough understanding of the effects of measures. There is also a second consequence: if the one country wants to learn from the other while the circumstances differ, not only the measure itself, but also its bedding needs to be taken into account. Only then can insight be attained in the possibilities of successfully 'importing' a measure that has been effective elsewhere.

Bliss & Breen discuss seven management functions:
• Results focus
    The foremost and pivotal institutional management function which can be interpreted as a pragmatic specification of its ambition to improve road safety and the means agreed to achieve this ambition.
• Coordination
    This concerns the orchestration and alignment of the interventions and other related institutional management functions delivered by government partners and related community and business partnerships to achieve the desired focus on results.
• Legislation
    This concerns the legal instruments necessary for governance purposes to specify the legitimate bounds of institutions, their responsibilities and accountabilities, their interventions, and their related institutional management functions to achieve the desired focus on results.
• Funding and resource allocation
    This concerns the financing of interventions and related institutional management functions on a sustainable basis using rational evaluation framework to allocate resources to achieve the desired focus on results.
• Promotion
    This concerns the sustained communication of road safety as a core business for government and society emphasizing the shared societal responsibility to support the delivery of the interventions required to achieve the desired focus on results.
• Monitoring and evaluation
    This concerns the systematic and ongoing measurement of road safety outputs and outcomes (intermediate and final) and evaluation of interventions in terms of achieving the desired focus on results
• Research and development and knowledge transfer
    This concerns the systematic and ongoing creation, codification, transfer and application of knowledge that contributes to the improved efficiency and effectiveness of the road safety management system to achieve the desired focus on results.

Hence, the basic concept here is 'results focus' and then the different functions are considered from this perspective. It is an attractive idea to try and attach an interpretation to these seven functions from the SUNflower pyramid concept. Chapter 3 makes an initial attempt.

The Bliss & Breen report rather emphasizes the government's role in increasing road safety and, indeed, there are no examples of a real and lasting progress without the government having a (very) prominent role. Therefore, it is under-standable that the WHO/World Bank report argues for a 'lead agency' as a drive behind the initiatives for and the implementation of road safety policy. In countries

where insurance companies are part of the government, like in Victoria, Australia, and in British Columbia in Canada, these companies are active precisely because they are part of the government. But here it must not be underestimated that it is not just the role of a central government that is important. This is evident in countries with a federal form of government. But much policy is made by regional and local governments and in and by local communities. Here the hidden demand for more road safety, for example a safe route to school for children or dangerous road section treatment, can fulfil an important role. Social organizations could, and sometimes have an important role in this. And their role in a successful road safety policy should really also be made more visible, and therefore be incorporated in performance indicators. It is recommended to pay attention to this in the near future.

Finally we will need to address the individual responsibility of citizen and road user, and the question whether it is possible to incorporate this in a performance indicator. After all, he or she carries the responsibility to avoid accidents. But this road user will need assistance in making safe decisions. This is done, for example, in the Sustainable Safety vision (Wegman & Aarts, 2005) and is also the basis for the safe system approach (OECD/ITF, 2008). This approach simply eliminates dangerous behaviour (almost completely). It prevents overtaking on a rural road, forbids pedestrians to walk alongside the motorway which as a result they rarely do in Europe. But this will not always be possible and then it can be tried to catch and punish the offender (a proven method) or to entice him or her into making safe choices. Incentives can be used to achieve this, for example a green wave of traffic lights if one keeps to the limit. Recently David Ward in his speech for an OECD conference called it 'to nudge the road user'. He based his idea on the book written by Thaler & Sunstein (2008), entitled *Nudge*. The cover of this book shows a mature elephant gently pushing a baby elephant forward. The baby elephant can actually do what he wants but is invited, be it insistently by the mature elephant's trunk, to take those decisions that really are good for him: 'choice architecture to nudge us in beneficial directions without restricting freedom of choice'.

2.5. Conclusions

Benchmarking the road safety performance of countries as a basis for learning and speeding up positive developments can be considered a promising step in improving road safety. Mainly because of the simplicity of the approach and the appeal to a wider audience, amongst which politicians and policymakers, benchmarking is already applied in many fields, but not really in the world of road safety yet. A simple ranking, but even better, a well-accepted benchmarking could result in inviting experts to explain positions and to explain changes in positions to a wider audience. Without any doubt, such benchmark results will attract attention from the media and this can be used to make further steps. However, if we consider benchmarking mainly as a basis for learning from each other, we are not only interested in the final score/rate/ranking, but in the backgrounds of those scores, in the components that contribute to the scores, and in the potential for improvements. Benchmark results need to be accepted by policy makers and scientists; this report has been written to obtain support for this in the field of road safety.

Benchmarking is a process in which countries or sub-national jurisdictions (states, provinces, 'länder', etc.) evaluate various aspects of their performance in relation to other practices, among which the so-called 'best in class'. The benchmark results

enable countries or jurisdictions to learn from others as a basis for developing measures and programmes which are aimed at increasing their own performance.

To be able to carry out meaningful benchmarking, performance indicators have to be designed. The advantages of working with these indicators are imminent: *simplification, quantification and communication.* In SUNflowerNext we distinguish three types of indicators covering all elements of the SUNflower pyramid: *road safety performance indicators, policy performance indicators* and *implementation performance indicators.* These three indicators should be combined into a composite index. A comparison of the pros and cons led to the conclusion that it would be attractive to develop a composite index for road safety. This means that a composite index for road safety must be developed in which all components of the SUNflower pyramid are represented and in which attention should be paid to the cons discussed in this chapter.

By developing a composite index for road safety (the *SUNflower road safety performance index*) it became apparent that we still lack for knowledge to include all relevant aspects. Nevertheless, it is considered feasible to study performance indicators based on information from all EU Member States. It is recommended to develop valid and reliable indicators for *policy performance* and for *implementation performance.* This chapter presents information which suggests in which directions these developments could take place. In addition it provides a basis and indicates the directions for the chapters to follow in this study.

3.   Designing a composite index for road safety

The number of indicators suggested for use in the field of road safety has been growing rapidly, especially over the last decade (e.g. ETSC, 2001; Wegman et al., 2005; Al Haji, 2005; Hakkert et al., 2007; Hermans et al., 2008). The purposes of road safety indicators are to enable meaningful national or sub-national (e.g. regional, local etc.) comparisons and monitoring through time of road safety developments. Recognising the complex character of the road safety phenomenon, today more and more indicators are intended to measure the factors contributing to accidents, to identify conditions which are associated with increased accident/injury risks, and to detail the structure of traffic injury patterns. In contrast, the traditional approach mainly considered the safety outcomes in terms of fatalities per head of population, vehicle fleet or exposure.

Moreover, road safety is steadily developing as a major policy area (Peden et al., 2004), where safety performance indicators could and should serve as supportive tools for policymakers. In comparing the safety achievements of countries there is a need to reduce the dimensions of the problem and to be able to work with a composite index which can describe all the relevant components in a concise and comprehensive way.

A number of studies were recently carried out that were aimed at the development of a composite road safety index. Al Haji (2005) suggested a Road Safety Development Index (RSDI) and used it for a comparison of road safety progress in ten Asian countries plus Sweden. The RSDI development was started with the definition of eight dimensions of the road safety domain, which are traffic risk, personal risk, vehicle safety, road situation, road user behaviour, socio-economic background, road safety organization and enforcement. For each dimension, one or several quantitative indicators were suggested and their applicability was analysed based on available data. For example, the road variable was defined as the percentage of paved roads out of the total road network; road user behaviour was defined as the percentage of seatbelt use and helmet use, and so on. Finally, each country was characterized by eleven separate indicators which were combined into one composite index. To make a composite index, Al Haji (2005) applied three ways of weighting, which were 1) the simple equal average, 2) the use of theoretical weights, and 3) the principal component analysis. The results of the different methods were consistent and enabled a robust classification of countries into three groups of high, medium or low safety development.

Hermans et al. (2008) studied the issue of assigning weights to individual indicators, to provide a combined road safety index. The researchers considered the seven safety domains which were defined by the SafetyNet project (Hakkert et al., 2007): alcohol and drugs, speed, protective systems, visibility (daytime running lights), vehicles, infrastructure, and trauma care. They suggested one indicator for each domain. Based on the data available in the international databases, from the World Health Organisation, and from the SARTRE project, the indicators were estimated for 21 European countries. Five weighting techniques as suggested by Nardo et al. (2005) were used to combine the separate indicators into one index: factor analysis, analytical hierarchy process, budget allocation, data envelopment analysis, and equal weighting. The rankings resulting from these weighting methods were further compared with the countries' rankings according to the personal safety (the number of traffic fatalities per million inhabitants). It was found that different weighting

methods agreed most on the ranking of countries with a low road safety ranking. Moreover, of the five methods, the data envelopment analysis method resulted in a ranking which best approaches the countries' ranking based on the personal safety.

Both studies have clearly demonstrated the possibilities for creating composite road safety indices. However, they both considered a relatively small number of basic indicators, for some of which the quality of the data for the quantitative measures selected can be questioned. At the same time, the limitations of basic indicators used in these analyses were probably caused by the lack of real data on other, theoretically more suitable indicators.

In the current project, we aim to create and explore a comprehensive composite road safety index, based on the recent concepts of the road safety domain developed by the SUNflower (Wegman et al., 2005) and SafetyNet (Hakkert et al., 2007) projects. The types of benchmarking discussed in the literature will be considered, and data on the European countries that were collected in the SafetyNet project and which are available from international databases, will be used.

The SUNflower approach described the road safety domain as a pyramid consisting of several layers, from bottom to top: safety measures and programmes (as the road safety policy performance); safety performance indicators (as intermediate outcomes); the numbers of accident fatalities/injuries (as the final outcomes) and the social costs of accidents/injuries at the very top. An additional 'Structure and culture' layer has been added at the bottom of the pyramid to include the background conditions of the system or the policy context (Koornstra et al., 2002).

The reason for the development of safety performance indicators (SPIs) is the assumption that accidents and injuries are only the tip of the iceberg, because they occur as the 'worst case' result of unsafe operational conditions in the road traffic system. At the same time, those who are responsible for road safety need to take into account as many factors influencing safety as possible or, at least, those factors that they are able to affect or control. Hence, additional safety performance indicators (besides accident/ injury numbers) are required to provide a means for monitoring the effectiveness of the safety actions that are taken. Safety performance indicators can be seen as measures that are causally related to accidents or injuries and are used in addition to the figures about accidents or injuries, in order to indicate safety performance or understand the processes that lead to accidents (ETSC, 2001).

The SafetyNet project (Hakkert et al., 2007) provided a further methodological basis for the SPIs' development. A precondition in the development of SPIs was that they should be able to reflect unsafe operational conditions of the road traffic system and should, therefore, be more general than the direct outputs of specific safety interventions. Based on the potential of different road safety domains for increasing road safety as well as on the experiences and data available, seven problem areas were designated as central to road safety activities in Europe and were selected for the development of SPIs. They are:

- Alcohol and drug-use
- Speeds
- Protective systems
- Daytime running lights (DRL)
- Vehicles (passive safety)

- Roads
- Trauma management

According to Hakkert et al. (2007), SPIs that are developed for a certain safety domain should reflect the factors contributing to road accidents/injuries and characterize the scope of the problem identified. The development of SPIs begins with a definition of the problem (i.e. the operational conditions of the road traffic system which are unsafe and result in accidents/fatalities as the 'worst case') and continues with the conversion of this information into measurable variables. Using the data provided by the national representatives of the 27 EU Member States plus Norway and Switzerland, SPIs were developed and country comparisons were performed – see Vis & Van Gent (2007).

3.1.   Basic indicators

This study sets out to develop a composite road safety performance index for benchmarking purposes, which combines all layers of the road safety pyramid. In Section 2.2 three types of indicators were defined:
1. Road safety performance indicators (quality of road safety);
2. Policy performance indicators (quality of road safety policies);
3. Implementation performance indicators (quality of implementation of road safety policy).

We still have to develop sound *Implementation performance indicators*, in which we would like to use the distinction as indicated by Bliss & Breen (to be published): institutional management functions and interventions. This was described in Chapter 2, and we recommend to develop these indicators and to collect the necessary data.

For *Policy performance indicators* we developed a set of five indicators (A1-A5). In *Road safety performance indicators* we made a distinction between final outcome (B1-B7) and intermediate outcome (C1-C7).

A fourth group of indicators (D) was added trying to present some background variables for each country, as a first attempt to identify components of the lowest level of the pyramid: *Structure and culture* (D1-D2).

To develop a composite index, basic indicators should first be defined, for each layer of the pyramid that needs to be considered.

In the present context, the benchmarking of road safety policies (the A-group of indicators) is described in terms of the quality of national road safety plans. Five components are included and analysed:

A1   Safety targets – the availability and ambition of quantitative national safety targets;
A2   Selection of interventions – whether a sound analysis preceded the development of the national safety programme;
A3   Economic evaluation – whether a sound economic evaluation preceded the design of the national safety programme;
A4   Monitoring – whether the national safety programme is systematically monitored;
A5   Stakeholders – who is responsible for the programme's performance.

The values (categories) for each indicator are presented in Table 3.1. When a national road safety policy is characterized (safety measures and programmes in the pyramid), for each indicator one of the categories is selected. The values selected for each indicator (a, b, c or d) are based on the national road safety programme, other background papers and available follow-up reports, including those prepared by the ETSC, OECD or other international working groups.

Indicators	Possible values
A1 Safety targets	a. Ambitious b. Available but not ambitious c. Not available
A2 Selection of interventions	a. Sound analysis and diagnosis of road safety problems preceded the programme's development, and evidence-based interventions were selected b. Some analysis was performed, and evidence-based interventions were selected c. Detailed analysis of road safety problems was performed, however, the selection of interventions was arbitrary d. The diagnosis of road safety problems was poor and the selection of interventions was arbitrary
A3 Economic evaluation	a. Sound economic evaluation preceded the programme's composition b. Some economic evaluation was performed c. Economic evaluation was not performed
A4 Monitoring the programme's performance	a. Systematic monitoring takes place b. A need for monitoring is stated but monitoring reports are not found c. No evidence of monitoring activities
A5 Programme's stakeholders	a. Commitment was stated on the governmental level, and the programme is supervised by a central authority which is empowered to coordinate the activities of all other bodies b. No commitment from the government, however, a central authority was commissioned for the programme's performance c. A number of authorities share the responsibility for the programme's performance d. No authority has a clear responsibility for the programme's performance

Table 3.1. *Definition of basic indicators for the A-group: characteristics of national safety policies (Policy performance indicators)*.

The benchmarking of road safety performance, the B-group of indicators, deals with the final outcomes of the system, i.e. the numbers of road crash fatalities and injuries, which should be presented in a form suitable for comparisons. The present study focuses on four issues: personal safety, traffic safety (rates and risks), the scope of traffic injury, and the scope of the problem of vulnerable road users. For each issue one or several indicators are defined, see Table 3.2.

Issues considered	Indicators defined*
Personal safety	B1 Fatalities per million inhabitants
Traffic safety rate Traffic safety risk	B2 Fatalities per million passenger cars B3 Fatalities per 10 billion passenger-km travelled
Scope of traffic injury	B4 Injury accidents per fatality**
Scope of the problem of vulnerable road users	B5 Share of pedestrian fatalities out of the total fatalities B6 Share of bicyclist fatalities out of the total fatalities B7 Share of motorcyclist fatalities out of the total fatalities

*Note: Obviously, various definitions are possible. B2 can for instance be defined per total vehicle fleet instead of passenger cars, B3 per vehicle kilometre travelled instead of passenger kilometre, etc. The selection was based on the estimates available to the EU Member States.
** Considering the reporting problems and definition's differences among the countries, a preferable indicator would be the 'number of hospitalized injuries per 1 fatality', which is unavailable as yet.

Table 3.2. *Definition of basic indicators for the B-group: Road safety performance indicator, final outcomes*.

The second group of Road safety performance indicators, the C-group of indicators, captures the intermediate outcomes, containing the safety performance indicators which characterize the safety quality of the road traffic system. Having analysed the data availability in the seven pre-defined SPI areas (Vis & Van Gent, 2007) as well as the summaries on safety performance indicators (PIN Flashes) recently published by the ETSC, it was decided to limit the present project to only those safety areas for which the estimates are available for a significant number of the Member States. The three remaining safety areas are: alcohol-impaired driving, use of protective systems in cars, and vehicles (passive safety) which includes the crashworthiness of the passenger car fleet and the vehicle fleet composition. For each area one or two indicators have been defined, see Table 3.3.

Safety areas considered	Indicators defined
Alcohol-impaired driving	C1 Share of total for fatalities in drink-driving accidents
Use of protective systems in cars	C2 Daytime wearing rates of seatbelts in the front seats (aggregated for driver and front passenger) C3 Daytime wearing rates of seatbelts in the rear seats

Vehicles:
    Crashworthiness of the passenger car fleet
 	
    Vehicle fleet composition
	C4 Average EuroNCAP score of passenger car fleet
	C5 Median age of the passenger car fleet
	
	C6 Share of motorcycles in the vehicle fleet
	C7 Share of heavy goods vehicles (HGV) in the vehicle fleet

Table 3.3. *Definition of basic indicators for the C-group: Road safety performance indicator, intermediate outcomes, SPIs*.

In addition, two background indicators were added (D-group) to characterize the motorization level and the population density of the country, see Table 3.4.

Characteristic considered	Indicators defined
Motorization level	D1 Number of passenger cars per 1000 inhabitants
Population density	D2 Population per 1 km^2 of country's territory

Table 3.4. *Definition of basic indicators for D-group: background characteristics*.

The choice of indicators and their definitions have a preliminary character. The choice of indicators used was also influenced by the immediate availability of data. The aim of this chapter is to demonstrate along which lines a composite index can be designed.

3.2. Data collection

In total, 21 basic indicators were defined for consideration. The estimates of the indicators and/or data for their calculation were taken from a wide range of international databases and recent publications of international working groups, including:

For group A – OECD/ITF (2008), OECD/ECMT (2008);

For group B – EC (2007), ERSO (2008);

For C1 – ETSC (2007a); for C2, C3 - ETSC (2007b); for C4 - Vis & Van Gent (2007); for C5 - UNECE (2008); for C6, C7 - EC (2007) and OECD country reports (2008).

Table 3.5 contains the basic indicators which were estimated for 27 countries: 25 Member States of the European Union plus Norway and Switzerland. The majority of indicators are not yet available for the new Member States Bulgaria and Romania.

3.3. Method of analysis

The purpose of this analysis is to create a composite road safety performance index and to explore the similarities in basic indicators. The composite index will enable ranking countries in accordance with their safety performance or, at least, to define several groups of countries with different levels of safety performance.

As can be seen in Table 3.5, only six countries have values for the whole set of basic indicators A to D. Therefore, prior to the analysis, missing *data imputations* should be performed. A description of the imputation method and the final data set, with initial and imputed values of basic indicators, are presented in Appendix 1.

The initial examination revealed that the effect of the Malta data was very strong and that it should be considered an outlier. Hence, Malta was excluded from the composite index' building process. However, using the factors developed, the scores - combined indices - for Malta can still be calculated, and, consequently, these appear in the final plots.

	Code	B1 Fatalities per mln inhabitants-2006	B2 Fatalities per million passenger cars-2006	B3 Fatalities per 10 billion pkm-2006	B4 Injury Accidents per fatalities-2006	B5 Pedestrian fatalities as % of total-2006	B6 Bicyclist fatalities as % of total-2006	B7 Motorcyclist + moped fatalities as % of total-2006	D1 Number of passenger cars per 1000 inhabitants, 2006	D2 Population per 1 km² of area-2006	C1 Share of drink-driving accidents-2005	C2 Wearing rate-Front seats aggregated-2005	C3 Wearing rate-Rear seats-2005	C4 Average EuroNCAP score-2003	C5 Median age of passenger cars-2003	C6 % Motorcycles in fleet-2006	C7 % HGV in fleet-2006	A1 Safety targets	A2 Selection of interventions	A3 Economic evaluation	A4 Monitoring	A5 Stake-holders
Austria	AT	88	175	100	54.6	15.1%	6.6%	18.4%	507	98.9	6.0%	83	52	n/a	7.5	12.4%	7.0%	a	c	b	b	a
Belgium	BE	101	216	96	38.5	11.4%	8.6%	15.5%	470	347.0	4.4%	71	n/a	21.3	6.7	6.0%	11.1%	b	b	b	b	b
Switzerland	CH	50	95	n/a	58.1	20.5%	9.5%	21.6%	519	181.8	19.3%	82	53	n/a	7.3	12.5%	6.4%	a	a	a	b	a
Cyprus	CY	111	236	167	31.1	22.1%	2.3%	29.1%	479	83.8	22.5%	80	n/a	n/a	9.3	7.6%	21.7%	n/a	n/a	n/a	n/a	n/a
Czech Republic	CZ	104	264	146	20.8	19.0%	10.3%	10.9%	399	130.4	5.5%	72	13	20.7	11	15.1%	9.0%	b	c	b	b	b
Germany	DE	62	110	57	64.4	14.0%	9.5%	17.7%	566	230.6	5.1%	96	89	20.1	6	10.5%	5.1%	a	b	b	a	b
Denmark	DK	56	154	56	17.7	19.6%	10.1%	14.7%	371	126.4	23.0%	85	63	n/a	7.3	6.7%	18.7%	a	b	b	b	b
Estonia	EE	152	389	175	12.7	27.2%	4.1%	4.1%	413	29.7	28.4%	74	30	n/a	12.7	1.9%	14.0%	b	c	b	b	a
Greece	EL	149	375	174	9.8	16.1%	1.3%	30.0%	407	84.6	10.7%	n/a	n/a	20.7	8	17.2%	17.4%	a	b	b	b	b
Spain	ES	93	201	117	24.3	15.3%	1.8%	17.6%	464	87.9	n/a	74	51	n/a	7.6	14.6%	16.7%	a	c	b	b	b
Finland	FI	64	136	53	20.1	11.9%	11.3%	9.5%	475	15.6	23.5%	88	78	n/a	9.1	10.5%	11.6%	a	b	b	b	b
France	FR	77	153	64	17.1	11.4%	3.8%	23.5%	504	113.1	28.8%	97	70	n/a	8.3	6.4%	13.7%	a	a	b	a	a
Hungary	HU	129	446	271	16.1	22.7%	11.7%	10.1%	293	108.2	8.8%	67	34	20.6	8	3.7%	12.5%	a	c	b	b	b
Ireland	IE	86	211	130	18.6	19.0%	3.0%	16.3%	418	61.4	n/a	86	46	n/a	5.1	1.6%	14.7%	b	b	b	a	b
Italy	IT	96	162	74	42.0	12.6%	4.8%	23.8%	597	196.3	n/a	71	n/a	n/a	7.9	20.5%	8.7%	c	d	c	c	d
Lithuania	LT	224	498	191	8.9	34.0%	n/a	n/a	470	51.9	11.8%	60	n/a	n/a	14.5	1.4%	7.7%	b	c	b	b	b
Luxembourg	LU	76	116	54	21.2	9.7%	1.6%	0.0%	661	183.1	0.0%	80	60	n/a	4.4	10.0%	8.0%	n/a	n/a	n/a	n/a	n/a
Latvia	LV	178	520	256	10.6	38.0%	6.0%	4.0%	360	35.3	21.7%	77	n/a	21.3	10	3.7%	12.2%	b	c	b	b	b
Malta	MT	25	46	49	84.1	35.3%	0.0%	17.6%	535	1360.0	n/a	96	28	18.6	9	4.4%	16.4%	a	c	b	b	b
Netherlands	NL	45	102	48	33.6	9.4%	18.3%	18.4%	442	394.2	15.3%	90	64	20.2	6	6.5%	11.3%	a	a	b	a	a
Norway	NO	52	116	n/a	32.7	14.5%	3.3%	15.3%	445	14.4	n/a	91	83	21	8	9.4%	17.0%	b	a	a	b	b
Poland	PL	137	408	235	8.9	32.3%	11.1%	3.9%	351	121.9	9.8%	78	45	n/a	11.8	4.7%	14.4%	b	c	b	b	b
Portugal	PT	92	228	131	36.8	16.0%	4.1%	24.1%	405	115.3	n/a	86	n/a	n/a	9.7	9.0%	21.3%	b	c	b	b	b
Sweden	SE	49	107	45	40.7	12.4%	5.8%	15.7%	461	20.3	34.0%	92	73	22.6	7	9.6%	9.2%	a	a	a	a	a
Slovenia	SI	131	270	113	44.4	13.7%	5.3%	20.5%	488	99.0	32.2%	87	30	n/a	5.0	4.8%	6.3%	b	c	b	b	b
Slovakia	SK	107	439	215	13.8	9.3%	5.5%	7.4%	247	110.5	12.0%	n/a	n/a	n/a	n/a	3.7%	11.9%	b	c	b	b	b
Great Britain	UK	54	116	48	58.9	21.0%	4.6%	17.5%	471	249.3	17.5%	90	84	20.6	5	3.7%	10.7%	a	b	b	a	a

Table 3.5. *Basic indicators estimated for 27 European countries (n/a = not available).*

To combine the basic indicators into a composite one, weights based on statistical models are applied. We examined both Principal Component Analysis (PCA) and Common Factor Analysis (FA) weighting (Tabachnick & Fidell, 2006). Both methods group collinear indices to form a composite index that captures as much common information among sub-indicators as possible. The idea under PCA/FA is to account for the highest possible variation in the set of indicators using the smallest possible number of factors (Nardo et al., 2005). If there is no correlation between indicators these methods can not be used to obtain the weights.

The first step in the FA is to check the correlation structure of the data, and the second step is to identify a certain number of latent factors, smaller than the number of indicators, representing the data. In the PCA, we retain those factors that account for the largest amount of variance.

We used Kaiser-Meyer-Olkin (KMO) statistics to predict and demonstrate if the data are likely to factor well, based on their correlations and partial correlations. There is a KMO statistic for each individual variable, and an overall KMO statistic. It is customary that the KMO overall should be 0.60 or higher, to proceed with the factor analysis. If this condition is not satisfied, one should drop the indicator variables with the lowest individual KMO statistic values, until the KMO overall rises above 0.60.

In both methods (PCA/FA), the combination of factors into a composite index is done by their weighted sum, where the weights are taken in accordance with the variance explained by each factor. At this point, different estimation procedures are possible. For both PCA and FA, we used orthogonal rotation[1] of factors and, hence, 'the variance explained by each factor' was applied for estimating the weights.

The Principal Component Analysis and the Common Factor Analysis were used because both PCA and FA are suitable procedures for analysis. Since it is not clear beforehand which one is the most suitable, five trials of creating a composite index were performed. The reasons why we decided to make five trials are explained in more detail later in this chapter. The five types of analysis are:

1) **PCA-all** – a PCA in which all the variables (basic indicators) were analysed together.
2) **PCA-groups** – a PCA in which each group of basic indicators (A, B, C, D) was first analysed separately to create the group factors. The group factors were then analysed together to provide the final composite index.
3) **FA-4Factors** – a common factor analysis with all variables considered and four factors' solution accepted.
4) **FA-2Factors-noC4** a common factor analysis with two factors' solution, where C4 (average EuroNCAP score) is excluded from the analysis, due to statistical reasons.
5) **FA-2factors** – a common factor analysis with two factors' solution, where C4 is retained in the analysis.

Note: in trials 3-5, variables B6 (share of bicyclist fatalities), B7 (share of motorcyclist fatalities), C7 (percentage of HGV in the vehicle fleet) were excluded from creating a combined indicator due to statistical reasons (low values of the KMO statistics).

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[1] VARIMAX: change of coordinates in PCA that maximize the sum of the variance of the loading vectors

Once the factors are created, the following procedure is applied to calculate a composite index, for each country:

a. Standardize the data, for each country, i.e. subtract mean and divide by standard deviation, for each variable.
b. Multiply these standardized variables by their respective standardized scoring coefficients.
c. Sum up these products over all the relevant variables. The sum is the value of the new variable Factor 1.
d. Repeat steps a-c for Factor 2, Factor 3, etc (if relevant). This creates the data set scores.
e. The composite index is a weighted sum of the factors.

The results of each of the five trials made it possible to produce a combined safety index (called WF – weighted factor or weighted index) for each country, as well as for the clusters of countries with similar values of the combined index. In addition, the development of a composite index provided an insight into similarities and dissimilarities in the behaviour of basic indicators (when the indicators' involvement in building the factors is considered).

Detailed results of each of the five analyses are presented in Appendix 2. In addition, Appendices 3 and 4 present the tools that were accordingly produced by the PCA and FA analyses for the estimation of country scores. Section 3.4 gives a brief summary of the findings. Comparisons of the results of the five trials, including considerations of their meanings and practical implications for the development of a composite road safety performance index, are further discussed in Section 3.5.

3.4.   Summary of findings

As mentioned earlier, the statistical methods applied (PCA/FA) group together basic indicators that are collinear to form a composite index, which should capture as much of common information among basic indicators as possible. The idea under PCA/FA is to account for the highest possible variation in the set of indicators using the smallest possible number of factors. As a result of the analysis, a number of factors are fitted to the data, where each factor presents a composition of basic indicators. Considering the factors created one can see which variables (basic indicators) contribute more to each one of the factors. Moreover, considering the 'safety-desirable' behaviour of basic indicators and their coefficients when the factor values are estimated, one can state whether higher or lower values of each factor are associated with better safety performance (see Appendix 2).

1) PCA-all

In the PCA-all analysis, five factors were fitted to the data. Factor 1 mainly reflects the road safety performance indicators, car fleet's age and seatbelt use. Factor 2 mainly reflects the policy performance indicators but also includes a negative correlation with C1 (share of drink-driving accidents). Factor 3 reflects the share of bicyclist fatalities, EuroNCAP scores for cars and population density. Factor 4 reflects the share of motorcycles in the fleet and the share of motorcyclist fatalities. And Factor 5 reflects the share of HGVs in the fleet, the number of injury accidents per fatality and the motorization level of a country.

When separate indicators are plotted against the factors, similarities in their behaviour can be recognized. This way, similar behaviour was noted for variable groups such as: B1-B2-B3 (number of fatalities per head of population, vehicles, passenger kilometres travelled), A1-A4 (safety targets, monitoring the programme performance), A2-A3-A5 (other characteristics of safety programmes) and C2-C3 (safety belt wearing rates in front and rear seats).

Furthermore, the factors built are weighted together to provide a composite index (weighted index – WF). The weighted index can be applied to countries' ranking. Furthermore, using the WF and a WARD clustering procedure, a classification tree can be produced, i.e. the countries can be classified into similar groups. Inside the group the WF values are close, but there are distances between the groups (The classification trees produced by the WARD procedure are presented in Appendix 2). Using a classification tree, various country groups (clusters) can be defined, depending on the level of 'distances' between the countries in the same group, which is selected as a threshold.

For example, Figure 3.1 presents the countries' subdivision into six clusters based on the WF values. The country positions in Figure 3.1 are plotted using the WF values and Factor 1 values. According to this classification, the countries with the best safety level are Sweden, Great Britain and France; the second group includes Luxembourg, Norway, Germany and Ireland; the third group consists of Slovenia, Finland and the Netherlands; the fourth group of Switzerland, Austria, Denmark and Estonia; the fifth group of Cyprus, Spain, Belgium, Slovakia, Portugal, Malta and Latvia; and the sixth group consists of Lithuania, Greece, Hungary, Poland, Czech Republic and Italy.
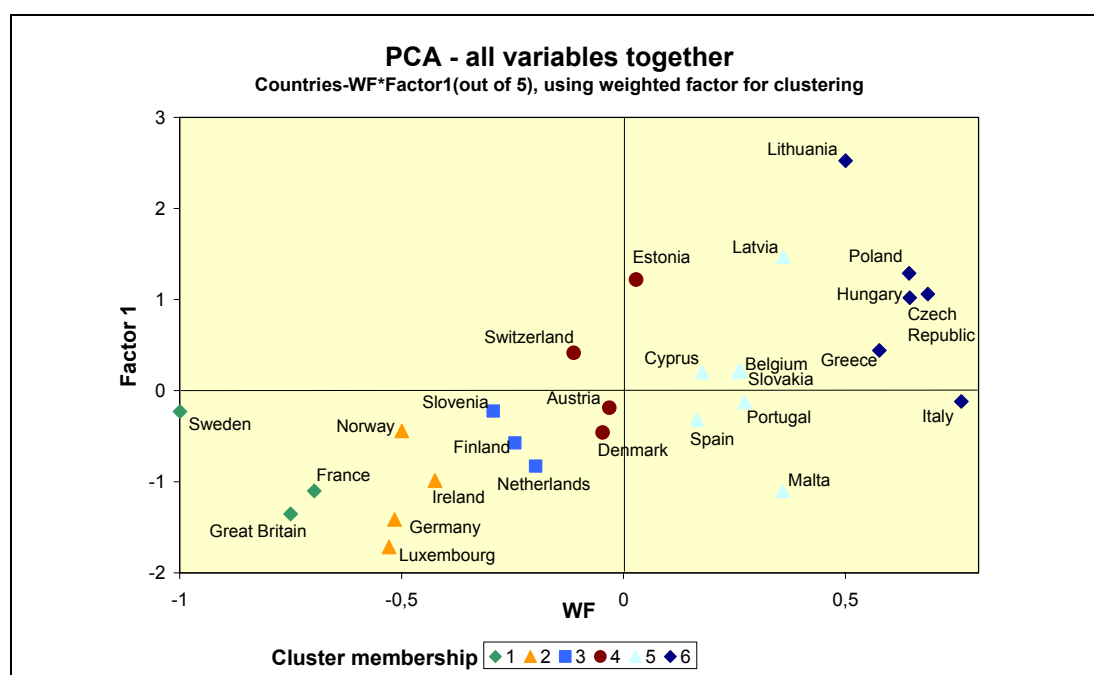

Figure 3.1. *Countries plotted using the WF values and Factor 1 values (PCA-all analysis)*.

2) PCA-groups

The first step in the *PCA-groups* analysis was to fit one combined factor for each group of indicators separately, namely for the A, B, C and D groups of basic indicators. The four combined factors obtained are then subjected to another PCA, where the final composite index is generated.

For the A-group indicators (policy performance), one factor was fitted to all basic (A1-A5) indicators in the first step of this analysis.

For the B-group indicators (road safety performance – final outcome), two factors were chosen where variables B1-B2-B3-B4-B5 (number of fatalities per head of population, vehicles, passenger kilometres travelled, injury accidents per fatality, and share of pedestrian fatalities) contribute to Factor 1 and B6-B7 (shares of bicyclist and motorcyclist fatalities, accordingly) contribute to Factor 2. The results demonstrated similarities in the behaviour of B1-B2-B3-B5 indicators and very different behaviours of B4, B6, B7.

Exploring the C-group indicators (road safety performance – intermediate outcome), low communalities with other indicators were observed for C6, C7 indicators (the percentages of motorcycles and HGV in the vehicle fleet, respectively), which, consequently, were excluded from the analysis. For the retained indicators, two factors were chosen, where variables C2-C3 (seatbelt wearing rates) and C5 (median age of passenger cars) contributed mostly to Factor 1, while C1 (share of drink-driving accidents) and C4 (average EuroNCAP score) contributed mostly to Factor 2.

For the D-group indicators (background characteristics), one factor was chosen, which reflected both motorization level and population density.

In the second step of this analysis two factors were chosen, where the combined factors of A- and C-groups composed Factor 1, and the combined factors of B- and D-groups composed Factor 2. Plotting the positions of the initial group factors and the positions of the countries on the dimensions of these two combined factors clearly showed a lack of similarity in the behaviour of the group factors. For the countries one general 'cloud' was noted, with several outsiders (e.g. Italy, Malta), see Figure 3.2. Inside the 'cloud', the countries with better safety-related positions are: France, Great Britain, Sweden, Switzerland, the Netherlands, Germany and Norway.
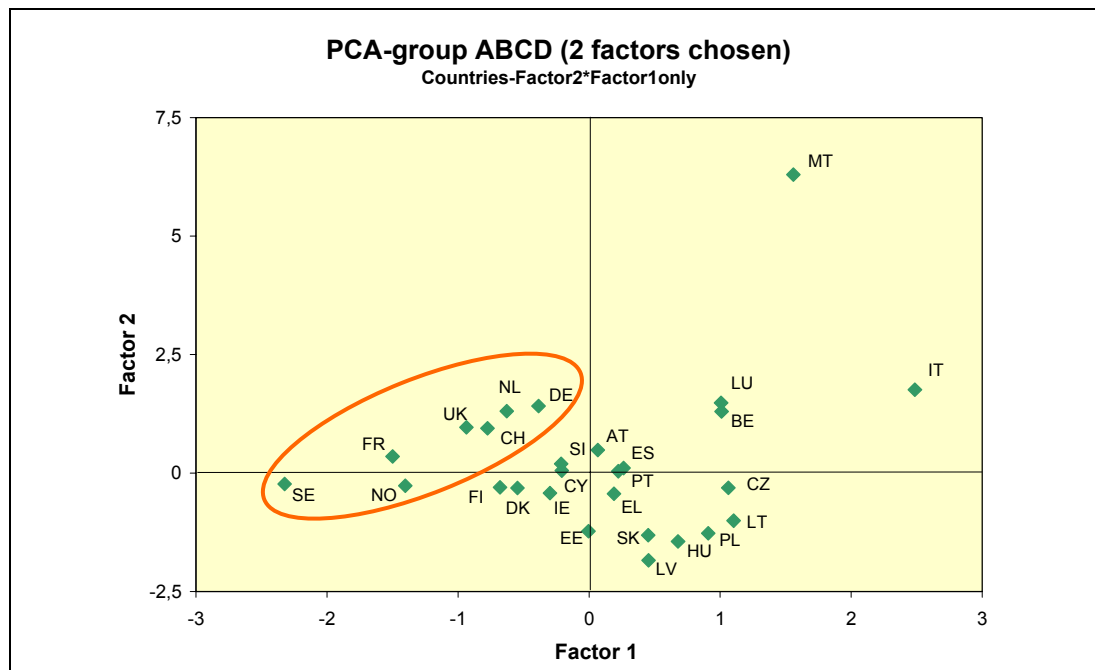
Figure 3.2. *Countries' positions on the dimensions of the combined factors (combining FA, FB, FC, and FD).*

The three trials of creating a composite index using FA considered 18 variables (basic indicators), where B6 (share of bicyclist fatalities), B7 (share of motorcyclist fatalities) and C7 (percentage of HGV in fleet) were excluded due to their low values in the KMO statistics.

3) FA with four factors

In the *FA with four factors* the basic indicators B1-B3 (number of fatalities per head of population, vehicles, passenger kilometres travelled), B5 (share of pedestrian fatalities), C5 (median age of passenger cars), C2-C3 (safety belt wearing rates in front and rear seats), B4 (injury accidents per fatality), and D1 (number of passenger cars per head of population) provided a major contribution to Factor 1, whereas Factor 2 reflected mostly the behaviour of policy performance indicators A1, A2, A4, A5 and C6 (percentage of motorcycles in vehicle fleet). Factor 3 consisted of the C4 variable only (average EuroNCAP score), whereas Factor 4 reflected mostly the behaviour of D2 (population density), A3 (quality of economic basis of safety programmes) and C1 (share of drink-driving accidents).

Based on the combined indicator (WF values) and Factor 1 values obtained in this analysis, the countries were subdivided into five groups (Figure 3.3). The countries with the best safety level (first group) are Sweden, Norway, Switzerland, Great Britain, France, the Netherlands and Germany; the second group includes Finland, Denmark, Malta, Austria, Luxembourg and Ireland; the third group consists of Cyprus, Slovenia, Spain, Portugal and Belgium; the fourth group of Greece, Czech Republic and Estonia; and the fifth group consists of Slovakia, Italy, Poland, Hungary, Latvia and Lithuania.

Malta, Luxembourg and, especially, Italy, are 'outsiders' of their groups, having much lower values on Factor 1 in comparison with the countries with a similar level of the WF values.
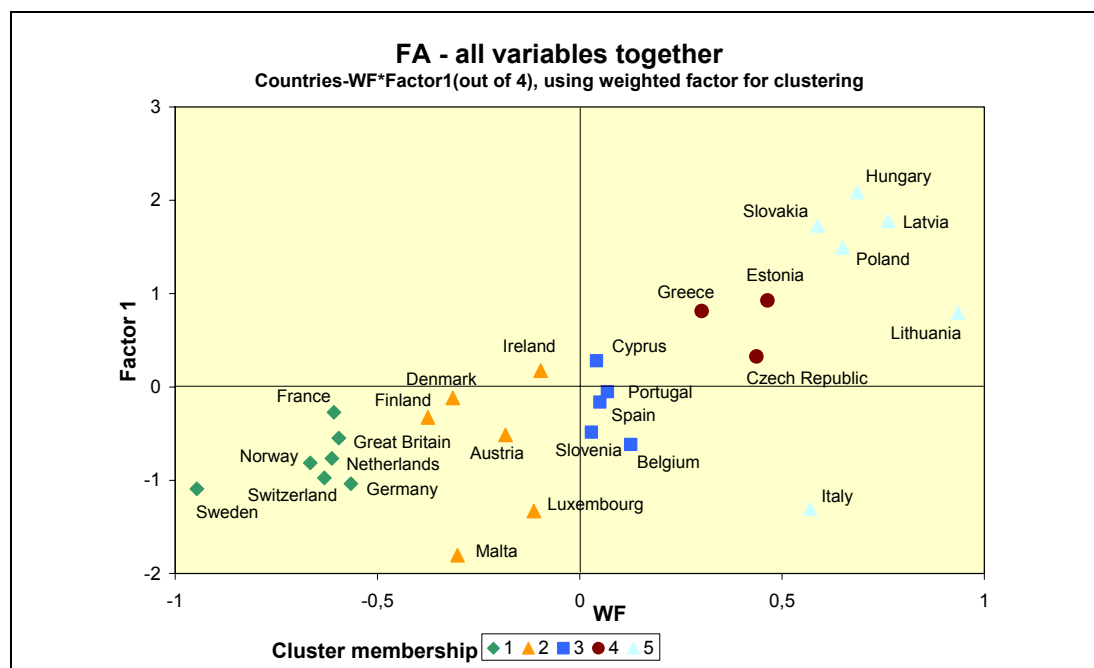
Figure 3.3. *Countries plotted using the WF values and Factor 1 values (FA with four factors' solution).*

4-5) FA with two factors

In the *FA with two factors* two alternatives were considered: including and excluding the C4 indicator (average EuroNCAP score). This is because within the FA with four factors, C4 variable's behaviour was nearly identical to one of the factors, where in such cases (an additional factor consisting of only one variable) it is customary to exclude such a variable from the analysis. The exclusion of C4 enabled fitting two factors to the rest of the variables (indicators), but with a significantly lower value of the explained variance than in the four factors' analysis (71% versus 84%). A further consideration revealed that keeping C4 inside the set and limiting the results to two factors fitted yielded a comparable value of the explained variance (about 69%). Therefore, we decided to present and compare the results of both trials: including and excluding the C4 indicator.

In both trials of the 'FA with two factors' (with C4, average EuroNCAP score, excluded or included), Factor 1 reflects mostly the behaviour of B1-B5 indicators ('safety product'), D1-D2 ('background characteristics'), C5 (median age of passenger cars), C6 (percentage of motorcycles in vehicle fleet) and C4 (if included in the analysis); whereas Factor 2 reflects mostly the behaviour of policy performance indicators A1-A5, C2-C3 (safety belt use) and C1 (share of drink-driving accidents) indicators.

In both cases, similar behaviour was observed for basic indicators: B1-B2-B3-B5-C5 (road safety performance – final outcome - and median age of cars), A1-A2-A3-A4-A5 (policy performance), C2-C3 (use of seatbelts) and D1-D2 (background charac-

teristics). Moreover, C4 indicator is relatively close to the group of 'safety outcomes' plus 'median age of cars', whereas C1 (share of drink-driving accidents) behaves different from all the other indicators. Besides, B4 (injury accidents per fatality) and C6 (percentage of motorcycles in fleet) are relatively close to the D1-D2-group.

In both cases of the 'FA with two factors', the groups of countries with similar values of combined indicators (WF values) were as follows (see Figure 3.4 with the results including C4). The countries with the best safety level (first group) are Malta, the Netherlands, Sweden, Great Britain, Germany, Switzerland, France and Norway; the second group includes Finland, Denmark, Austria, Luxembourg and Ireland; the third group consists of Spain, Belgium, Portugal, Cyprus and Slovenia; the fourth group of Greece, Czech Republic, Italy, Slovakia, Hungary, Estonia, and Poland; and the fifth group consists of Latvia and Lithuania.

Similar to the results of the 'FA with four factors', Malta, Italy and Luxembourg behave as 'outsiders' of their groups.

FA - all variables together
Countries-WF*Factor1(out of 2), using weighted factor for clustering
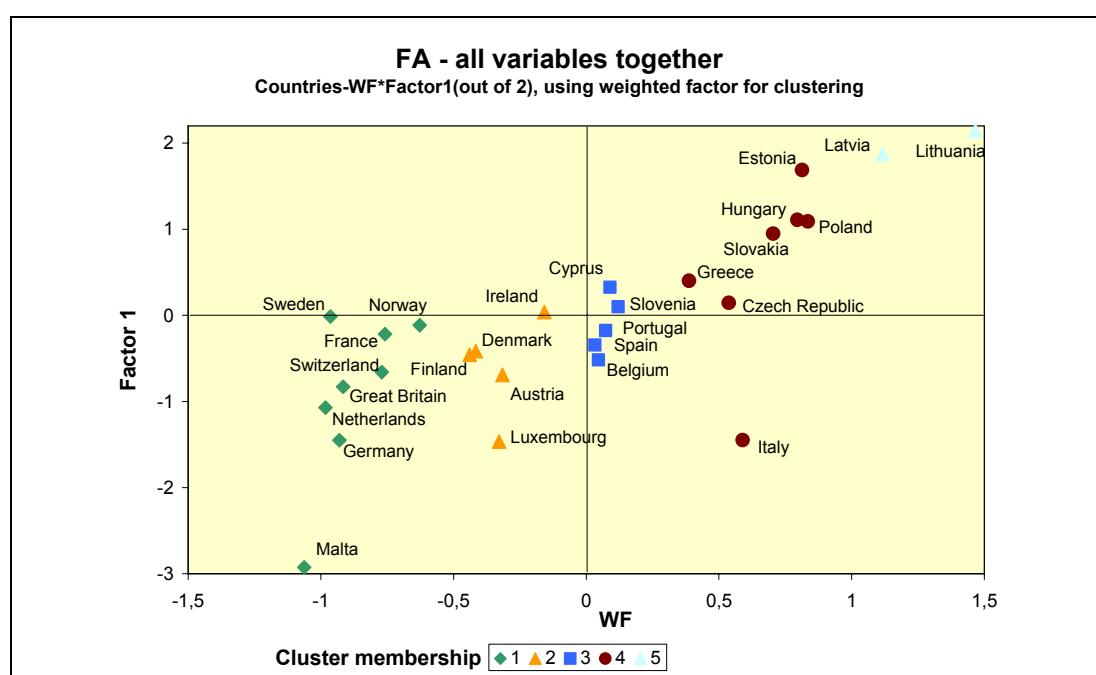
Figure 3.4. *Countries plotted using the WF values and Factor 1 values (FA with two factors' solution, C4 included)*.

3.5.   Discussion and conclusions

In this chapter, we examined Principal Component Analysis (PCA) and Common Factor Analysis (FA) weighting to create a composite index, based on four groups (A, B, C and D) of basic indicators. The groups of basic indicators that were considered refer to the three types of benchmarking we use: road safety performance (final and intermediate outcome), policy performance indicators and background indicators (motorization level, population density). The analysis used the data collected for 27 European countries.

Five trials of creating a composite index were performed, where each trial produced a composite road safety indicator for each country, and clusters/groups of countries

with similar values of the combined index. The composite index enables us to rank the countries in accordance with their safety performance.

The composite indices and clusters/groups of the countries are further compared among the trials.

3.5.1. Comparisons of countries' rankings

First, the weighted safety indices obtained with each analysis were considered together (Figure 3.5), where the basic countries' ranking is built using their final scores from the PCA-all analysis. It can be seen that:
- The results of the 'PCA-groups' analysis are very different from all other results.
- The results of the 'FA-2Factors' and the 'FA-2Factors-noC4' analyses are very close.
- In general, there is a certain similarity between the results of 'PCA-all', 'FA-4Factors', 'FA-2Factors' and 'FA-2Factors-noC4' analyses.

The different character of the results obtained with the 'PCA-groups' method probably stems from the different approach undertaken in this case, where the indicators were initially analysed in the pre-defined groups, not accounting for the inter-group correlations. Such a consideration enables a deeper insight into the behaviour of indicators in each group, in comparison to other analyses, but can provide a different final picture when a combined index is created.
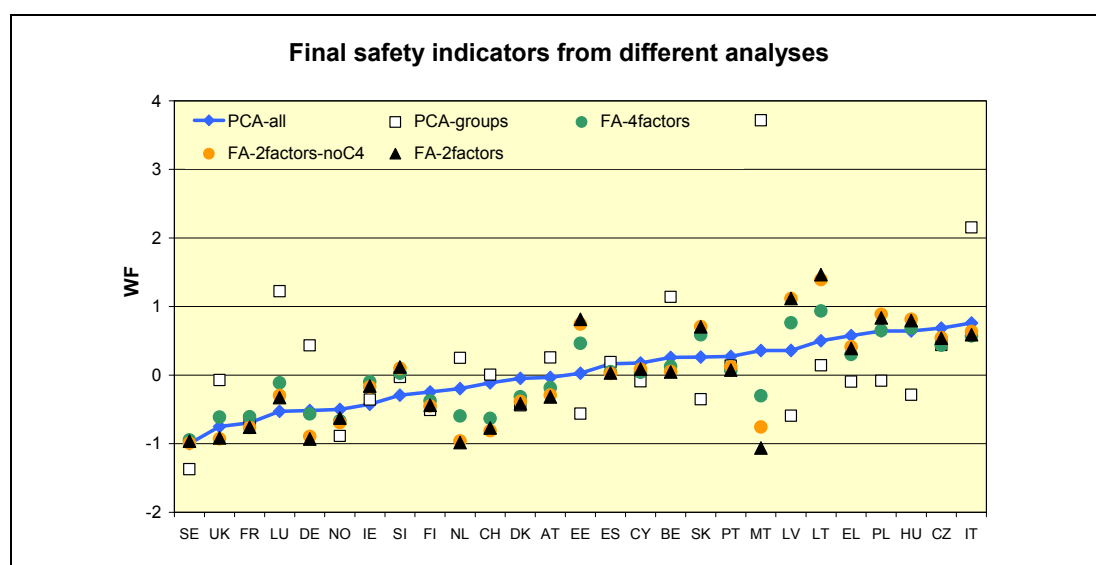
Figure 3.5. *Final safety indicators as a result of five trials*.

The 'PCA-groups' analysis indicated a lack of similarity in the behaviour of group factors. Therefore, it was interesting to compare the results of other analyses with the intermediate results of the 'PCA-groups' analysis, i.e. with the factors built for the A, B, C groups of indicators. Due to scaling reasons, prior to this comparison, we passed from the values of weighted indices to country ranks (where a country with the best combined safety indicator receives rank 1, the next country rank 2 and so on).

Figure 3.6 presents a comparison of country ranks from the PCA-all analysis with the country ranks based on the FA (A-group factor), FB (final B-group factor), FC (final C-group factor) and FC1 (factor 1 from the C-group analysis, which reflects seatbelt wearing rates and median age of passenger cars, only) values. The PCA-all ranks in Figure 3.6 are accompanied by ± 5 rank deviation bars (vertical grey lines). It can be seen that:

- The deviations from the PCA-all ranks are generally wider when the countries are ranked in accordance with FA or FB factors than with factors FC or FC1.
- Consideration of FC1 only instead of FC creates some differences in the countries' ranking.
- We can note a number of countries for which the ranks are consistent across the different considerations. These are: Sweden, Great Britain, France, Germany, Norway, Austria, Spain, Lithuania and Poland;
- The countries with wide deviations in ranks and therefore the most unstable answers as to their safety level are Luxembourg, Slovenia, Malta and Italy.
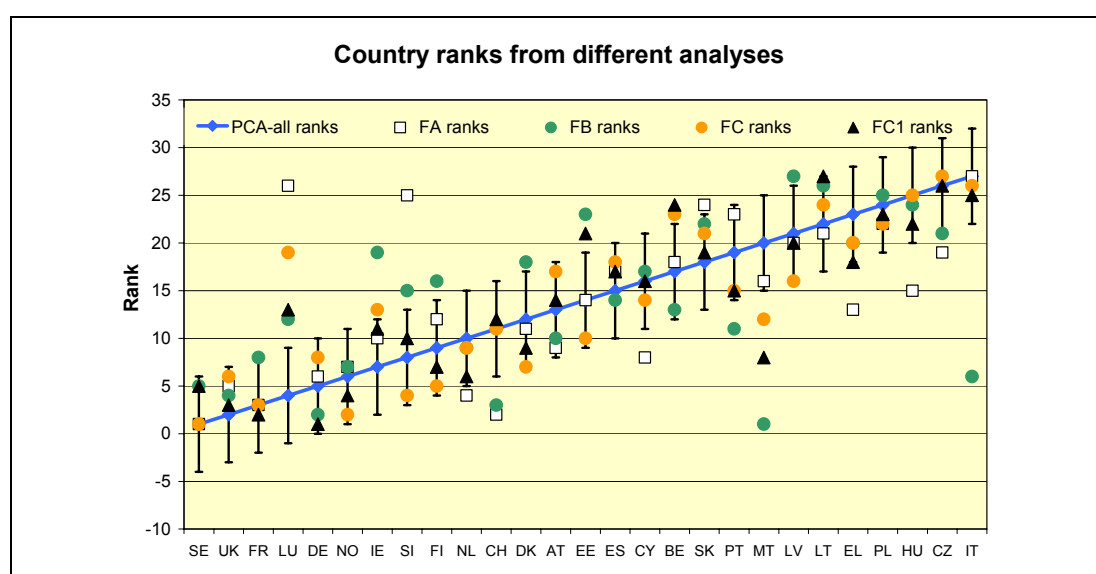
Figure 3.6. *Countries' ranks resulting from the PCA-all analysis and group factors analyses*.

Figure 3.7 presents another comparison of country ranks from the PCA-all analysis and separate factor analyses, where the basic countries' ranking is built using a traditional approach of countries' comparison in terms of fatality rates (per population, vehicles, etc.). Such a comparison was performed, for example, by Hermans et al. (2008), who used the countries' ranking based on personal safety as a basis for judging the results of other rankings. In our case, as a basis for comparisons, we applied a substitute to the traditional approach, i.e. FB1 - factor 1 built in B-group analysis, which reflects five B-indicators together (fatalities per population, vehicles, passenger km-travelled, injury accidents per fatality and share of pedestrian fatalities). The countries' FB1 ranks are compared with PCA-all ranks, FB (final B-group factor) ranks and FC (final C-group factor) ranks. The FB1 ranks in Figure 3.7 are accompanied by ± 5 rank deviation bars (vertical grey lines).

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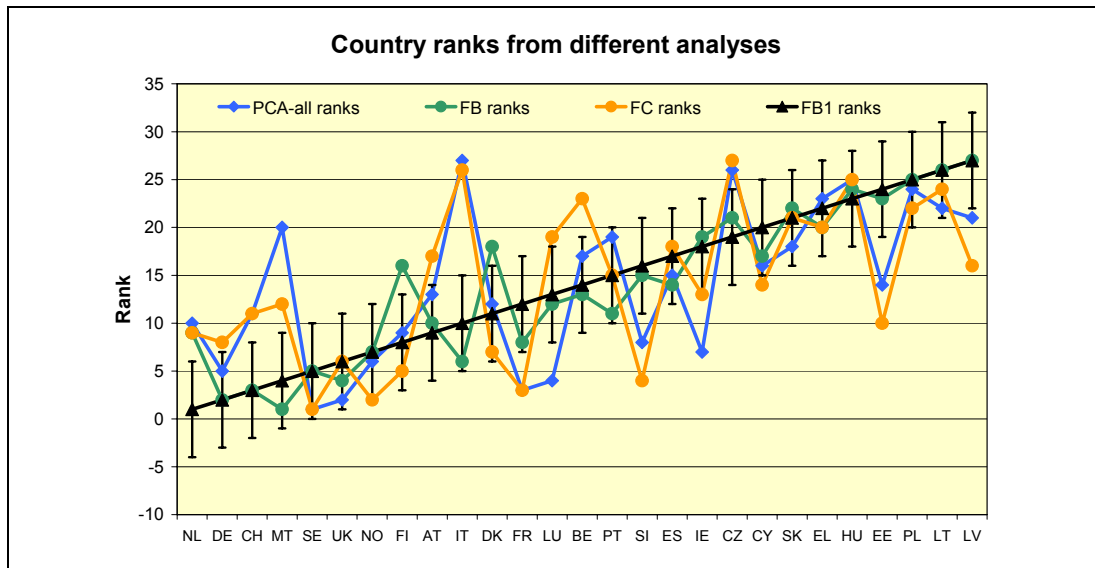
Figure 3.7. *Countries' ranks resulting from the FB1 ranks versus PCA-all, FC and FB ranks*.

It can be seen from Figure 3.7 that:
- For the majority of countries, the total FB ranks are close to the FB1 ranks, which confirms the leading role of FB1 indicators (fatalities per head of population, vehicles, passenger kilometres travelled, injury accidents per fatality, and share of pedestrian fatalities) in countries' estimation by 'safety outcomes'.
- Both PCA-all ranks and FC ranks create deviations from the countries' ranks based on safety outcomes only. The countries with the widest deviations in ranks and therefore with the most unstable answers in this context are Malta and Italy. Essential deviations from the FB1 ranking are also observed for France, Luxembourg, Slovenia, Ireland, Estonia and Latvia.
- At the same time, we can note a number of countries for which the ranks are relatively consistent across the different considerations. These are: Sweden, Great Britain, Norway, Portugal, Spain, Slovakia, Greece, Hungary, Poland and Lithuania.

Finally, to compare the countries' ranks based on the combined indicators, we decided to present the results of four analyses, i.e. PCA-all, FA-4Factors, FA-2Factors, and FA-2Factors-noC4 (where the results of the PCA-groups analysis are left out due to their different nature), see Figure 3.8. As a basic ranking we chose the one that provided the minimum sum of squared deviations from other rankings, i.e. the FA-2Factors-noC4 ranking.

Figure 3.8 shows that:
- Similar to countries' ranking based on the weighted safety indices (see Figure 3.5), the results of FA-4Factors, FA-2Factors and FA-2Factors-noC4 analyses are reasonably close, whereas PCA-all ranks are associated with large deviations.
- Essential differences between all rankings are observed for Malta.
- Relatively large deviations between some rankings are observed for the Netherlands, Switzerland, Norway, Luxembourg, Ireland, Slovenia, the Czech Republic, Italy and Estonia.

Final ranks according to different analyses
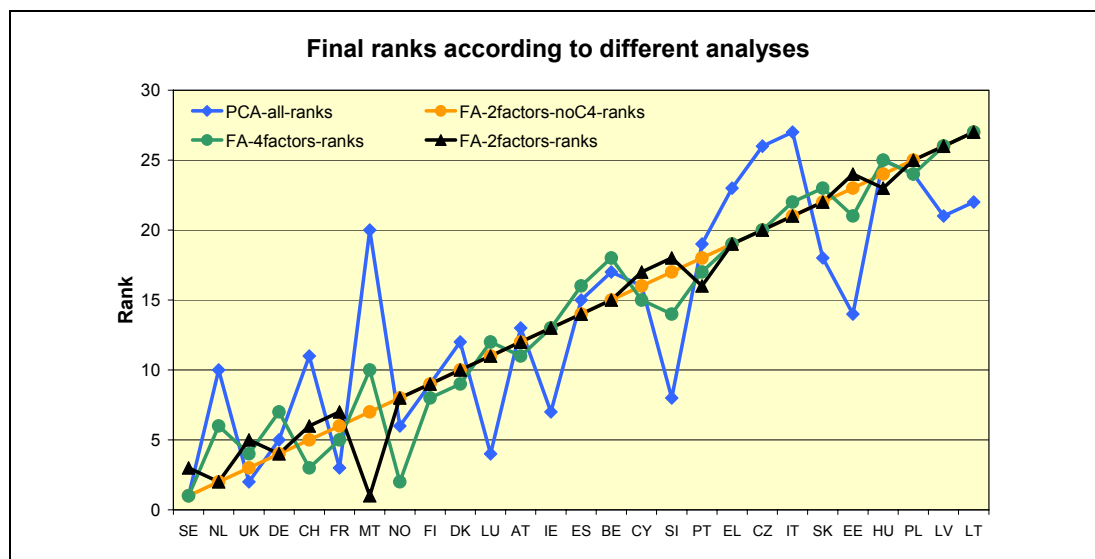
Figure 3.8. *Final countries' ranks resulting from four analyses*.

In general, the level of consistency between the different rankings seems mediocre, whereas the most similar results are provided by a similar type of analysis (e.g. common factor analysis).

3.5.2. Identification of groups of countries

Due to various reasons (e.g. data quality, method of analysis, random variations in data), the country rankings from different analyses will probably never be identical. Therefore, a more reasonable comparison of the results of several analyses could be made by forming groups of countries with similar safety performance. Such a comparison is possible in our case, because each analysis produced clusters of countries with very similar values of the combined indicator.

Using the results of countries' clustering presented in Section 3.4 and Appendix 2, we chose to compare the countries' classifications into five groups. Table 3.6 summarizes the findings. The left part of Table 3.6 illustrates the country groupings obtained from the four analyses with more consistent results, i.e. FA-4Factors, FA-2Factors, FA-2Factors-noC4 and PCA-all, whereas the right part of the table illustrates the country groupings obtained from the initial and final steps of the PCA-groups' analysis. The two central columns, i.e. 'Final group: based on four analyses' and 'Final group: based on PCA-group', give the final classifications of the countries.

Table 3.6 clearly shows that the countries' classifications in the left part are much more consistent than those in the right part of the table. Based on the left part of the table (results of four analyses), five groups of countries with different levels of safety performance can be defined as follows:
1. Countries with the highest level of safety performance: Sweden, Norway, France, Great Britain, Germany;
2. Countries with a relatively high level of safety performance: Switzerland, the Netherlands, Finland, Denmark, Ireland, Austria, Luxembourg, Malta;
3. Countries with a medium level of safety performance: Cyprus, Slovenia, Portugal, Belgium, Spain;

Country code	FA-4factors	FA-2factors-noC4	FA-2factors	PCA-all	Final group: based on four analyses	Final group: based on PCA-group	FA	FB	FC	WF (combined index)
SE	1	1	1	1	1	1	1	1	1	1
NO	1	1	1	2	1	1	2	1	1	1
FR	1	1	1	1	1	1	1	1	1	1
UK	1	1	1	1	1	2	1	1	2	2
DE	1	1	1	2	1	2	2	1	2	2
CH	1	1	1	3	2	2	1	1	3	2
NL	1	1	1	3	2	2	1	1	2	2
FI	2	2	2	3	2	2	3	2	2	1
DK	2	2	2	3	2	2	3	2	2	1
IE	2	2	2	2	2	2	3	2	3	1
AT	2	2	2	3	2	3	3	1	4	2
LU	2	2	2	2	2	3	4	2	4	3
MT	2	1	1	4	2	3	3	1	3	4
CY	3	3	3	4	3	3	3	2	3	2
SI	3	3	3	3	3	2	4	2	2	2
PT	3	3	3	4	3	3	4	2	3	2
BE	3	3	3	4	3	3	3	2	5	3
ES	3	3	3	4	3	3	3	2	4	2
EE	4	4	4	3	4	3	3	4	3	1
SK	5	4	4	4	4	3	4	3	4	1
EL	4	4	4	5	4	3	3	2	4	2
CZ	4	4	4	5	4	4	4	3	5	2
LV	5	5	5	4	5	3	4	4	3	1
HU	5	4	4	5	5	3	3	4	5	1
PL	5	4	4	5	5	4	4	4	5	2
LT	5	5	5	5	5	4	4	4	5	2
IT	5	4	4	5	5	4	5	1	5	3

Table 3.6. *Groups of countries with similar safety performance, based on the results of various analyses*.

4. Countries with a relatively low level of safety performance: Estonia, Slovakia, Greece, Czech Republic;
5. Countries with a low level of safety performance: Latvia, Hungary, Poland, Lithuania, Italy.

3.5.3. Behaviour of basic indicators

In the analyses performed, similarities in behaviour were observed for the following groups of indicators:

B1-B2-B3-B5-C5 (safety outcomes, i.e. fatality rates per population, per vehicles, per passenger kilometres travelled; share of pedestrian fatalities, and the median age of passenger cars),

A1-A2-A3-A4-A5 (indicators of the quality of national safety programs),

C2-C3 (wearing rates of safety belts in front and rear seats) and

D1-D2 (the country's background characteristics).

Moreover, the C4 indicator (average EuroNCAP score) was relatively close to the group containing safety outcomes, where B4 (injury accidents per fatality) and C6 (percentage of motorcycles in fleet) were relatively close to the D1-D2 group. On the other hand, C1 (share of drink-driving accidents) behaved different from all the other indicators, whereas indicators B6 (share of bicyclists fatalities), B7 (share of motorcyclist fatalities) and C7 (percentage of HGV in fleet) were excluded from several analyses due to low correlation with other variables.

Based on the analyses performed, basic indicators with more consistent behaviour and a clearer contribution to the final composite index can be identified. Such indicators are: B1-B2-B3 (fatality rates), B5 (share of pedestrian fatalities), A1-A2-A3-A4-A5 (quality of national safety programs), C2-C3 (wearing rates of safety belts) and C5 (median age of cars). These indicators can serve as a core set of basic indicators for the characteristic of a country's safety performance.

3.5.4. Towards the SUNflower road safety performance index

The purpose of our analysis was to create a composite road safety performance index and, concurrently, to explore the similarities in basic indicators. It has been demonstrated that both tasks can be realized by the statistical weighting methods applied. The composite indices, estimated by several methods, enabled us to rank the countries according to their safety performance.

Because of differences in rankings obtained by the different methods used, a more reasonable comparison can be made by using groups of countries with similar levels of safety performance. Countries can be grouped based on the values of composite indices received. In particular, among the 27 European countries considered, five groups with different safety performance were recognized. With the methodology used and with the available data, the countries with the highest level of safety performance are: Sweden, Norway, France, Great Britain and Germany. This group remained fairly consistent among the different methods used. Although, of course, a particular country could move from one group to another (neighbouring) group, depending on the method used. The analysis revealed that the results of countries' rankings based on the combined indicators are not necessarily identical to the traditional ranking they receive based on mortality rates or fatality rates only.

We believe that adding the information on policy performance indicators and implementation performance indicators to the ranking and grouping process

improves the results from the established methods and makes them more comprehensible and meaningful.

Moreover, it was observed that the indicators belonging to the final outcomes and intermediate outcomes, both part of the road safety performance indicator, are not uniform in their behaviour in the analyses. Indicators which were found to be more consistent and named 'core set of basic indicators' are recommended for future uses.

The overall conclusion is that it is realistic and meaningful to design a composite road safety performance index in which relevant information from the different components of the road safety pyramid has been captured and weighted. Moreover, such an indicator gives a more enriched picture of road safety than a ranking only based on data on mortality or fatality rates, which is normal practice today. Grouping countries in this process is promising and seems to be preferable to simply ranking countries. Country grouping will be done in the following chapter, Chapter 3. Before defining the SUNflower road safety indicator and actually using the results for policy making, two improvements are recommended: firstly to design the Implementation performance indicator and secondly to develop procedures for collecting high-quality and comparable data for all three indicators for all EU Member States.

4.   Grouping countries

It is important for countries to compare their safety performances with those of other countries. A first motivation for comparison is to know how the overall safety situation in the most recent year compares with that in other countries. Sometimes the comparisons are expressed in terms of rankings. In order to do so, it is necessary to define safety. Safety is often defined in terms of mortality rates: fatalities per head of the population. Mortality rates are used primarily to rank traffic safety or traffic risk to other risks, such as mortality due to diseases, during labour accidents, or accidents in and around the house. For the comparison of traffic risks this has the disadvantage that the degree of motorization is not taken into account. Therefore, another indicator is commonly used as a criterion for traffic safety: fatality risk, defined as the number of fatalities per motor vehicle kilometre. For those countries in which the motor vehicle kilometres are not available, the fatality rate - defined as the number of fatalities per motor vehicle - will be used instead.

Not only the recent safety situation is of interest, but also the safety development over time: has the country's safety been increasing or decreasing over time? Therefore, trend analyses will be carried out in this chapter to enable comparisons between countries over time.

A third reason for comparison is to learn from other countries. How can we improve the safety situation in our country? Are there useful examples of safety policies in other countries that can be identified? In this case more detailed information is necessary.

For all three types of comparison the most important question is: which country do we want to compare ourselves with? This question is not easily answered. The answer depends on the purpose of the comparison. If only a simple ranking of countries in a certain year is required, then the fatality risk indicator seems to be clear enough. However, even then it is not fair to carry out a direct comparison between all countries. Some countries have a more difficult task to fulfil than others and a correction for such a handicap should be applied. However, it is not easy to measure and quantify such a handicap.

If a comparison over time has to be carried out, then the situation is even more complicated. In that case there is not one single indicator that unambiguously ranks countries. It is not easy to define 'the-best-in-class' this way. Nor is a comparison of a large number of trends easy to make. Comparisons between a smaller range of countries with similar traffic systems or safety levels, or with a more general common background seem to be more promising. Of course countries can learn from measures taken in all other countries. But to formulate targets or plans it is more realistic to compare with countries in the same situation, and/or with the same economical, historical and geographical background, and/or the same level of motorization and safety development.

Therefore it was decided to research the possibilities and consequences of grouping European countries in such a manner that comparisons can be made against more similar backgrounds. This chapter identifies three alternative ways to carry out such a grouping. The first can be considered as an extension of the Sunflower+6 study which used three groups of three countries each: the North-West European 'SUN' countries (Sweden, the United Kingdom and the Netherlands), the Southern

European countries (Spain, Portugal and Greece) and the Central European countries (the Czech Republic, Hungary and Slovenia). The second grouping is based on the level of safety and the safety development in the European countries for which data is available. The third grouping is done on a much larger number of social, economic and geographic characteristics. The first grouping differs from the other two, because it is not directly based on objective data. Other than the number of characteristics, the last grouping differs from the second one, in that it is based on the recent situation only and not on past developments.

Pilot studies of all three ways of grouping have been carried out and are compared with each other in this chapter. These pilots are preliminary and carried out on existing data that was easily available. The objective was primarily to show how the existing techniques could be applied and how the results relate to each other. This is also the case for the grouping that was finally chosen. For example, the first grouping can be replaced by a study using a large number of experts, e.g. a study in which a number of safety experts from different countries are asked to rank the countries on a number of pre-selected characteristics. Techniques are available that translate such similarity data into ranking of countries. The second way of grouping is carried out using fatality risks (fatalities/motor vehicle kilometres) and fatality rates (fatalities/motor vehicles) because vehicle kilometre data is lacking for many countries. The analysis of fatality risks is highly preferable. There are ways of estimating motor vehicle kilometres from the number of motor vehicles and fuel sales. For the third method it turned out that a number of characteristics of countries could not easily be collected, although this data will be available in some format in various databases. Therefore, with this method a more decisive grouping is possible than the groupings carried out in this study. Two approaches have been tried here. In the first approach 13 variables which were readily available have been selected, including 3 road safety related variables. In the second approach the 3 road safety related variables were excluded.

4.1. Grouping by safety experts based on the Sunflower+6 study

The first grouping was carried out by a small number of traffic safety experts based on the grouping in the Sunflower+6 project, the safety development of the countries and their geographical position. The following grouping was suggested for the European countries:

Group 1: Denmark, Finland, Iceland, Ireland, the Netherlands, Norway, Sweden, United Kingdom;

Group 2: Austria, Belgium, France, Germany, Italy, Luxemburg, Switzerland;

Group 3: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia;

Group 4: Cyprus, Greece, Malta, Portugal, Spain.

There was some discussion about whether Italy should be placed in group 2 or group 4, Ireland in group 1 or group 2, the Netherlands in group 1 or group 2 and Slovenia in group 2 or 3.

In Section 4.2 this grouping based the opinion of road safety experts will be compared with the grouping obtained with a Singular Value Decomposition (SVD) of the annual fatality risks in the years 1980-2003. In Section 4.3 the grouping will be done according to a Multiple Correspondence Analysis (MCA) of a number of characteristics of the countries as observed in the most recent years; here their fatality risks are just one of the characteristics involved in the analysis.

The purpose of both the SVD and the MCA technique is to detect trends in characteristics that countries have in common: that is, to capture the most important and salient relations between the variables. In the SVD these are the developments in fatality risk, in the MCA they are the characteristics of the countries (the observational units) in just a few (e.g. two) dimensions. The main purpose of this study is to capture the most important similarities between the countries. Both techniques produce a plot in which each country is represented by a dot; in this plot small distances between dots imply that the corresponding countries are quite similar to each other (in terms of the values of the variables used in the analysis) while large distances between dots represent countries that are very different from each other. Analysis of the distances between countries in this plot is therefore particularly suited for the grouping of countries, even though – as we will see – there is still a certain amount of subjectivity involved in the grouping of countries based on these plots.

As was mentioned earlier, a second result of these techniques is that they allow for an assessment of the most salient relations between the variables used in the analysis. In the context of the SVD of fatality risks of the countries, some attention will therefore also be paid to this aspect of the analyses' results.

Whether to use an SVD or an MCA for our purposes typically depends on the measurement level of the variables used in the analysis. When continuous numerical variables (such as fatality risk) are used SVD is the most appropriate technique. On the other hand, when we use discrete nominal variables, such as religion, MCA is the appropriate technique.

4.2. Singular Value Decomposition of traffic safety developments

4.2.1. General description

One way of grouping countries is to look for similarities in the risk level and the risk development. To investigate these similarities between European countries, a Singular Value Decomposition (SVD) of the developments in fatality risks was performed. A detailed description of this technique is given in Appendix 5. The SVD looks for common trends in the risk development. The original trends for each individual country will then be replaced by a small number of general, underlying, or latent trends, in such a manner that the individual trends are best represented by this small number of general trends. The result is that for each country a combination of general trends is found with a minimum of deviations from this combination. If, except for a multiplicative factor, all countries had the same development of risk over time, then one common trend or dimension would be found, with a factor representing the level of risk for each country. This is often called a factor score: the score of a country on a dimension. A low average risk will then be represented by a low risk factor, a high level by a high factor. If we plot

these values on a straight line, then countries with similar levels of risk will be close together.

In general, countries will differ not only in the level of risk, but also in the risk development. That means that there are more general trends, and that the SVD will find more than one dimension.

The first dimension will be the best representation of the development for all the countries. It is a weighted average of all risk developments. The next dimension is the best representation of the residuals from the first dimension. This dimension represents the most important 'correction' of the first general trend. For example, if a large number of countries have exactly the same correction over time, then their deviation from the general trend will be made visible by this second dimension. For each country a factor is found that represents the degree to which this trend is important for that country. If the factor is almost zero, then the trend is not relevant for that country. If the factor is positive, then the trend is relevant for that country, if it is negative then the reverse of the trend is relevant for that country. If the factors for the first and second dimension are plotted in a plane, the countries that have the same general level of risk and the same deviation from the general trend will be close together.

In principle, if the number of countries is lower than the number of years, there are as many factors as there are countries. At the same time, less important factors represent less variation in the risk developments. Each dimension has a so-called 'eigenvalue', representing the importance of that dimension for the description of the risk developments. The eigenvalues are a decreasing series. If all general trends are found, only white noise remains, and the dimensions representing the white noise will all have comparably small eigenvalues. These dimensions can then be ignored. The choice of a cut-off value for the number of dimensions is somewhat arbitrary. However, this study will focus on the first two or three dimensions to represent the similarities between countries in risk development, even if more dimensions show real trends.

4.2.2. Fatality risk developments (fatalities per motor vehicle kilometre) in 13 European countries

A first analysis was performed on the fatality risk developments. The fatality risk is defined as the total number of fatalities in a country in one year divided by the total number of motor vehicle kilometres for that year. The IRTAD data was used, supplemented with additional information available from the Sunflower+6 project. Data of motor vehicle kilometres for a long enough series of years was available for only 13 countries. Data of the years 1980 through 2003 was used for the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, the Netherlands, Norway, Portugal, Slovenia, Sweden and Switzerland. For some countries one or two values were missing and hence interpolated.

Five dimensions were used in the analysis. Four of these represented some trend or trend correction; the last one already represented white noise. Table 4.1 shows the country factors, the eigenvalues and the cumulative proportion of explained variance in the total matrix of scores for the four dimensions.

Table 4.1 shows that in the first dimension Sweden, Great Britain, Norway, Finland and the Netherlands have the lowest average risk over the years, followed by

Denmark, Switzerland and Germany. Portugal and Slovenia have the highest average risk, followed by Austria, Belgium and France. The table also illustrates that the first dimension is by far the most important one. The eigenvalue is 0.5955, which means that the first dimension explains 99% of the variance in the total data matrix. This shows clearly that all countries generally have the same risk development. Figure 4.1 shows this general trend in combination with the best exponential fit. It turns out that there are two major deviations from the general smooth trend: one around 1983 and one around 1987.

Country	Dimension 1	Dimension 2	Dimension 3	Dimension 4
Austria	0.2598	-0.0949	0.0618	**0.7291**
Belgium	0.2335	0.0794	**0.3644**	0.0173
Denmark	0.1453	0.1916	0.2002	**-0.2899**
Finland	0.1216	0.2107	0.1635	**-0.2911**
France	0.2213	0.1588	**0.3263**	0.0643
Germany	0.1741	0.0943	0.2037	**0.3614**
Great Britain	0.1090	0.0404	0.1684	0.0509
The Netherlands	0.1262	0.0718	0.1990	0.0600
Norway	0.1116	0.2047	**0.2553**	-0.0877
Portugal	0.6205	**-0.7205**	-0.0276	-0.2817
Slovenia	0.5529	**0.4977**	**-0.6557**	-0.0050
Sweden	0.0951	0.2016	0.2175	**-0.2640**
Switzerland	0.1512	0.1153	0.1937	0.0410
Eigenvalue	0.5955	0.0343	0.0297	0.0188
Cumulative proportion of variation	0.99279	0.99608	0.99856	0.99955

Table 4.1. *Country factors, eigenvalues and the cumulative proportion of explained variance in the total matrix of scores for four dimensions from an SVD analysis of fatality risks (fatalities per 10^6 motor vehicle kilometres) for 13 European countries*.

The second and third dimensions have much smaller eigenvalues than the first dimension, but they do not differ much. Figure 4.2 shows the second and third dimension and a weighted combination of these two dimensions. The bold figures in the third column of Table 4.1 show that the second dimension is dominated by Portugal and Slovenia. The negative value for Portugal means that the correction on the general trend is reversed. This means that Portugal is mainly responsible for the peak in 1987, and that especially Slovenia has a low value in that year. The third dimension is negatively dominated by Slovenia and positively by Belgium, France and Norway. This means that Slovenia is primarily responsible for the peak in 1983. Norway also had a rather high positive score on the second dimension, which indicates that especially Norway has a relatively low value in 1983. Both correction trends increase with time, and are more or less mirrored. The weighted average of the trends shows a rather linear correction which increases with time. For countries with a positive factor on these dimensions, and especially for those countries with a positive factor on both, such as Norway, Denmark, Finland, Sweden and France, this means that the development over time decreases a bit less than the general trend suggests.
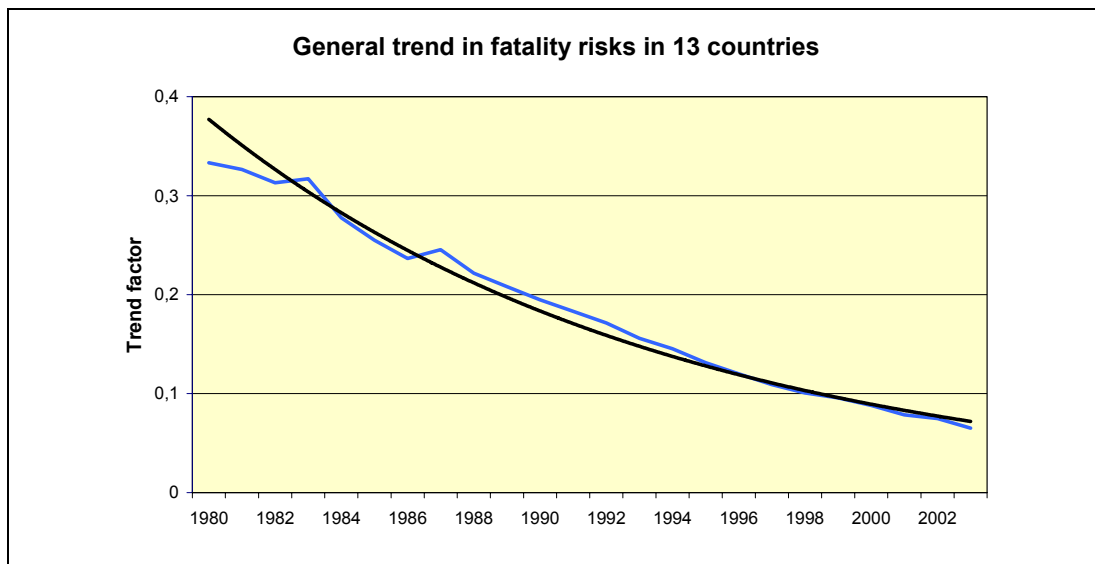
Figure 4.1. *General trend (first dimension) in fatality risks, resulting from SVD analysis of 13 countries, together with the best fitting exponential trend*.
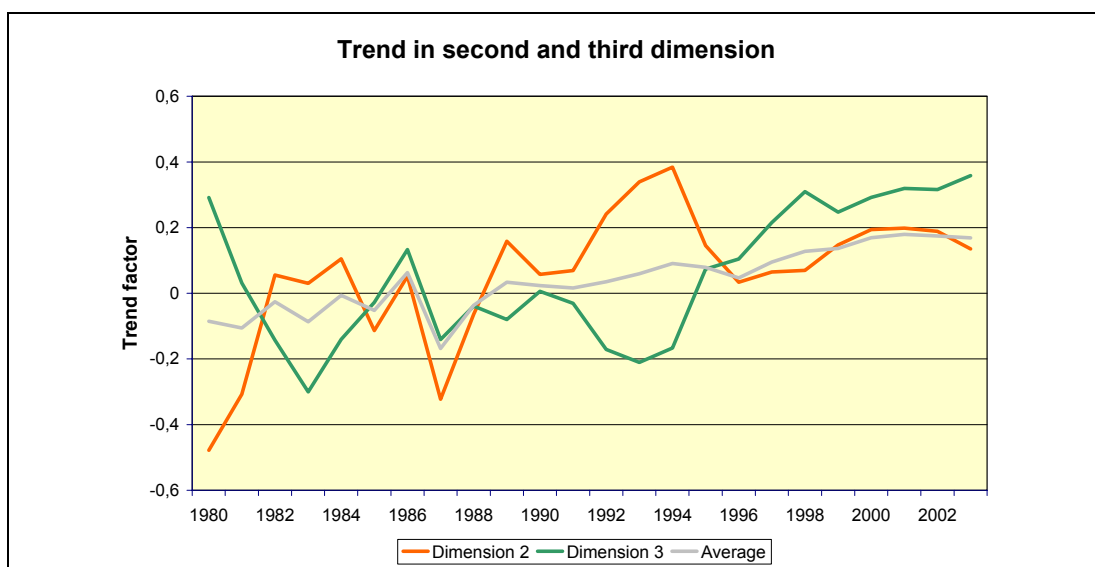
Figure 4.2. *Second and third dimension (residuals), and their weighted average, resulting from the SVD analysis of the fatality risks of 13 countries*.

Slovenia has opposite factors, which suggests a relatively high risk in the early 1980s and early 1990s, a relatively low risk in the late 1980s, and an average risk at the late 1990s and the early years of the second millennium. The negative score for Portugal on the second dimension shows that there was a relatively high peak in risk around 1987, a low risk during the first half of the 1990s and also, although to a lesser amount, from the late 1990s onwards. The fourth dimension is dominated by Austria (showing a relative high risk in the early 1980s, compared to a relatively low risk in the late 1980s). Figure 4.3 shows the factor scores on dimensions 1 and 2 from Table 4.1 plotted for the 13 countries.

Factor scores of SVD analysis of fatality risks
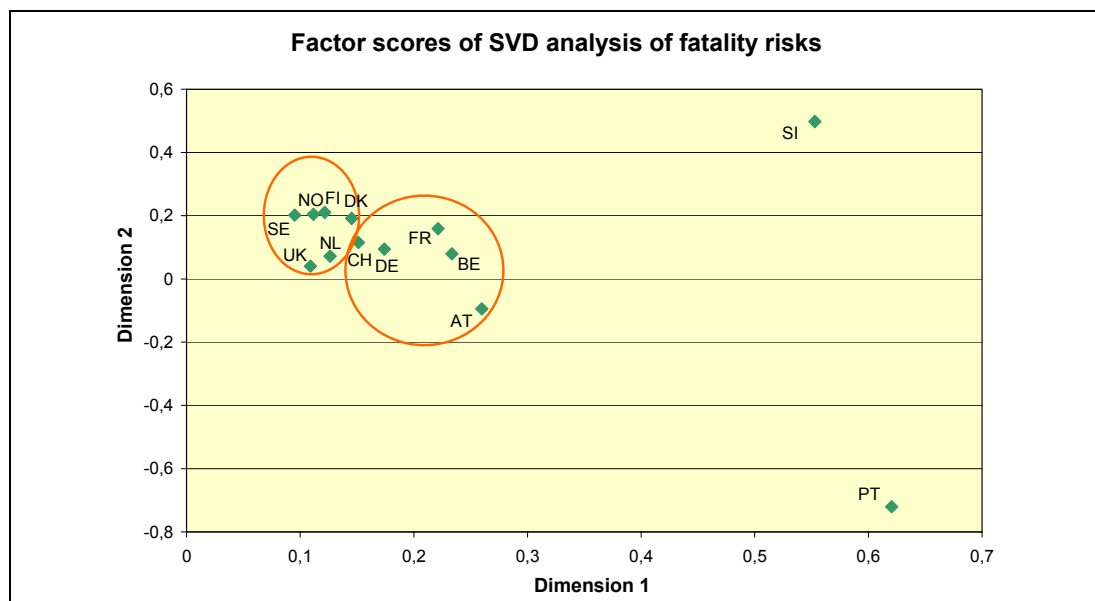
Figure 4.3. *Factor scores for 13 countries on the first two dimensions of a SVD analysis on fatality risks*.

Based on Figure 4.3, the following grouping of countries can be made: in the upper-left part of the plane the Nordic countries together with Great Britain and the Netherlands are located. To the right of this group and a bit lower Switzerland, Germany, France, Belgium and, a bit further away, Austria can be viewed as a second group. Ellipses have been drawn only to indicate these two groups, suggesting a possible grouping of these countries. Slovenia and Portugal have isolated positions.

As expected, the countries with a low risk level - Sweden, Great Britain, Norway and the Netherlands - are located at the left of the first dimension; Slovenia and Portugal at the right.

4.2.3. Fatality rate developments (fatalities per number of motor vehicles) in 20 European countries

To investigate the similarities between more countries, an SVD analysis was performed of the fatality rates (fatalities divided by the number of motor vehicles) for each country for each year. The following countries were added to the previous list: Czech Republic, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg and Spain. Not enough data was available from among others Poland, Slovenia and Slovakia. Fatality rates from 1980 through 2005 were used. The results are given in Table 4.2.

Although a bit less than in the analysis of fatality risks, the first dimension is once more the dominant one. The countries with the lowest factor scores on the first dimension are: Norway, Sweden, Great Britain, the Netherlands and Switzerland, followed by Italy, Germany and Switzerland. The countries with the highest factor scores on the first dimension are Portugal, Greece and Hungary. The second dimension has the highest positive factor scores for the Czech Republic and Hungary and to a lesser extent for Portugal. Austria and Greece have the largest negative factor scores. The third dimension is dominated by Norway, which has a positive factor score. Second is the Czech Republic with a somewhat smaller

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negative factor score. On the fourth dimension the Czech Republic has a high positive score while Portugal and Hungary have large negative scores.

Country	Dimension 1	Dimension 2	Dimension 3	Dimension 4
Austria	0.2239	**-0.3332**	0.0273	-0.0613
Belgium	0.2165	-0.0878	-0.1318	-0.0601
Czech Republic	0.1968	**0.4825**	**-0.3756**	**0.6123**
Denmark	0.1592	0.0493	-0.2234	-0.0744
Finland	0.1491	-0.0434	-0.1134	-0.1131
France	0.2168	-0.1314	-0.0915	0.0064
Germany	0.1442	-0.1774	0.0077	0.1385
Great Britain	0.1115	-0.0988	-0.0801	-0.0425
Greece	0.4027	**-0.3045**	-0.1493	0.1203
Hungary	0.3873	**0.5736**	-0.1046	**-0.3905**
Iceland	0.0996	-0.0096	-0.0863	0.0947
Ireland	0.2250	-0.0916	-0.0944	0.1644
Italy	0.1415	-0.1374	0.0248	0.1416
Luxemburg	0.1880	-0.1884	-0.0594	0.0540
The Netherlands	0.1325	-0.1437	-0.1601	-0.0182
Norway	0.0908	-0.0478	**0.8005**	0.2113
Portugal	0.4438	0.1828	0.0062	**-0.5437**
Spain	0.2430	0.0343	-0.1219	-0.0703
Sweden	0.0944	0.0095	-0.0070	-0.0198
Switzerland	0.1330	-0.2084	-0.1677	-0.0806
Eigenvalues	9.1632	0.7887	0.6246	0.4817
Cumulative proportion of variance	0.9826	0.9899	0.9944	0.9971

Table 4.2. *Country factor scores, eigenvalues and the cumulative proportion of explained variance in the total matrix of scores for four dimensions from a SVD analysis of fatality rates (fatalities per number of motor vehicles) for 20 European countries*.

Figure 4.4 shows the first dimension of the SVD analysis on fatality rates. A sudden rise in the fatality rate in the early 1990s can be observed. This rise is driven by the Czech Republic, Hungary and Portugal, as can be seen in Figure 4.5, which displays the graphs for the second, third and fourth dimension. The graph of dimension 2 also shows a peak value in the early 1990s. From Table 4.2 it can be seen that most countries have a negative factor, showing a correction on the rise in dimension 1. Especially Hungary and the Czech Republic have high positive values, showing that the peak in those years was underestimated for these countries. The third dimension has a similar peak as dimension 2, but shows a steeper decline later. Except Norway, most countries again have a negative or neutral factor score. This shows a more than average safety improvement in Norway from the early 1990s onward. Compared with Portugal and to a lesser extent with Hungary, the positive factor for the Czech Republic on dimension 4 shows that the relatively

positive development until 1990 turned into a relatively negative trend in later years, tending to neutral in most recent years.

General trend in fatality rates in 20 countries
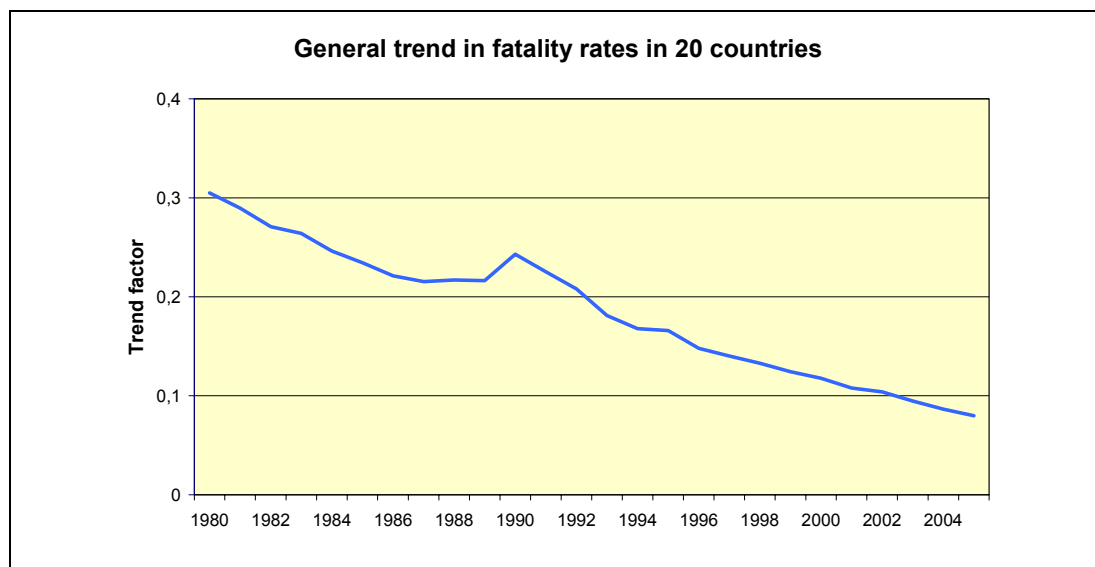
Figure 4.4. *General trend (first dimension) in fatality rates, resulting from SVD analysis of 20 countries.*

Trend in second, third and fourth dimension
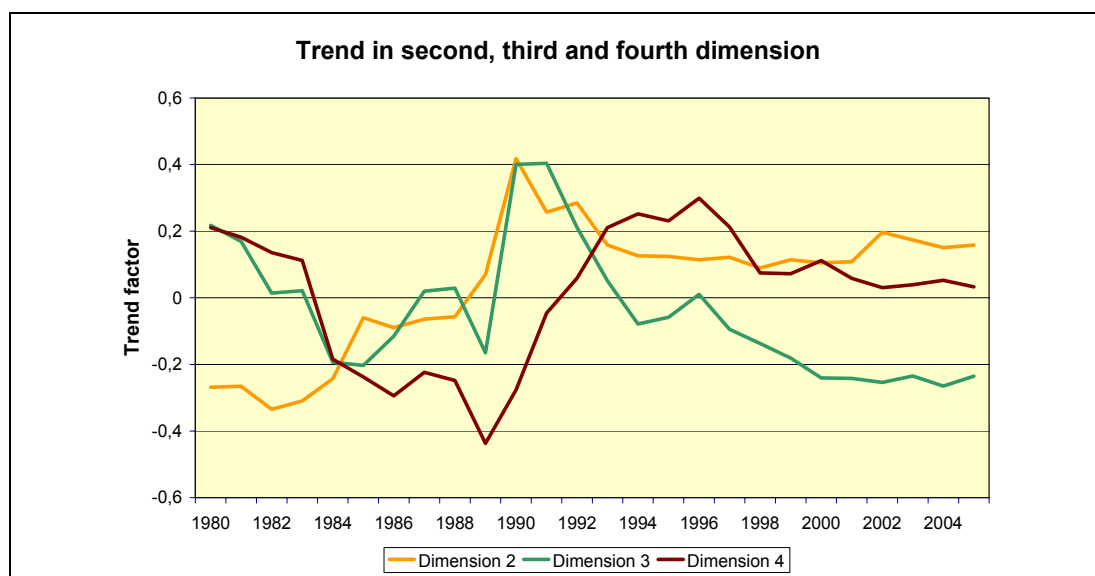
Figure 4.5. *Second, third and fourth dimension (residuals) resulting from the SVD analysis of the fatality rates of 20 countries.*

Figure 4.6 shows the factor scores on the first and second dimension. Compared with Figure 4.3 we see that Germany has slightly moved in the direction of the Netherlands. It can also be observed that the development in Iceland is similar to that in the Nordic countries and that Luxembourg is rather close to France and Belgium. Ireland is close to Belgium and France; Spain is in between this last group and Portugal, although closer to Belgium and France. Hungary and the Czech

Republic are close to each other on the second dimension, but not on the first. Greece is a bit isolated, but closest to Portugal and Spain.

Factor scores of SVD analysis of fatality rates
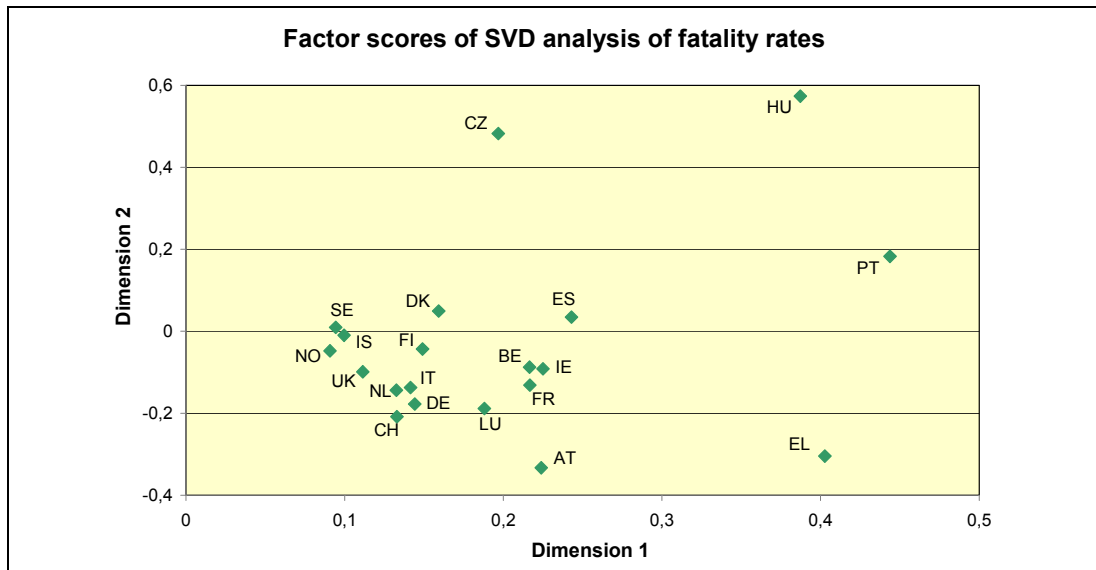
Figure 4.6. *Factor scores for 20 countries on the first two dimensions of a SVD analysis of fatality rates*.

Considering the grouping of countries, it can be concluded that the grouping as result of the SVD analysis of fatality risk and rate trends is largely in agreement with the grouping by the experts. The group 1 result for the Nordic countries, together with Iceland, the Netherlands and Great Britain agrees with the expert selection for group 1. Italy seems more similar to the countries in group 2 than to the Southern countries Spain, Portugal and Greece. It also seems best to add Ireland to group 2. The Czech Republic, Hungary and Slovenia can be grouped together in group 3.

4.3. Multiple Correspondence Analysis

The idea behind this approach is that there are many factors other than traffic and safety characteristics that might influence the traffic system or restrict possibilities for safety measures. Examples are the geographical, social or cultural characteristics of a country or society. To compare a country's safety situation with that in other countries, it is convenient to select those countries that are similar regarding these background variables. There is a great variety of characteristics and they are not all directly measurable in the ordinary sense. Examples are type of religion, literacy etc. An alternative to the Principal Components Analysis (PCA) technique which is suitable for this type of data is the Multiple Correspondence Analysis (MCA).

Because the data are of a different nature and are not directly related to traffic safety, it is difficult to collect the necessary information for all European countries. In order to show how such a technique can be used for the purpose of grouping countries, a small number of readily available characteristics were used in the analysis discussed in this section. A disadvantage of the choice that was made is the fact that many of the used characteristics are of the same type or are strongly correlated with other characteristics. Examples are variables 6 (winter temperature),

7 (summer temperature), 9 (latitude) and 10 (religion), which are defined below. The outcome of any MCA analysis will therefore be dominated by such clusters, because these are shown as dominant underlying components. In a more balanced set of variables such artefacts disappear. Despite its drawbacks, the analysis is still reported here, in order to show the usefulness of the technique for grouping countries.

The data used in the analysis was collected for 23 countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and Switzerland.

The technique considers all variables to be measured at a nominal level; this means that the categories of a variable are just labels, without any order in the categories. Thirteen variables were used. The values of the countries on these variables, if numeric, were divided into a small number of classes. The classes were defined in such a way that each category has an approximately equal number of countries.

The following discretized categories of the original variables were used in the MCA[2]:

1. Growth of vehicle fleet (mean growth between 2000-2005): less than 1.75%; 1.75-2.15%; 2.3-2.99%; 3-4.2%; more than 4.5%.
2. Fatality rate per vehicle fleet (mean killed per thousand motor vehicles between 2000-2005): less than 0.120; 0.120-0.160; 0.165-0.205; 0.206-0.305; higher than 0.305.
3. Fatality rate per population (mean killed per 100,000 inhabitants between 2000-2005): less than 7.5; 7.5-10; 11-12; 12.5-13.5; higher than 13.5.
4. Seatbelt use (average of three road types): less than 80%; 80-91%; higher than 91%.
5. Mountain area (percentage of mountainous area): less than 5%; 5-30%; more than 30%.
6. Winter (mean January) temperature: less than 0°C; 0-1° C; 1.5-4°C; more than 4°C.
7. Summer (mean July) temperature : less than 18°C; 18-19° C; 19.5-22°C; more than 22°C.
8. Part of population with at least upper secondary education: less than 75%; more than 75%.
9. Latitude (of capital, in degrees): less than 48°; 48-50°; 51-53°; more than 53°
10. Main religion: catholic; protestant; orthodox; secular.
11. Literacy (in population): less than 99%; 99%; 100%.
12. Population density (in absolute numbers per square km): less than 25; 25-99; 100-120; 122-180; more than 180.
13. GDP: gross domestic product (in million Euros): less than 90,000; 99,500-210,000; 220,000-310,000; more than 400,000.

The classification results in a matrix of 23 countries by 13 variables. The scores range from 1 to a maximum of 5: e.g., 1 or 2 for education, 1, 2 or 3 for literacy and 1-5 for growth of the vehicle fleet. The MCA of this data set was performed in two dimensions. The dimensions are abstract characteristics, representing combinations of the original variables that best represent similarities between countries. The first dimension is again the most important 'common trait' of the countries. The second

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[2] The categories are in increasing order (1, 2, …)

dimension is the next important one, describing best the residuals that cannot be described by the first dimension. The two dimensions are independent from each other. To what extent all information in the original matrix of 23 x 13 scores can be displayed in the two dimensions can be measured by the total fit. It turns out that the total fit is equal to 0.853, which should be compared to a maximum fit of 2 (the number of dimensions). In order to 'understand' the meaning of the dimensions, the so-called discrimination measures give an indication.

The major outcomes in terms of the variables are given in Table 4.3. In this table the 'discrimination measures' of the variables are given. The variables with the largest discrimination measures on the first dimension are best represented by this dimension. They are: main religion, summer temperature, population density, latitude, fatality rate per vehicle fleet (fatalities/1000 vehicles), winter temperature and fatality rate per population (fatalities/100,000 inhabitants). Growth of vehicle fleet, seatbelt use, mountain areas, education and GDP are least represented by the first dimension.

For the second dimension the most discriminating variables are: fatality rate per vehicle fleet, summer temperature, latitude and population density. The least discriminating variables are: growth of vehicle fleet, fatality rate per population, seatbelt use, mountain areas, winter temperature, education main religion, literacy and GDP.

The most discriminating variables on both dimensions are given in the last column: summer temperature, fatality rate per vehicle fleet, latitude and population density; in that order. Least discriminating are: mountain area, growth of vehicle fleet, GDP, education and literacy. According to the MCA this means that, given the selection of variables, the 23 countries can best be grouped on the basis of the most discriminating variables. These variables discriminate best between (groups of) countries.

Variable	Dimension		Mean
	1	2	
Growth of vehicle fleet (5)	0.208	0.134	0.171
Fatality rate per vehicle fleet (5)	0.633	0.882	0.758
Fatality rate per population (5)	0.617	0.251	0.434
Seatbelt use (3)	0.209	0.266	0.238
Mountain areas (3)	0.214	0.055	0.135
Winter temperature (4)	0.620	0.291	0.456
Summer temperature (4)	0.741	0.814	0.778
Part of population with at least upper secondary education (2)	0.254	0.293	0.274
Latitude (4)	0.687	0.647	0.667
Main religion (4)	0.743	0.254	0.498
Literacy (3)	0.489	0.079	0.284
Population density (5)	0.694	0.620	0.657
Gross domestic product (4)	0.102	0.297	0.199
Total	6.210	4.885	5.548

Table 4.3. *Discrimination measures of the 13 variables from a MCA analysis in two dimensions*.

Figure 4.7 displays the outcomes for the countries on the two dimensions. Also in this case, countries that are close together have more in common than countries that are far apart.

Figure 4.7. *Plot of the 23 countries in the two-dimensional plane, resulting from the MCA, using 13 characteristics of these countries*.

Four groups of countries can be distinguished. Table 4.4 shows these groups. The countries marked with * are similarly grouped as with the earlier two methods. Group 1 and group 4 agree to a large extent with the previous grouping by the experts and the SVD analysis. Group 2 seems to be a mix of the original group 2 and group 3. The new group 3 represents the countries in the centre of the plot, countries that are least represented by the two dimensions. A third dimension could possibly show how to best classify these countries.

Group 1	Group 2	Group 3	Group 4
Denmark* Finland* Germany Great Britain* Iceland* The Netherlands* Norway* Sweden* Switzerland	Austria* Czech Republic France* Hungary Luxembourg* Poland Slovakia	Belgium Ireland Slovenia	Greece* Italy Portugal* Spain*

Table 4.4. *Grouping of 23 countries in four groups resulting from an MCA using 13 characteristics*.

We will end this section by presenting the results of an MCA of the same data set, but now after removing the three main road safety variables 'growth of vehicle fleet', 'fatality rate vehicles', and 'fatality rate population' from the analysis, see Figure 4.8.
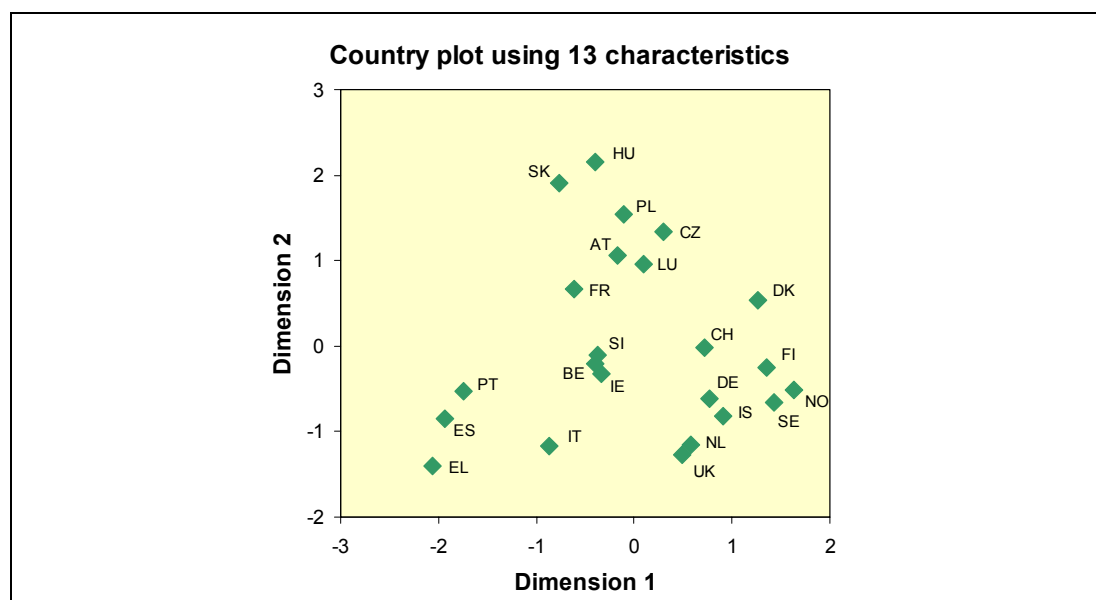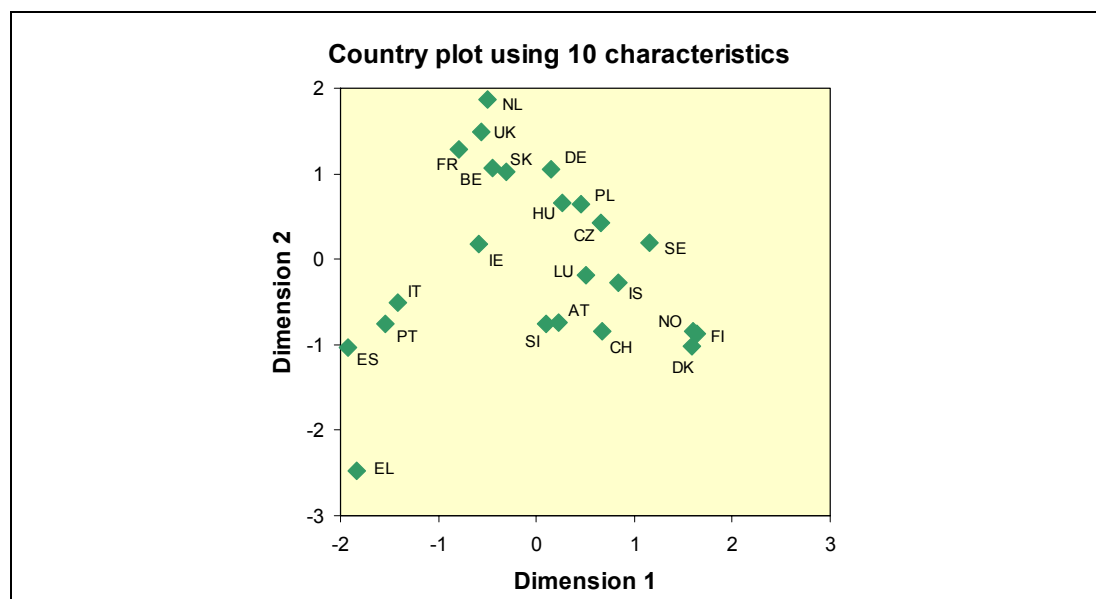

Figure 4.8. *Plot of the 23 countries in the two-dimensional plane, resulting from the MCA, using only 10 characteristics of these countries.*

There are some similarities between how the countries are clustered in Figures 4.7 and 4.8. Greece, Italy, Spain and Portugal, for example, still form a group in Figure 4.8. But there are also some large differences. For instance, other than in Figure 4.7, the Netherlands and Great Britain are not in the same cluster as Denmark, Finland and Norway anymore, because the clustering is no longer based on the similarities between these countries in terms of their respective road safety levels. The most important variables responsible for the clustering found in Figure 4.8 are (non-linear transformations of) the categories of 'latitude', 'population density', and 'winter temperature'. This illustrates the importance of a careful selection of the variables used as the basis on which to form groups of countries.

4.4.   Grouping countries, based on three strategies

Combining the results of the three grouping strategies discussed above, the countries of which some time series data is available were classified into four groups for further analysis. Countries for which annual fatality data and the number of vehicles from 1970 onward were available were used in the analyses. Data from 1980 onward was available for the group 3 countries Czech Republic and Hungary; this data was used for group 3. However, for Iceland, Poland, Slovakia and Slovenia there was not enough data available for the annual number of vehicles in early years to be used in most of the analyses. The final grouping of countries is given in Table 4.5. These groups are used for further analyses in Sections 5.4 and 5.5.

Group 1	Group 2	Group 3	Group 4
Denmark	Austria	Czech Republic	Greece
Finland	Belgium	Hungary	Portugal
Great Britain	France	Poland	Spain
Iceland	Germany	Slovakia	
The Netherlands	Ireland	Slovenia	
Norway	Italy		
Sweden	Luxemburg		
	Switzerland		

Table 4.5. *Final grouping of countries on the basis of three grouping strategies*.

5.   Time series analysis

This chapter will first show a graph of the safety developments in 20 European countries from 1970 onward (Section 5.1). In the following sections two different approaches will be presented that can be used for time series analysis of safety data: the SVD technique which was introduced in Chapter 4 and a special application of the structural time series model developed by Harvey (1989).

In Chapter 4, SVD analyses were carried out to investigate whether similar developments in fatality risk and rate could be used as a basis for grouping. Section 5.2 will continue with a more detailed study of the fatality risk development found from the SVD analysis. It will mainly be concerned with the developments themselves and not with the grouping of countries.

In Section 5.3 safety developments of individual countries are analysed to investigate whether statistically unexpected safety outcomes are found in a certain year. A crude way of doing so is to compare a safety outcome in a certain year with the outcome of the previous year. Under the assumption of Poisson distributed fatality numbers, significant changes can be noted. However, it is better to use the whole range of information about the fatalities as well as travel over a series of previous years and not just information from the one previous year. An elegant way of doing this is by making use of Harvey's time series analysis technique. In this study this has been done by modelling the development of fatalities as well as the number of vehicles or vehicle kilometres. Then error bounds are not just based on the number of fatalities in the previous year, but on the expected figures for the amount of traffic and fatalities in the present year, given the outcomes in the past. When available, fatality risks are used, for the other countries the fatality rates. In Harvey's structural time series model, observed fatality risk or rate outcomes are compared with expected outcomes given the developments so far, together with forecasts for the next three years. Error bounds are estimated for the safety data over the whole range and also for the forecasts. This way it is possible to evaluate annual fluctuations in safety risk or rate as well as trends, whether these are within or beyond the margins of expectation. The expectation is determined based on the number of vehicle kilometres or the traffic volume expected in a particular year and on the expected risk or rate for that year, given the values in previous years. Significant deviations in the number of fatalities can be caused by unexpected fleet or traffic volume data as well as by unexpected changes in fatality risk or rate. Harvey's time series analysis technique distinguishes between these effects.

In Section 5.4 trends for groups of countries are analysed with the SVD technique. General trends for groups of countries are shown, together with deviations from these trends for individual countries. Differences in outcomes for the different groups are discussed.

Section 5.5 discusses the developments of disaggregate safety data for countries within groups. Differences in age, traffic mode and road type will be presented for each group. Some examples will be discussed in detail. All disaggregate developments will be given in a separate appendix.

5.1. Fatality and mortality developments in 20 European countries

Figure 5.1 shows the developments of the fatality and mortality rates in 20 European countries from 1970 onward over five year periods. For some countries data is not available over the entire period.

Figure 5.1 shows that in general all trends are the same, moving from the upper right to the lower left. For the countries with a later start of mass motorization such as the Czech Republic, Greece, Hungary, Poland, Portugal and Spain the beginning of the curve is a bit chaotic.
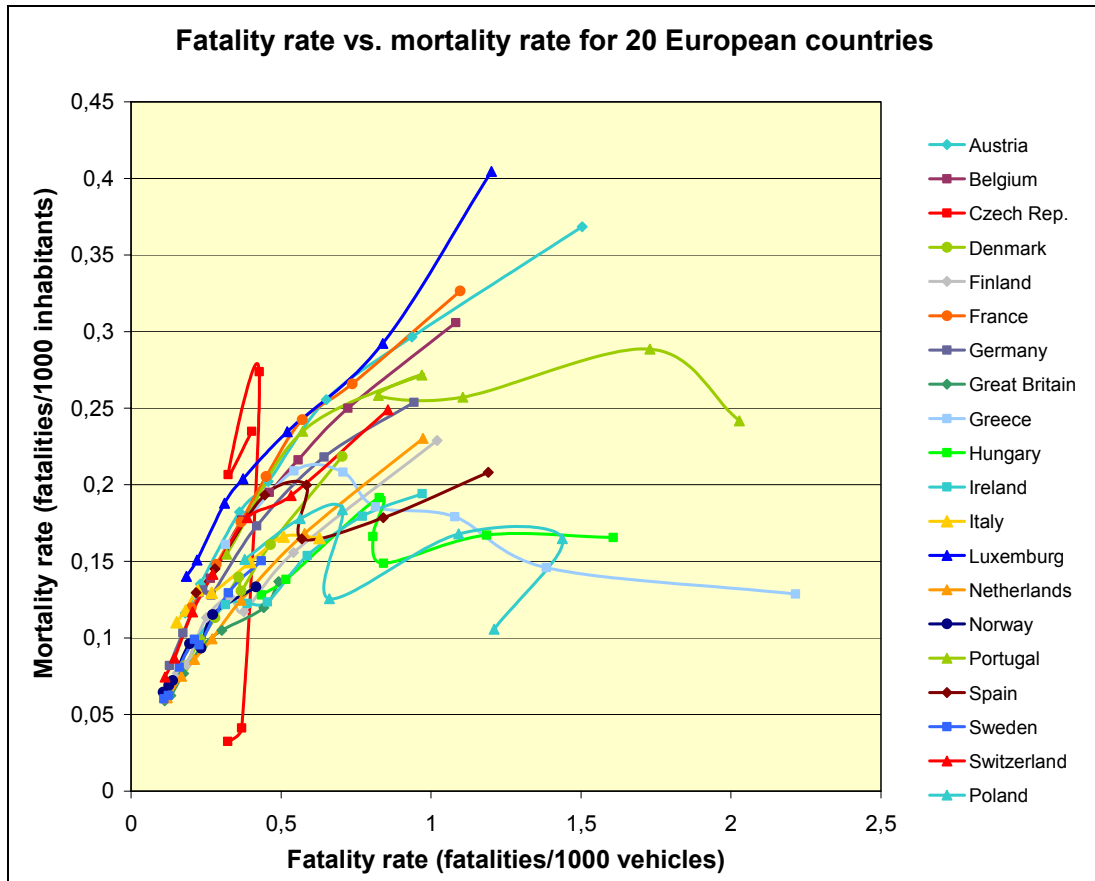
Figure 5.1. *Fatality rate vs. mortality rate in five year periods since 1970 for 20 European countries*.

Generally, at the beginning of motorization, the mortality rate in particular can be expected to rise with an increase of the number of vehicles, and to drop again later, after an increased implementation of safety measures to counter the negative safety effects. This is the case in Portugal, Greece and Hungary. For the Czech Republic, the situation is different. Although the mortality rate rose steeply during the first periods, there has been an only minor improvement in the fatality rate afterwards. This causes a minor dip in the mortality rate. Compared with the other Central and Eastern European countries the fatality rate was already rather low in the 1980s. For the other countries this turning point lies before 1970, when the measurements commenced. The general impression is that initially developments show a great

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variety in values, to end within a narrow band. This suggests that, although developments have different starting points in different countries, all countries end up the same. However, countries leading in the field of safety generally remain ahead of the other countries, albeit with a decreasing advantage.

5.2.   SVD analysis of the fatality risk developments in 11 European countries

In order to study the general fatality risk trend that was found in the SVD analysis of 13 countries with vehicle kilometre data in Section 4.2.2 more closely, an SVD analysis was carried out, leaving out the two most disturbing countries, Portugal and Slovenia. The result for the first dimension together with an exponential trend is given in Figure 5.2. The percentage of variance explained by the first dimension is now 99.37%. It is also clear that the exponential fit is much better. 99.21% of the variation in the values on the first dimension is explained by the exponential function $Y = Exp(112.9638-0.0576*year)$ for the normalized fatality risks. The value for 1983 is relatively high compared with the exponential trend, while the values for 1987 and 1996 are relatively low. These deviating values are not explained by deviating motor vehicle kilometres in those years.
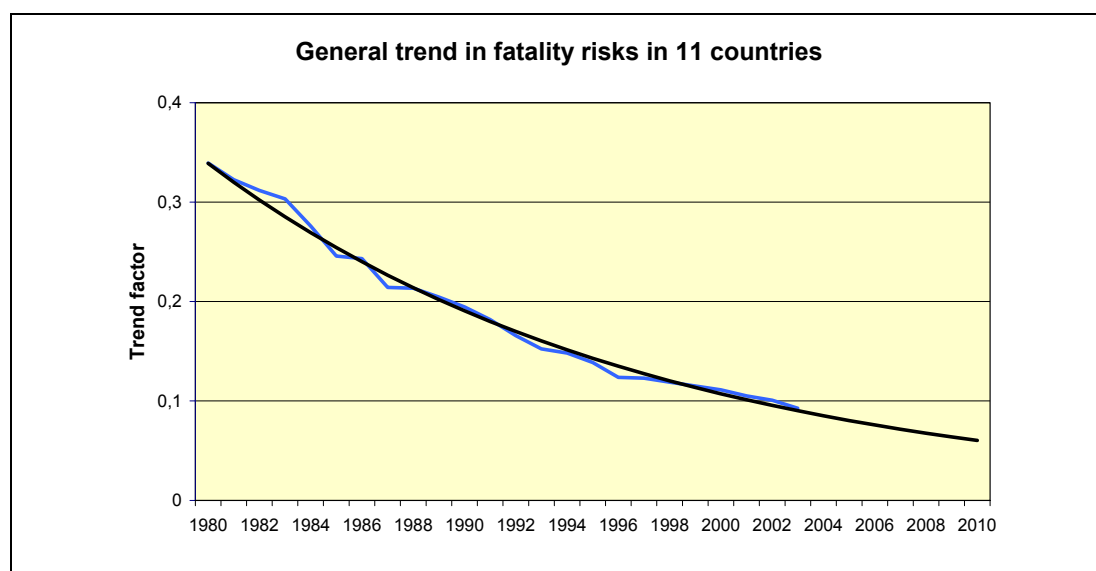
Figure 5.2. *General trend (first dimension) in fatality risks, resulting from SVD analysis of 13 countries, together with the best fitting exponential trend*.

Figure 5.3 shows the results for the 11 countries, if the first dimension is multiplied by the factor score for each country.
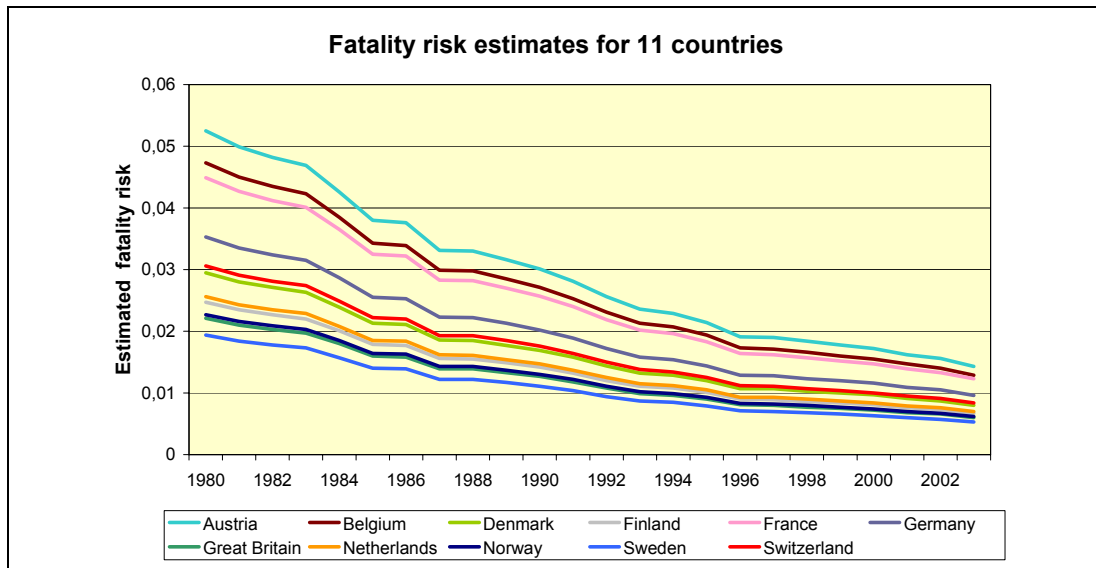
Figure 5.3. *Estimated fatality risks (fatalities per 1000 vehicle kilometres) from the first dimension of an SVD analysis of the fatality risks in 11 European countries*.

In Figure 5.4 the factor scores for the first SVD dimension of the 11 countries are plotted, together with the fatality risk in the last year of measurement, 2003. This figure shows that the overall decrease in risk from 1980 onward, measured by the factor score, is linearly related to the risk in the last year of measurement, 2003. Once more, this shows that the fatality risk development from 1980 onward largely follows the same curve for all 11 countries, with a country-specific multiplicative factor. This means that the absolute differences in fatality risk in the eleven countries become smaller with time. The relative difference in fatality risk, however, stays the same. If the fatality risk curves had been plotted on a log-scale, the curves would have been parallel lines. This means that the leading countries in road safety will keep their leading position if nothing changes.
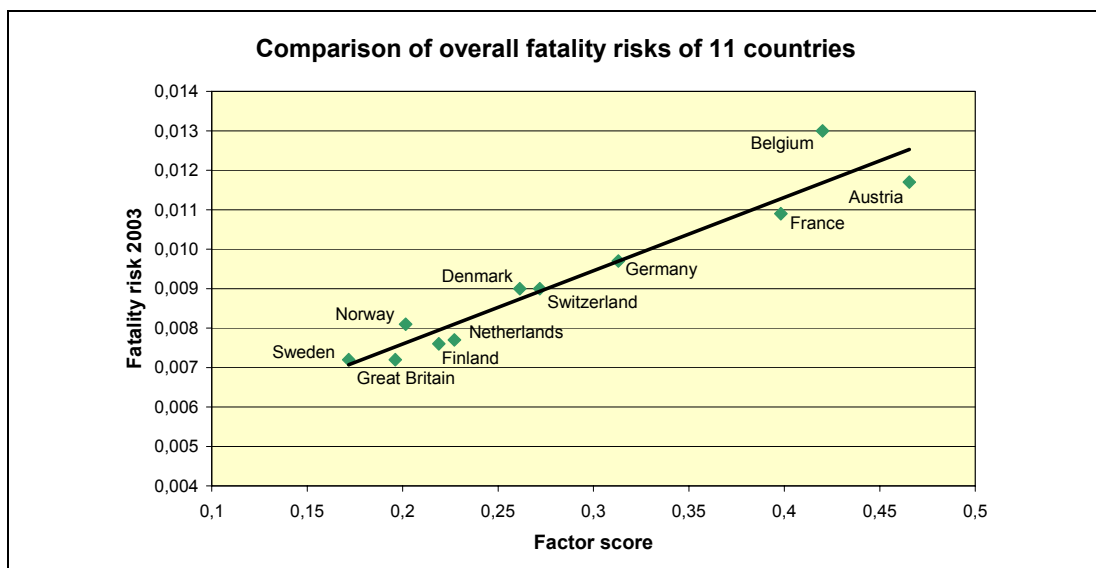
Figure 5.4. *Comparison of overall fatality risk, expressed by factor score and the fatality risk in 2003 (fatalities per 1000 vehicle kilometres) for 11 countries, together with a linear trend*.

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5.3. Trends in fatality risks and rates for individual countries

For all European countries with available vehicle kilometre or vehicle data, the Harvey structural time series model is used to analyse time trends for the number of fatalities. The total annual number of road fatalities in each country was used as an indicator for road safety. Whenever available the annual total number of motor vehicle kilometres driven was used as an indicator for the exposure in a country; if this was not available the annual figures for the total number of motor vehicles in a country was used for this purpose instead.

5.3.1. Model structure

For each country a bivariate local linear trend model, called the latent risk model, was used to estimate macroscopic trends and forecasts for the developments of road safety and exposure. Whereas in a classical regression model the intercept and the regression coefficient of the linear regression of a dependent variable in time are fixed, and do not change over time, in a local linear trend model these two parameters are typically allowed to change from time point to time point. In this context the time-varying intercept and the regression weight are called the level and the slope component, respectively.

The latent risk model is a special kind of state space method for the analysis of time series (Harvey, 1989; Durbin & Koopman, 2001; Commandeur & Koopman, 2007). In the latent risk model the development of road safety is assumed to be the product of the developments of two latent, unobserved factors: exposure and risk, see also Bijleveld et al. (2008). The model requires the estimation of 13 parameters: 3 for the disturbance variances of the mobility and fatality figures including their covariance, another 3 for the disturbance variances of the level components of exposure and risk including their covariance, yet another 3 for the disturbance variances of the slope components of exposure and risk including their covariance, and, finally, 4 parameters for the initial values of the two level and the two slope components.

The model input data consists of the number of fatalities and vehicle kilometres per year. The specific model structure is given in Appendix 6.

5.3.2. Results for three countries

In this section the outcomes of the time series analysis will be described in detail for three countries. The results for all countries are given in Appendix 7.

Figure 5.5 shows the observed fatality numbers (marked with +) for France from 1970 till 2006, together with model values and error bounds. At the end of the observation period forecasts are made for the next three years. It is seen that the error bounds in the beginning are wide, due to a low value for the observed number of fatalities in 1970 and the uncertainty of the model for the beginning of the period. The error bounds become narrower at the end of the curve, probably due to the smoother risk-curve. The error bounds are also wide for the forecast values, probably because of the substantial jumps in the number of vehicle kilometres over the whole period.

Overall, the majority of observations are located within the error bounds. Differences between observed values and the prediction line indicate the extent of random fluctuations. Such deviations should not be interpreted as significant changes.

Initially, the error bounds are rather wide because there is no information from previous years. After a few years the error bounds become narrower. Sometimes the bounds become wider at some points, because unexpected events (sudden changes in risk and/or motorization) were observed.

Figure 5.5. *Observed and predicted annual fatality numbers for France, using motor vehicle kilometre figures and fatalities in Harvey's structural time series model*.
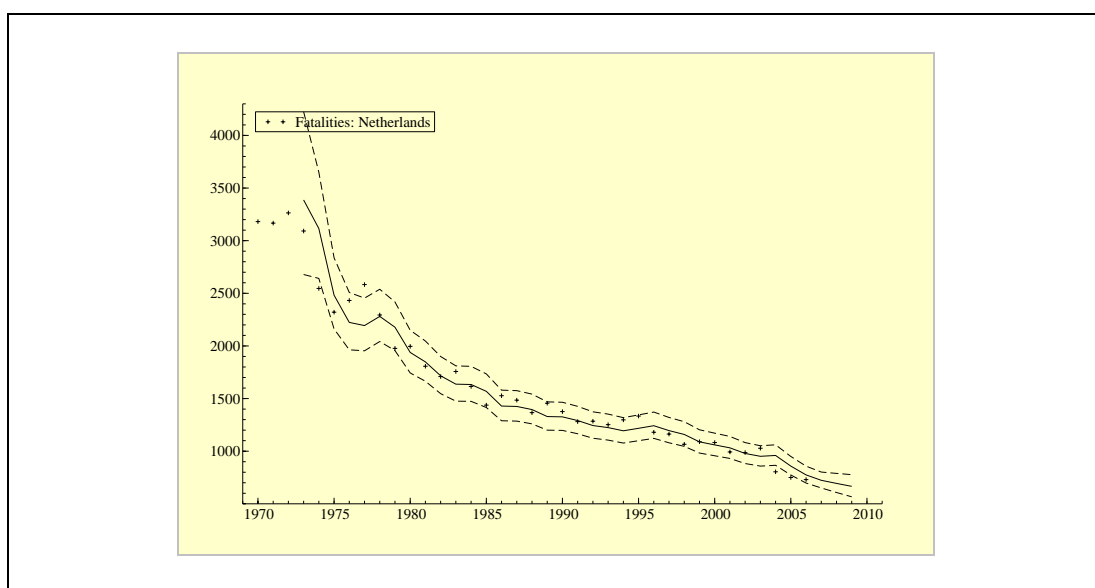
Figure 5.6. *Observed and predicted fatality numbers for the Netherlands, using motor vehicle kilometre figures and fatalities in Harvey's structural time series model*.

Figure 5.6 shows a somewhat different result for the Netherlands. The error bounds are wider, only partly due to the fact that there are fewer observations in a smaller country. The curve is even more unstable at the beginning of the observation period. Here the error bounds also become narrower at the end of the series. There are

three observations at the end of the observation period that are outside or just inside the error bounds. The estimation curve shows a dip just before that period. However, the three values are still extremely low. Therefore, this looks like a significant drop in the number of fatalities, asking for an explanation. However, the error bounds for the next three forecasted years remain reasonably narrow, despite this drop. This indicates that the drop is interpreted by the program as part of a trend and not as an incidental fluctuation.

Figure 5.7 shows the observed and predicted fatality numbers for Greece. Because motor vehicle kilometre data is missing, vehicle fleet data and fatalities are used. This figure shows that the linear trend model is flexible enough to cope with substantial changes in the shape of the curve. For almost all countries a steady increase in the number of fatalities, followed by a steady decrease is found for the number of fatalities. For some countries the increase in the number of fatalities is before 1975 and therefore not visible in the analysis from 1975 onwards. The model can cope with an initial increase in fatalities, later followed by a consistent decrease, because the basic developments used in the model are the vehicle kilometres or fleet data and the fatality risks or rates, and these developments in principle show a monotone increase and decrease respectively. The initially strong increase in the number of vehicles and thus in vehicle kilometres levels off in later years, while the fatality risk and rate decrease steadily. At the point where the exposure starts to level off, the maximum number of fatalities is found. If these developments are rather smooth, then the error bounds on the fatalities will not change. However, the uncertainty that results from incidental jumps is reflected in the wider error bounds at some of the periods and the very wide error bounds for the forecast period of three years.
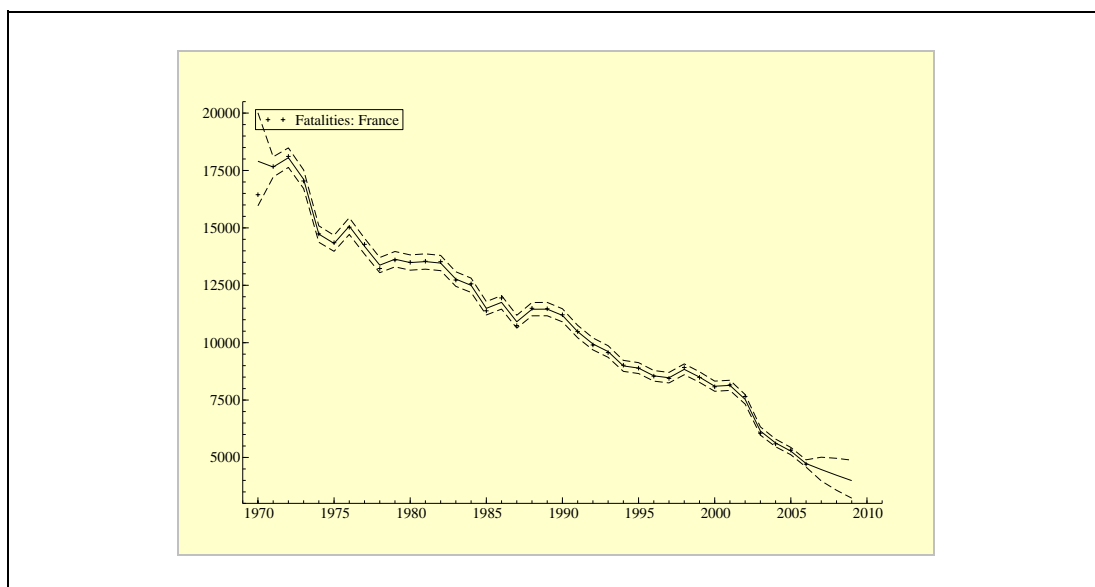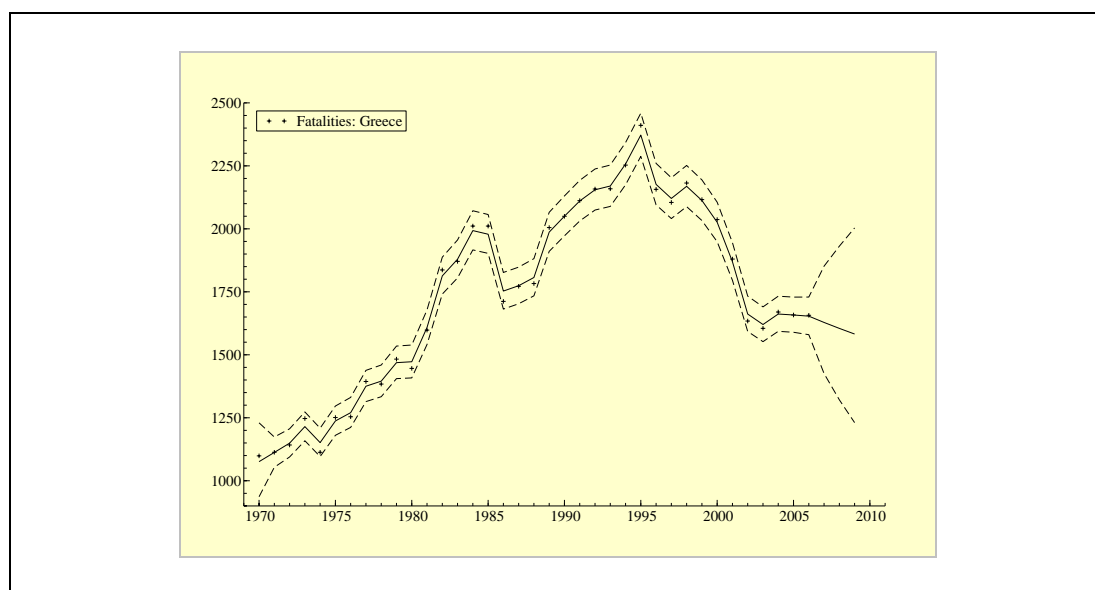

Figure 5.7. *Observed and predicted fatality numbers for Greece, using vehicle fleet figures and fatalities in Harvey's structural time series model*.

In general, it can be observed in all three graphs that changes in the number of fatalities from year to year are almost always within the error bounds. This means that year-to-year changes which are sometimes considerable, as is the case for

Greece in the mid-1980s, are either explained by sudden changes in exposure, or by mere chance.

5.4. Trends of fatality rates for grouped countries

Using the final grouping of countries from Section 4.4, a series of SVD analyses were carried out on the data of the four groups. It turned out that for all groups the first dimension was again the most important. The eigenvalues and the percentages of explained variance by the first dimension are given in Table 5.1. For group 3 the analysis in two dimensions gives a perfect fit, because only two countries were used.

	Eigenvalues			% Explained variance by
	Dimension 1	Dimension 2	Dimension 3	
Group 1	5.426	0.561	0.248	98.58
Group 2	9.602	0.729	0.545	98.96
Group 3	4.050	0.427		98.90
Group 4	10.772	0.971	0.422	99.04

Table 5.1. *Eigenvalues and the percentage of variance explained by the first dimension from four SVD analyses of fatality rates in four groups of countries*.

The trends of the first dimension for the four groups are given in Figure 5.8. The trends are normalized such that the sum of squares of all values is 1. Because group 3 only has rates from 1981 onward, its graph shows higher average values than the graphs of the other groups.

The trends for group 1 and 2 are rather similar. The trends for group 3 and 4 have peak values around 1990.
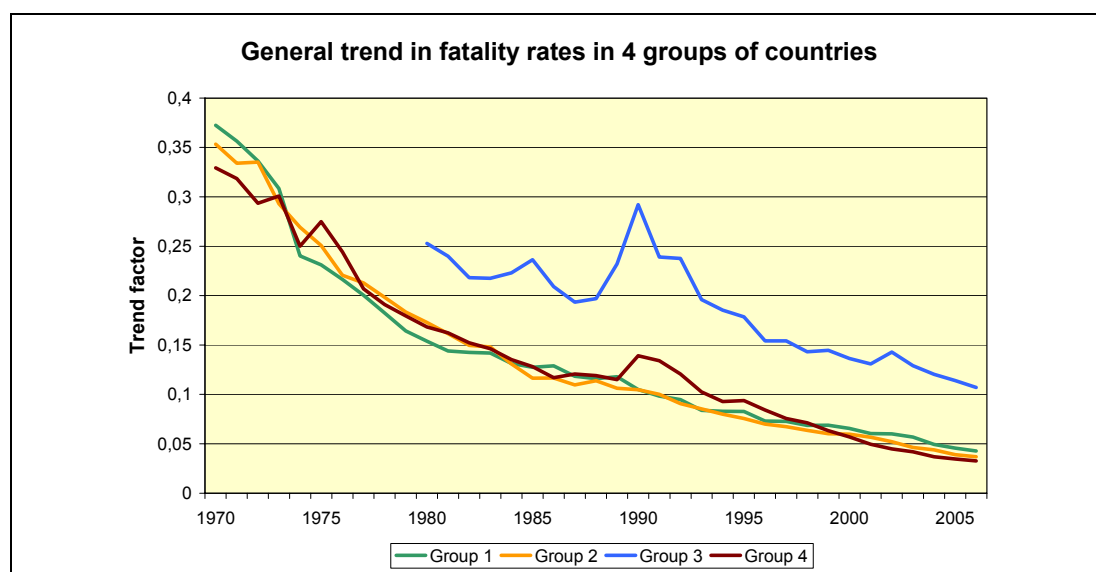
Figure 5.8. *General trend (first dimension) in fatality rates, resulting from SVD analysis of four groups of countries*.

The factor scores for the countries are given in Table 5.2. These factor scores can only be compared within groups. A comparison of these factor scores for all countries was given in the second column of Table 4.2.

Group 1		Group 2		Group 3		Group 4	
Country	Factor score	Country	Factor score	Country	Factor score	Country	Factor score
Denmark	0.441	Austria	0.467	Czech Republic	0.458	Greece	0.644
Finland	0.543	Belgium	0.368	Hungary	0.889	Portugal	0.673
Great Britain	0.317	France	0.372			Spain	0.363
The Netherlands	0.519	Germany	0.301				
Norway	0.257	Ireland	0.357				
Sweden	0.274	Italy	0.261				
		Luxembourg	0.387				
		Switzerland	0.269				

Table 5.2. *Factor scores for the countries per group for the first dimension.*

The residuals from the first dimension for each country in each group are given in Figure 5.9a-d.

In the first group (Figure 5.9a), the Netherlands and Finland show a better improvement from 1980 onward than the other countries. Especially Denmark lags behind during this period.
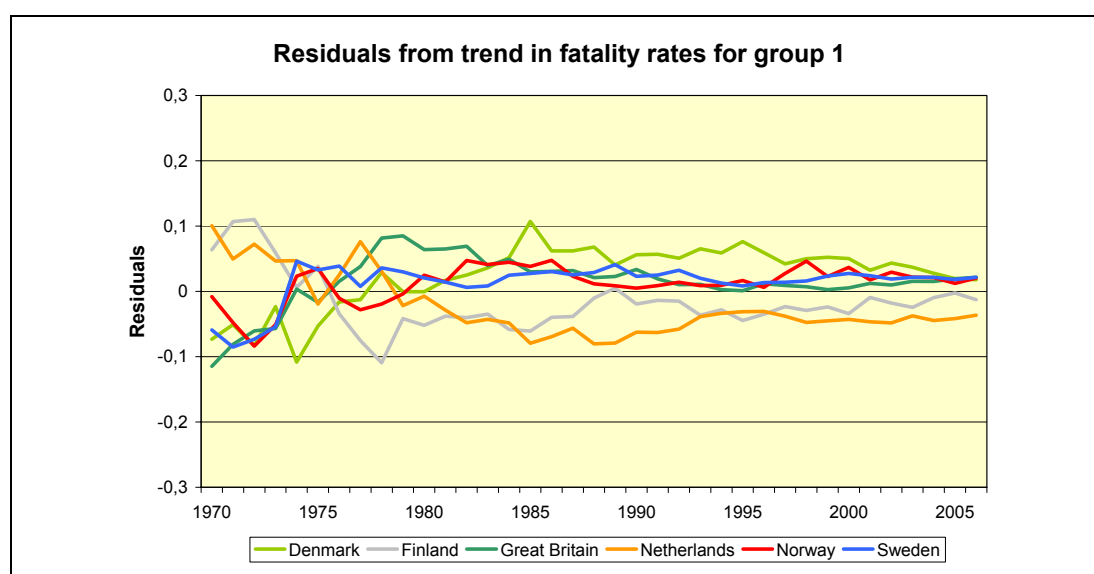
Figure 5.9a. *Residuals from the first dimension of an SVD analysis of the fatality rates of country group 1.*

In the second group (Figure 5.9b) there seem to be two subgroups, with respectively higher and lower values during the 1980s and 1990s: higher values for Ireland, Belgium and France; lower values for Austria, Luxembourg, Switzerland, and Germany; Italy's value is between those of the subgroups. The second subgroup performs better than the first subgroup during this period.

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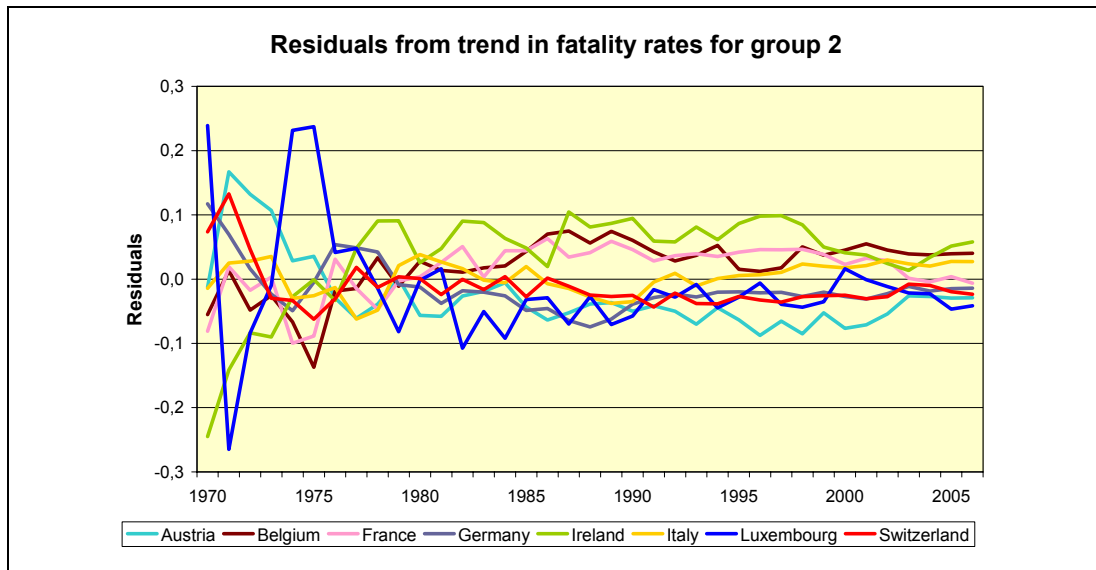
Figure 5.9b. *Residuals from the first dimension of an SVD analysis of the fatality rates of country group 2.*

Figure 5.9c shows that the Czech Republic performs better before the early 1990s, and Hungary after that period. In recent years these countries have been performing almost equally.
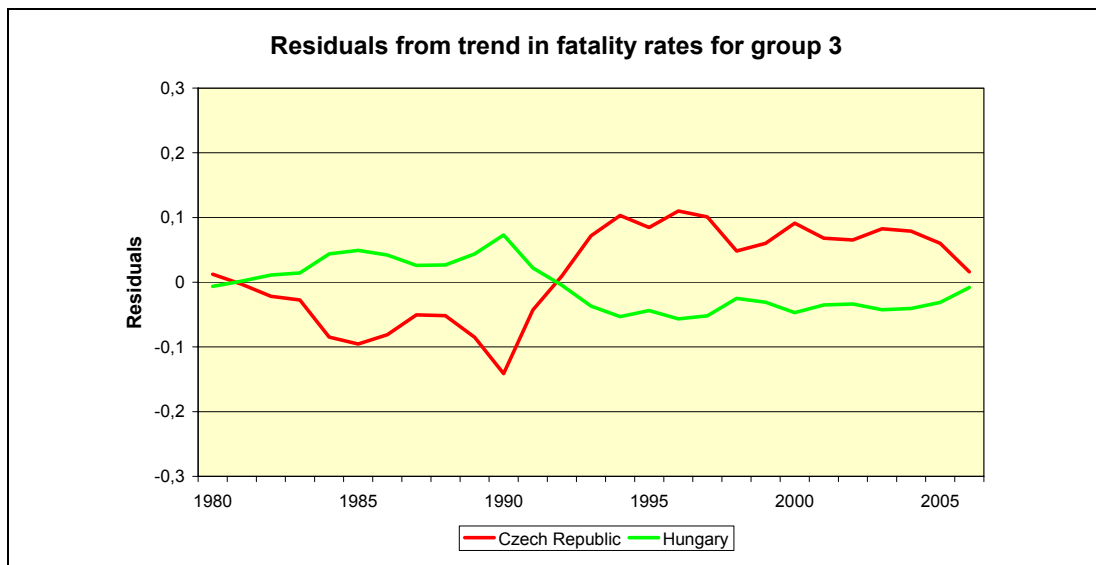
Figure 5.9c. *Residuals from the first dimension of an SVD analysis of the fatality rates of country group 3.*

Figure 5.9d shows that the increase in the fatality rate around 1990 is caused by Spain and Portugal; the residuals for Greece are highly negative during that period. From 1994 onward the fatality rate developments are more similar for the three countries.
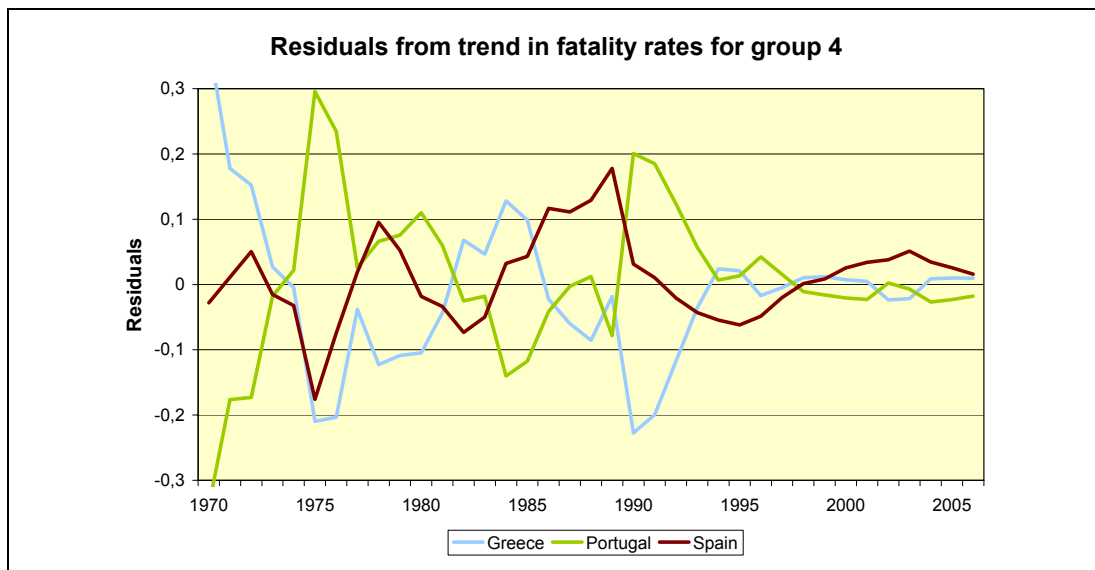
Figure 5.9d. *Residuals from the first dimension of an SVD analysis of the fatality rates of country group 4.*

Finally, an SVD analysis was carried out on the fatality rates of group 1 and group 2 together. For this analysis the numbers of fatalities for all countries in group 1 were added together and divided by the total number of vehicles for these countries. The same was done for group 2. The percentage of explained variance for the first dimension is 99.87%. Figure 5.10 shows this general trend, together with an exponential best fit.
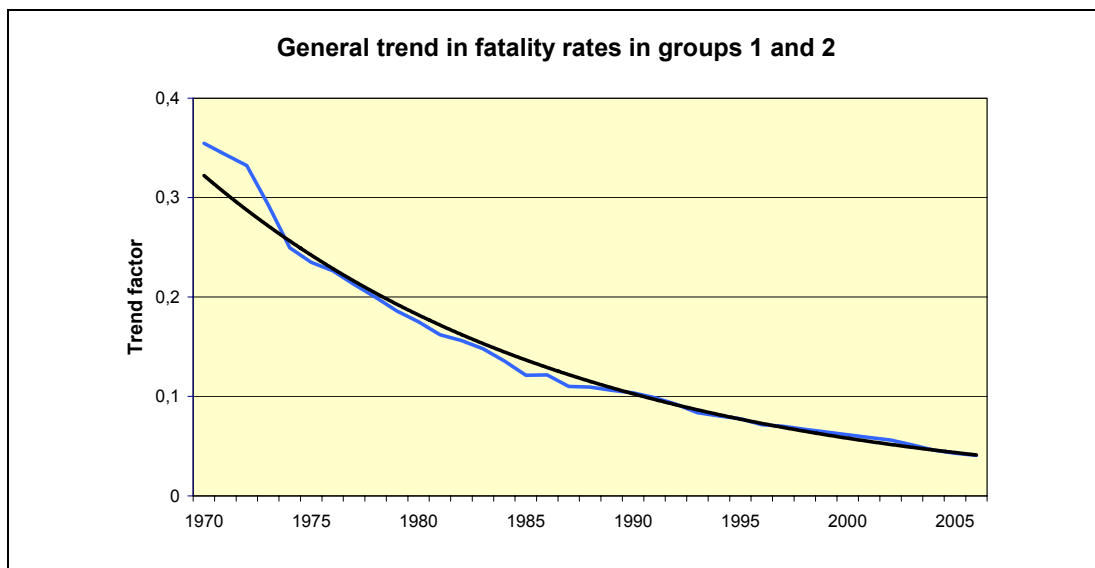
Figure 5.10. *General trend (first dimension) in fatality rates, resulting from SVD analysis of group 1 and group 2, together with the best fitting exponential trend.*

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Residuals from trend in fatality rates in groups 1 and 2
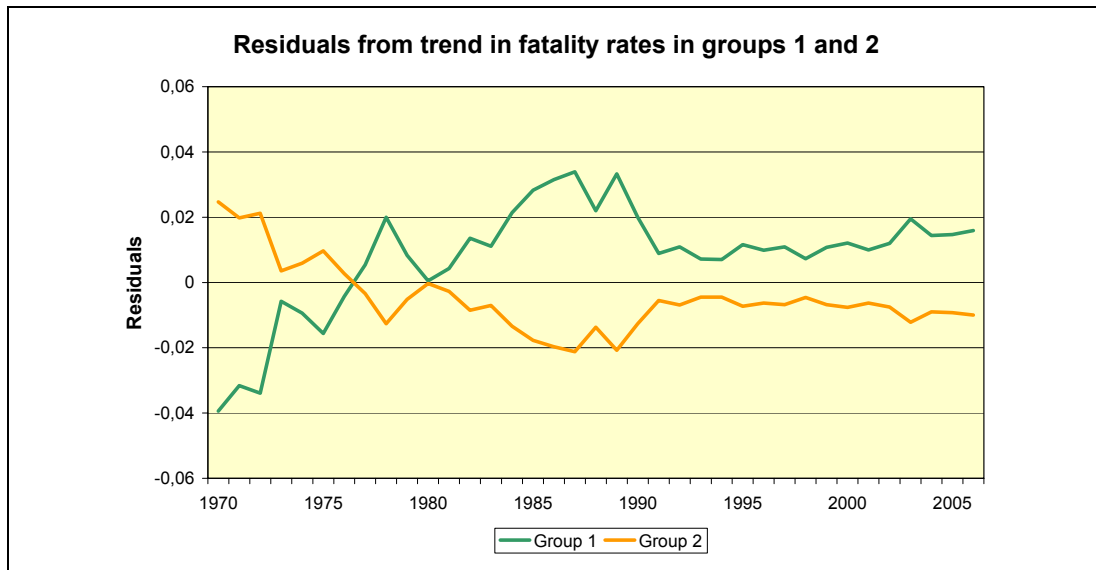
Figure 5.11. *Residuals from an SVD analysis of the fatality rates in group 1 and group 2.*

Figure 5.11 gives the residuals for both groups. These values, varying from 0.04 to -0.04, are rather small, but systematic.

In the beginning of the 1970s group 1 performs better than group 2. From the late 1970s until the 1990s a reversed trend can be noticed, which shows that group 2 performs better than group 1. This is the same period for which the dimension values deviate most from the exponential fit which is given in Figure 5.10. The better performance of group 2 is still present in recent years, although to a lesser extent.

If we look at the four Figure 5.9a-d, we see that in all groups the safety developments tend to become more and more similar in the later years. It is as if all European countries aspire to a common safety policy and position. This tendency agrees with the picture in Figure 5.1, which shows the developments in fatality rate and mortality rate. There smoother curves for all countries in the direction of the 0-0 point can also be observed in recent years.

5.5.　Analysis of disaggregate data for groups of countries

Using the selected group structure, three types of disaggregate developments are compared for the countries within groups. The disaggregate data concern age, traffic mode and road type. Some developments will be described in detail in this section. All disaggregate developments are given in Appendix 8.

In order to make comparisons easier, all data are summed over the years in five-year blocks, from 1970-1974, ..., to 2000-2004. The last block consists of the years 2005-2007, as far as data is available for these years.

Age is classified in four categories: 0-14 years, 15-24 years, 25-64 years and 65+ years. For each country, the fatalities in each age group are summed over the years in each 5-year block and divided by the total number of fatalities in that 5-year block. These results are pictured in graphs (Figure 5.12a-d and Appendix 8). The group

average is also added to each graph. This way each country can be compared with every other country in the group and with the group average.

Traffic mode is classified in three categories: 4-wheel motorized, 2-wheel motorized and non-motorized. Again, the share of fatalities for each transport mode related to the total number of fatalities is computed and the results and the group average are added to the graphs of each group (Figure 5.13a-d and Appendix 8).

Road type is classified in three categories: urban roads, country roads and motorways. The same procedure is used for this disaggregate data (Figure 5.14a-d and Appendix 8).

For each group, each disaggregation, and each category this data is plotted, resulting in 4 x 4 + 4 x 3 + 4 x 3 = 40 graphs in Appendix 8. Only one category for each group and one disaggregation will be presented in this section.

For group 1 (Figure 5.12a) one might say that the proportion of children among road fatalities decreased from around 11 percent in the early 1970s to around 3 percent around 2005. Overall, Sweden has the lowest share of children in road fatalities; Norway has the largest decrease, from around 16 percent to 2 percent.
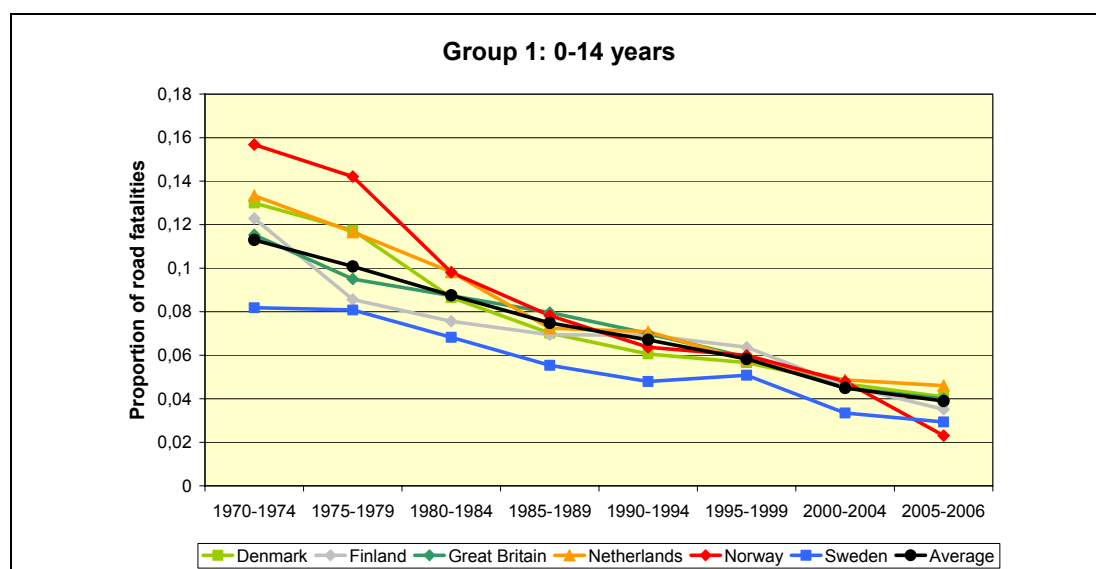
Figure 5.12a. *The proportion of 0-14 year old children in the road fatalities of group 1.*

Figure 5.12b shows that the proportions in group 2 are similar for most countries except for Ireland and Luxembourg. The proportion of children in road fatalities is approximately 9 percent in the early 1970s; this percentage is lower than for group 1. The share of children in road fatalities decreased to around 3 percent after 2000, a percentage that is comparable to that in group 1. The drop is most evident for Ireland: a fall from around 12 percent in 1980 to almost 2 percent in 2005. The data for (the small country) Luxembourg is a bit unstable. Since the 1980s, Italy has by far the smallest proportion.
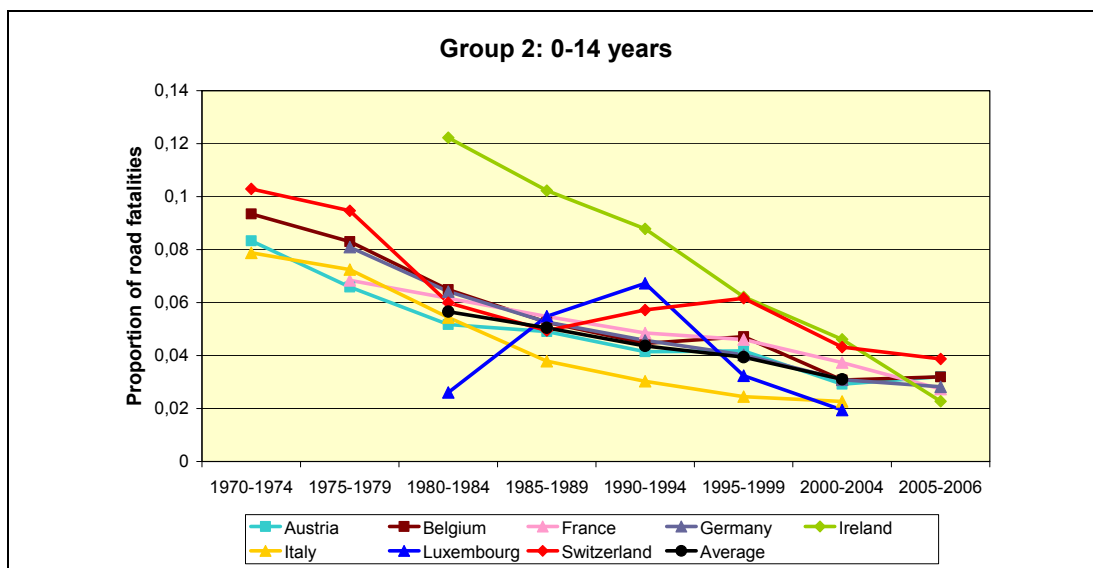
Figure 5.12b. *The proportion of 0-14 year old children in the road fatalities of group 2.*

Groups 3 and 4 (Figure 5.12c and d) show the same general picture: a drop over time to a final 3 percent in recent years for group 3 and two percent for group 4.
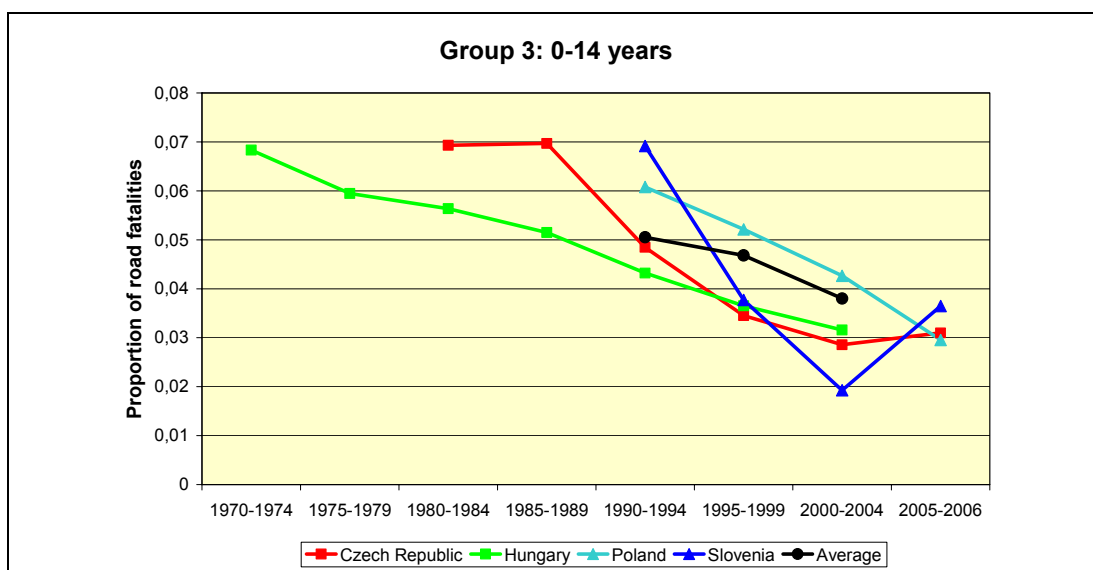
Figure 5.12c. *The proportion of 0-14 year old children in the road fatalities of group 3.*
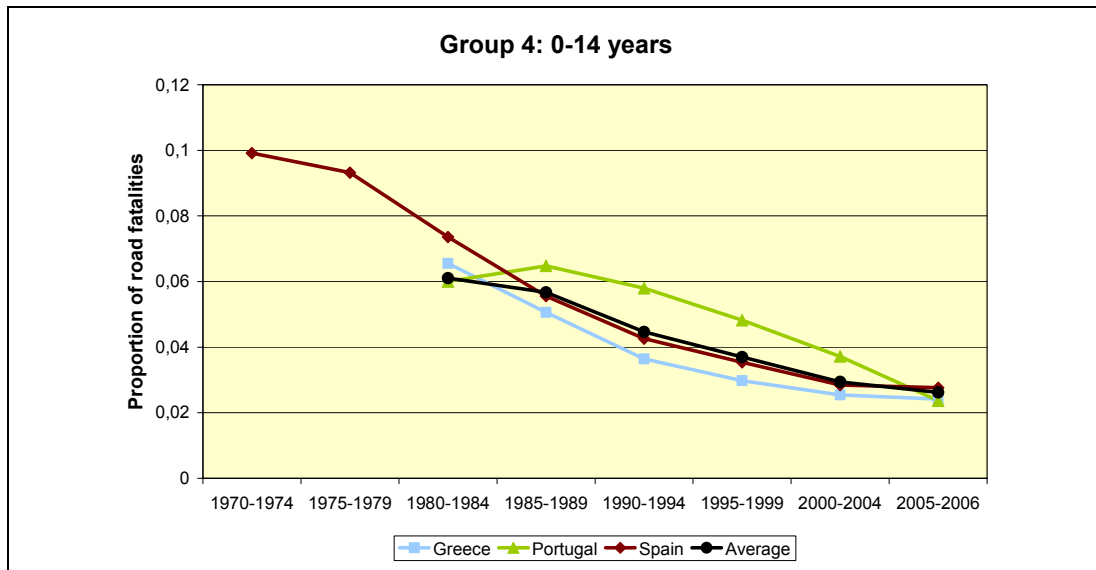
Figure 5.12d. *The proportion of 0-14 year old children in the road fatalities of group 4.*

If the outcomes of the four groups are compared, the proportion of fatalities for young children can be seen to decrease with time for all groups. Initially, the variation between groups and within groups is larger than in recent years. For groups 1, 2 and 3 the proportion is around 3 percent in recent years. The southern countries (Italy included) have the lowest percentage of fatalities among children between 0-14 years old. In those countries this percentage has been just above 2 percent in recent years.

Figure 5.13a-d show the proportions of non-motorized road users in fatal crashes. From group 1 (Figure 5.13a) it follows that all countries show the same decreasing trend for the proportion of non-motorized road fatalities as for that of the children. The percentages decrease from around 35 percent to 25 percent. Of course this is partly due to overlap: many of the non-motorized road users are children. Sweden, Norway and Iceland do better in this respect than the other countries in group 1.

For group 2 (Figure 5.13b) the decrease is a bit higher, from around 35 to 20 percent. Once more, the proportion is highest for Ireland, but from the 1990s onward the decrease continues to reach the group average in approximately 2005. The percentage is lowest for France.
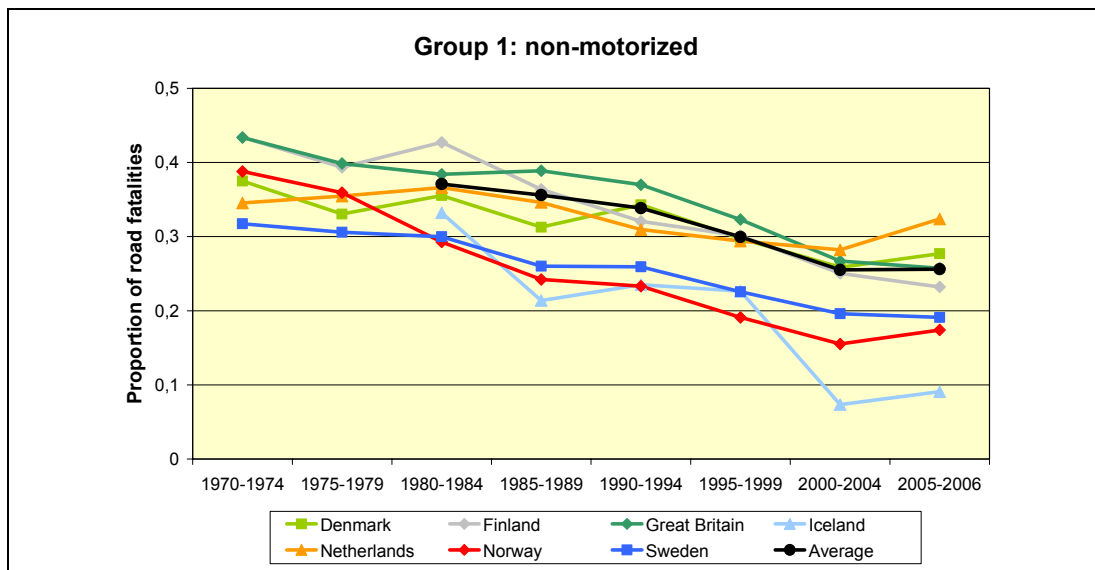
Figure 5.13a. *The proportion of non-motorized road users in the road fatalities of group 1*.
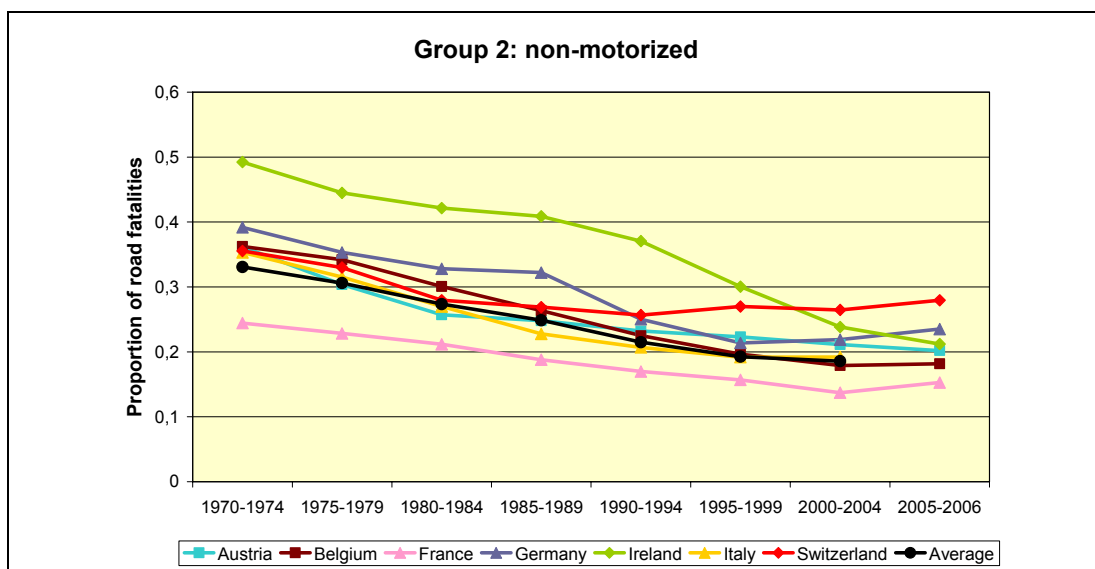
Figure 5.13b. *The proportion of non-motorized road users in the road fatalities of group 2*.

The situation is different for group 3 (Figure 5.13c). Here the drop is from around 50 percent to 40 percent non-motorized victims. Only Slovenia is doing much better, and its performance can be compared with group 2.

Group 4 (Figure 5.13d) is also comparable to group 2, with a drop from 35 percent to 20 percent.
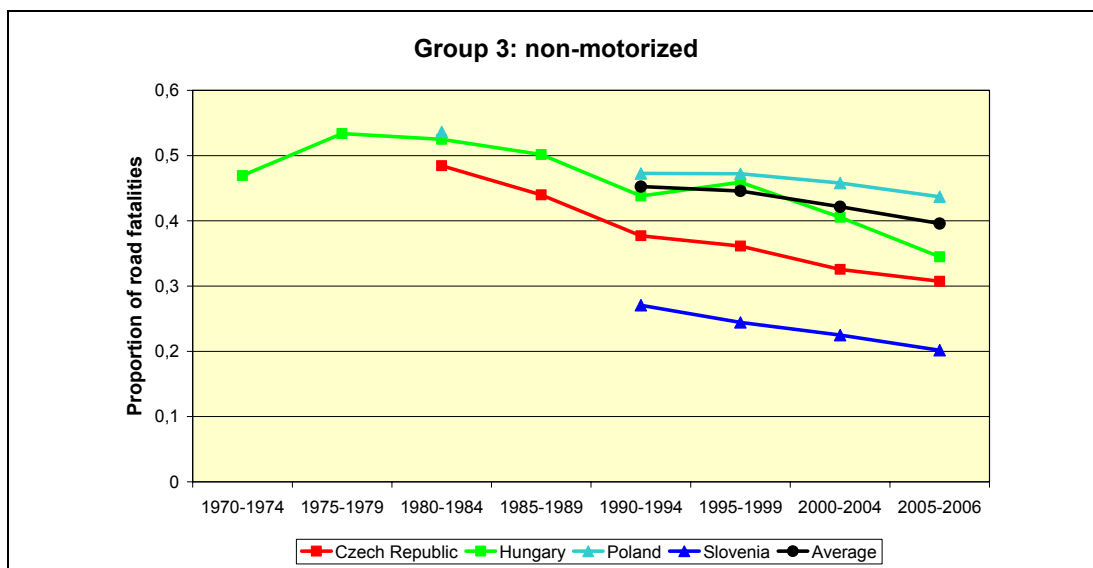
Figure 5.13c. *The proportion of non-motorized road users in the road fatalities of group 3.*
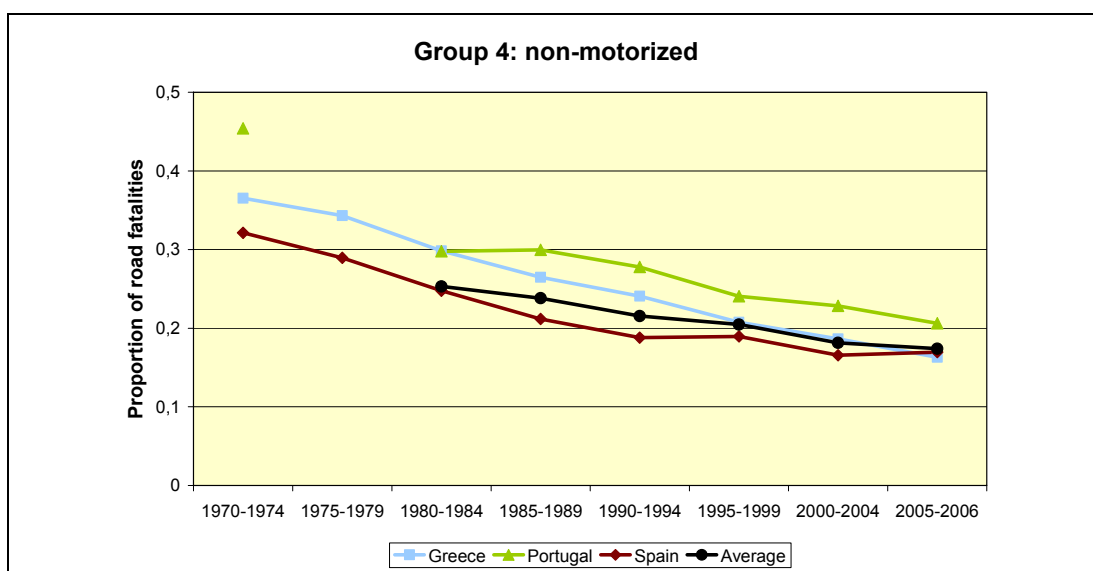
Figure 5.13d. *The proportion of non-motorized road users in the road fatalities of group 4.*

All groups again show a tendency for the percentage of non-motorized victims to decrease over time. In contrast with the previous decrease in the share of children, however, initial differences between countries within groups seem to remain unchanged over time. This results in larger differences between countries within groups, as well as between groups in recent years.

It should be realized that the observed drops in share of non-motorized victims (and the previous ones for children) are relative, compared to the fatalities for motorized road users (or other age groups). However, given the steady overall decrease in the number of fatalities over the years it can still be said that the drops in the number of fatalities for non-motorized road users and children are the most significant. Road

use has become much safer for the most vulnerable road users during the last 35 years.

Figure 5.14a-d show the proportions of fatalities on urban roads. Figure 5.14a shows a general tendency for this proportion to decrease over time. Of group 1, Great Britain has the highest overall percentage, while Finland and Sweden have the smallest proportion of fatalities on urban roads.

Notwithstanding the overlap with the group of children and the non-motorized road users, the drop from around 40 percent to around 30 percent is smaller and more diverse for the fatalities on urban roads than for the young victims in this group of countries.
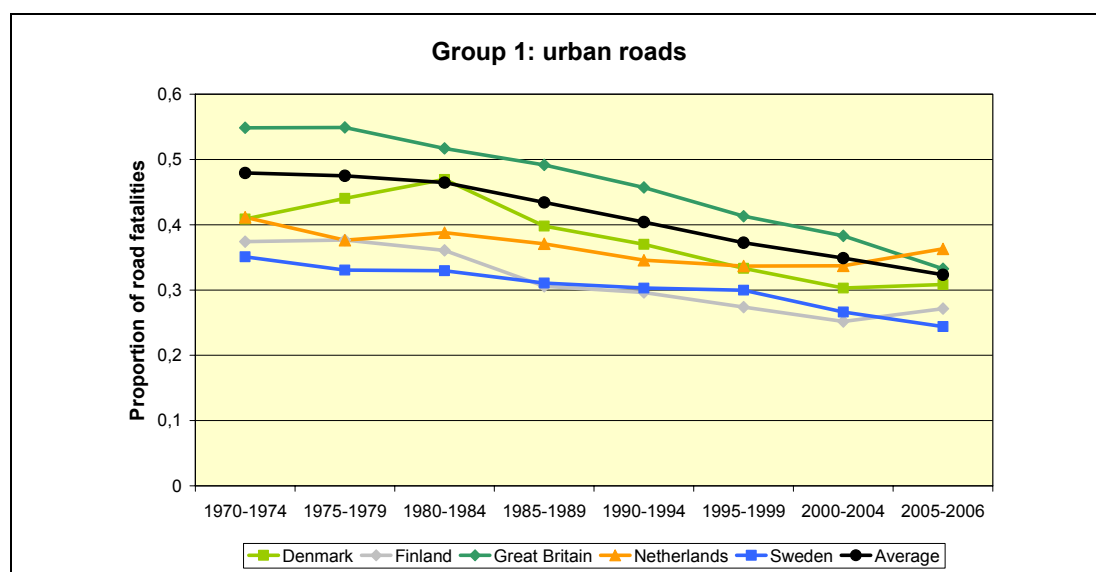
Figure 5.14a. *The proportion of fatalities on urban roads in countries of group 1*.

The same pattern is seen for group 2 (Figure 5.14b). Here the drop is also from around 40 percent to around 30 percent and the variation between countries is much larger than was the case for the proportion of 0-14 year old victims. All countries show this decrease in share of fatalities on urban roads, except Italy.

For group 3 (Figure 5.14c) the share of fatalities on urban roads drop from around 55 percent to 43 percent. These percentages are considerably higher than for groups 1 and 2. The proportions for Slovenia are again considerably lower than those for the other countries in group 3.
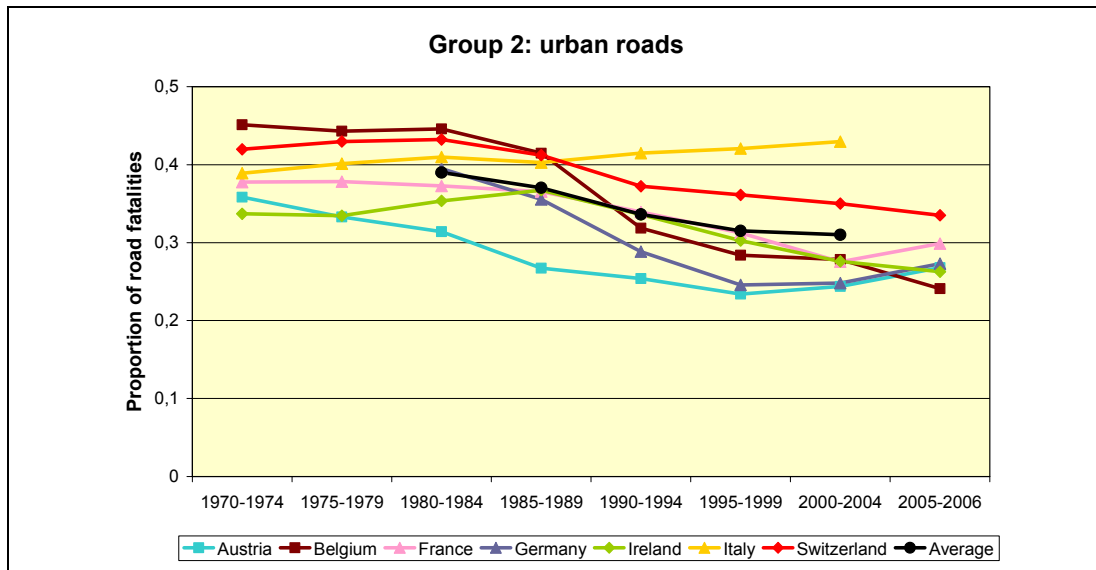
Figure 5.14b. *The proportion of fatalities on urban roads in countries of group 2.*
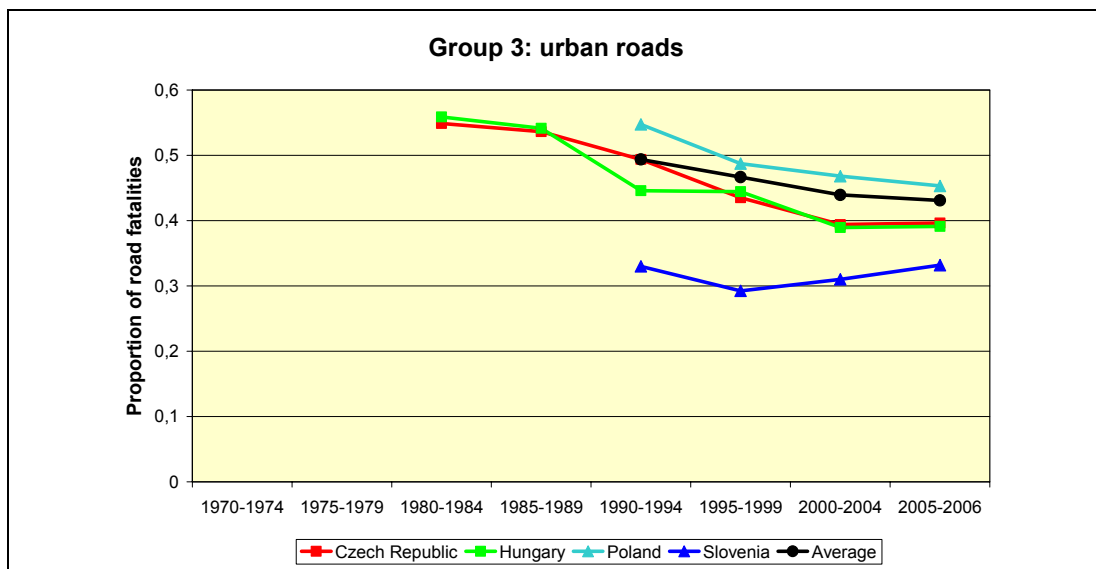
Figure 5.14c. *The proportion of fatalities on urban roads in countries of group 3.*

For group 4 (Figure 5.14d) only data from Portugal and Spain is available. Here we see a completely different trend. The percentages are very different but stable over time. For Portugal the percentage is around 45% and for Spain around 18%. Because there is a major overlap of fatalities on urban roads with age and travel mode, this suggests that the relative safety on urban roads has deteriorated since the 1980s. The same conclusion was already found for Italy, where the proportion even increased over time. In this respect the southern countries differ strongly from the other groups.

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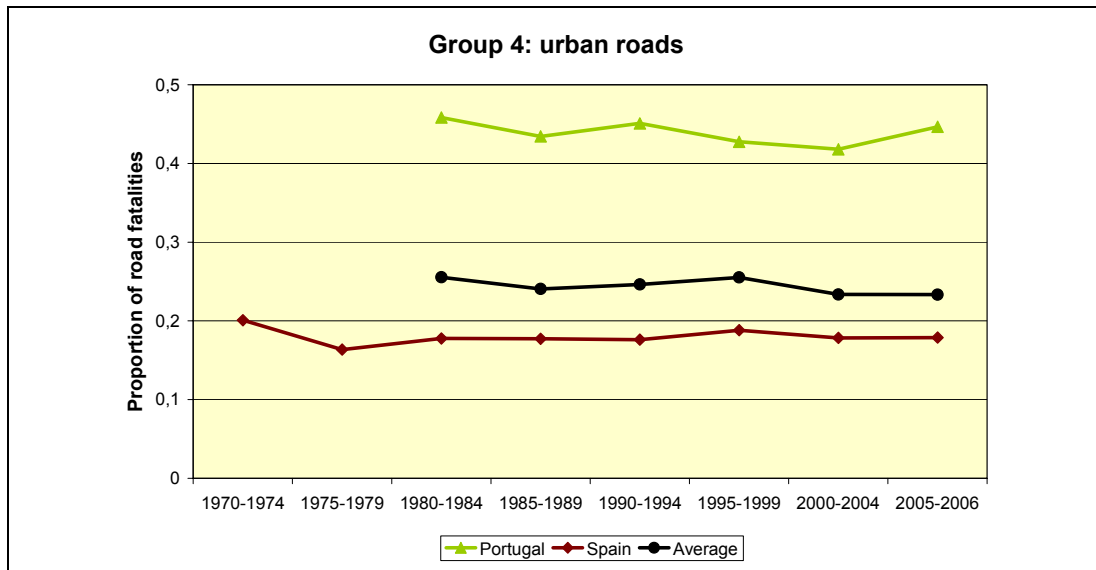
Figure 5.14d. *The proportion of fatalities on urban roads in countries of group 4.*

5.6. Conclusions and recommendations

Inspecting all these graphs and – more generally – all the results of the analyses discussed in this chapter, we may conclude that all European countries tend towards the same aggregated or macroscopic level of road safety (combination of personal safety and traffic safety) however the speed of improvements differ. When considering their focus on avoiding special types of accidents, there are important differences between the individual countries as well as between groups of similar countries in terms of how they reach this level of road safety. In other words, the general policy of improving road safety in each country ultimately could result in the same level of safety as that in other counties, but that level is achieved in different ways for different countries tackling different types of problems. More detailed analyses, such as those carried out in earlier SUNflower studies, are needed to understand these differences. It is recommended to carry out these analyses using methodologies such as SVD analysis and structural time series analysis.

6.   Application of SUNflower at regional or city level

SUNflower analyses to date have focussed on national comparisons and the lessons that can be learned by individual countries when comparing their road safety policies and resulting performance with that of other countries. A similar scope exists for the comparison of programmes and their performance at the sub-national level which consists of regions and municipalities.

In principle, such comparisons could be made at any level where an authority can pursue its own safety programme and policies or where developments in motorization or in economic activity result in changes in traffic levels by different modes, leading to changes in safety outcomes. Given the fact that policies were applied centrally by national authorities, it is straightforward to expect such comparisons to be most fruitful at national level. But in general, a comparison of performance is likely to be rewarding where the authority has sufficient autonomy to significantly influence the progress of safety performance in its area, and where the area is large enough to yield sufficient accident data to enable robust comparison of output measures. This is likely to be the case for either regions or large individual cities.

Historically, in Europe cities and regions have played an essential role in the formation of national-states and national societies. European integration has contributed to a certain relaxation of the 'constraints of state' and cities and regions have emerged as one possible level for regulation of interests, groups and institutions. Large national supervisory organizations and institutions have been losing their dominance in the context in which there is no longer one single centre where governance is concentrated and the sub-national levels should be considered to be of the same order as those of states or of the European Union. We have already been witnessing a movement in the redistribution of political power away from Member states to the advantage of sub-national governments (Hooghe, 1996; Le Galés, 1998). European structural funds in particular, have contributed to the development of the European polycentric governance. In parallel, the 'new governance' that is emerging is concerned with 'soft' forms of policy-making based on voluntary commitment, coordination in place of authoritative instruction, and subordination to common goals. In this context, new actors (stake-holders) appear on the stage, having something to say about road safety. It can be claimed, that territories have become the trial fields of numerous advances in road safety science, such as ISA, Alcolock, or the shared-space urban road design concept. Cities and regions should however not be seen only in the terms of governance, but also as behaviour-shaping areas, with their own culture, norms and habits.

Although the sub-national road safety performance will be influenced in part by national policies (just as national polices are influenced by international vehicle regulations), comparison at the lower level could be particularly useful where there are substantial differences in mobility patterns, social-economical conditions, residential and industrial densities or road network patterns, or where specific policies which are not evident on a national basis have been followed locally. The territorial level pertinent for such analysis should be given by the governance structure of a particular country.

Initial SUNflower comparisons of Sweden, the United Kingdom, and the Netherlands reflected that these three countries had reached similar levels of safety performance

(in terms of overall national statistics) despite the differences in population density and road networks. It was of interest therefore to see how this had been achieved. Each country was faced with similar general problems in terms of risk in driving behaviour – speeding, drinking and driving, seatbelt wearing - and their performance in these areas could therefore be compared directly. Lessons learned might be directly transferable. The observed differences in modal split reflected both cultural and spatial differences, which in turn partly reflect differences in population density, accessibility, social deprivation, but also investment in road networks. Each country was faced therefore with specific issues in tackling its own modal safety problems – e.g. cyclists and moped riders in the Netherlands, pedestrians and motorcyclists in the UK. The size of these specific safety problems and the extent to which each country had been effective in tackling their own major accident contributors would be reflected in the national casualty rates.

Thus there is a potential for innovation in terms of knowledge and road safety improvements which can be achieved through an approach which has so far been left unexploited: the application of the SUNflower method at sub-national level. The potential beneficiaries are not only local administrations, in preparing and applying programmes and policies at local level, but also national administrations in better understanding of structural factors influencing the application and results of road safety policies. The application at the sub-national level might however require a rethink and an adjustment of the method which has so far been applied at the national level. The purpose of this chapter is to explore the potential for comparisons of safety performance at the sub-national level and to propose methods allowing reliable comparison.

6.1.   Differences in application at the sub-national level

The differences between individual regions are averaged out when national accident statistics are quoted. When comparing road safety outcomes at a regional level or below, it is necessary for any rational analysis of road safety outcomes to take into account substantial structural differences such as demography, urbanization, social deprivation, which have a direct impact on accident risk factors, such as traffic volume, flow composition, traffic speed, and road network layout.

Some account of these factors can be taken at the national level by analysing using rural and urban statistics, or by looking at road user groups separately where those groups (e.g. pedestrians) are likely to be primarily at risk in urban environments. Similarly, analysis by separate road groups allows some difference between types of area to be shown. But such analyses, for example, still average all data from urban areas together rather than enabling differences between different urban areas to be explored. Also the traffic performance of some transport modes, for example powered two-wheelers, differs between urban and rural areas, which results in different modal patterns in these areas.

Similar problems arise when regions are compared which mainly reflect a sub-set of national data, with similar proportions of urban and rural environments, and a similar range of policies. To understand more fully the factors driving differences between safety performance it is therefore important to seek areas with differences in mobility patterns, modal split, network configurations, or in safety programmes or in attitudes towards safety improvement, either culturally or organizationally.

At the sub-national level there are a number of methodological issues which need to be considered compared to national approach. First, there are significant differences in the definitions of regions, which may have very different properties. For example, there are different ways of defining urban regions: administrative approach (legal/administrative status), morphological status (extent/continuity of urban space) and functional approach (core area vs. surrounding territory). So, clearly, the data compatibility remains an important issue. Second, analyses of aggregated data bring along potential errors in the interpretation of statistical data, such as Modifiable Area Unit Problem (MAUP), or ecological fallacy. The studies which compare lower administration areas are more likely to suffer from MAUP and ecological fallacy.

6.1.1. Potential uses of sub-national comparison

There are two basic reasons for comparing the safety performance of sub-national areas.

The first is to provide a ranking of the relative performance of each area – this will be most useful for comparison within countries. To do this in a meaningful way, factors which affect the ability of safety practitioners to achieve similar improvements in safety need to be included within the ranking process. This could be done by developing a model of safety outcomes which includes these factors.

The second is to provide better understanding of the factors affecting safety improvement, so that safety practitioners can achieve more effective programmes. This requires greater focus on understanding how the effects of programmes are modified by the nature of the safety problem faced by each area. Lessons can be learned not only from comparison within countries, but also from comparison between similar areas in different countries. This might be more effectively achieved by case studies comparing small groups of areas, than by attempts to model a wide range of areas.

The areas of most interest will be those taking prime responsibility for spending local budgets on safety programmes. In some countries, these will be regions, in others they will be individual urban areas, in yet others it will be a combination of both. It is likely that a modelling approach will be more appropriate for comparing regions, while city authorities might find a case study approach more effective. But the appropriate analysis setting should be determined individually for each Member state, rather than through a blind general application of corresponding administrative boundaries. The two types of territory will be discussed separately later in this chapter.

Regions are regarded in this context as parts of a country, usually administratively defined spatial units, which combined make up the national territory; they may be of varying sizes and may be largely urban, largely rural, or a combination of urban and rural areas. Cities are defined as individual relatively large urban areas; the boundaries of a city area are likely to be those for which relevant statistical data are available because it also has a particular administrative or legal status.

6.1.2. Understanding factors affecting sub-national comparison

There are two ways to make any statistical sub-national comparison meaningful and reliable. One is to compare areas that are similar in terms of their physical structure such as road network configurations, climate, relief, mobility patterns, modal split,

and attitudes towards road safety. The second is to try to adjust for as many of these factors as possible. The former way limits the number of areas available for comparison, the latter is sensitive to data reliability and availability, and implies the use of sophisticated statistical methods which could make the comparison less understandable to broader public and bring about the risk of the use of inappropriate and confounding factors.

At the same time, no barriers exist to carry out a meaningful and reliable comparison of time trends within countries over a shorter period of time, although this may also require the use of more complex statistical models due to scarcity and fluctuation of analysed road accident outcomes. Any comparison made for a longer period of time, on the other hand, would require considering the changes in structural factors behind accident risk, such as demographical or socio-economical development.

An alternative approach, consistent with the SUNflower case studies, is to explore the factors that are present or absent in situations where good or poor safety performance appears to have been achieved. This approach allows factors that may be difficult to define in numerical terms, such as organizational efficiency or the presence of constraints on the implementation of safety policy to be considered alongside numerical characteristics of an area. The outcome of such an approach will be less quantitative but allows a potentially wider range of factors to be considered.

6.1.3. Applying the pyramid approach

6.1.3.1. Safety outcomes

Accident statistics are likely to be less robust at sub-national level than at national level. While the reliability is generally not at stake, the problem of scarcity of accident outcomes becomes a serious problem raising questions about the significance of any differences that are identified. There are two ways of overcoming these difficulties. First, it is possible to work with the accident outcomes of higher frequency (killed and serious injuries, or all injuries) and the second way is to turn to the advanced statistical methods that are commonly used in epidemiological research (e.g. Bayesian spatio-temporal models).

The matter of using an appropriate measure of safety becomes even more important at the sub-national level. The SUNflower approach uses three road safety indicators: i.e. fatalities per head of population, fatalities per licensed vehicle, and fatalities per vehicle kilometre. Safety performance within a region will be strongly influenced by the amount of vehicular travel, and thus fatalities (or injuries) per vehicle kilometre (fatality or injury risk) is likely to be the most relevant measure. While amounts of travel within a city will also be reflected in safety performance, modal split and interaction between modes become more important factors in these areas and may be included among the explanatory factors.

The most direct measure of the amount of vehicular travel in an area is the length of roads of different types multiplied by the Average Annual Daily Traffic (AADT) on these roads. In the absence of such data, an estimate of vehicle kilometres may be made by developing a relationship between the amount of travel per inhabitant (in terms of billion vehicle kilometres) and the population density. The relationship between the population density and the travel per head of population is typically exponential, which is illustrated for French regions in Figure 6.1, showing higher

traffic performance per resident population in less densely populated regions. This reflects longer commuting distances for rural area residents, greater availability of public transport services in urban areas at individual level, and more transit traffic and less commercial trips at aggregated level in rural areas.
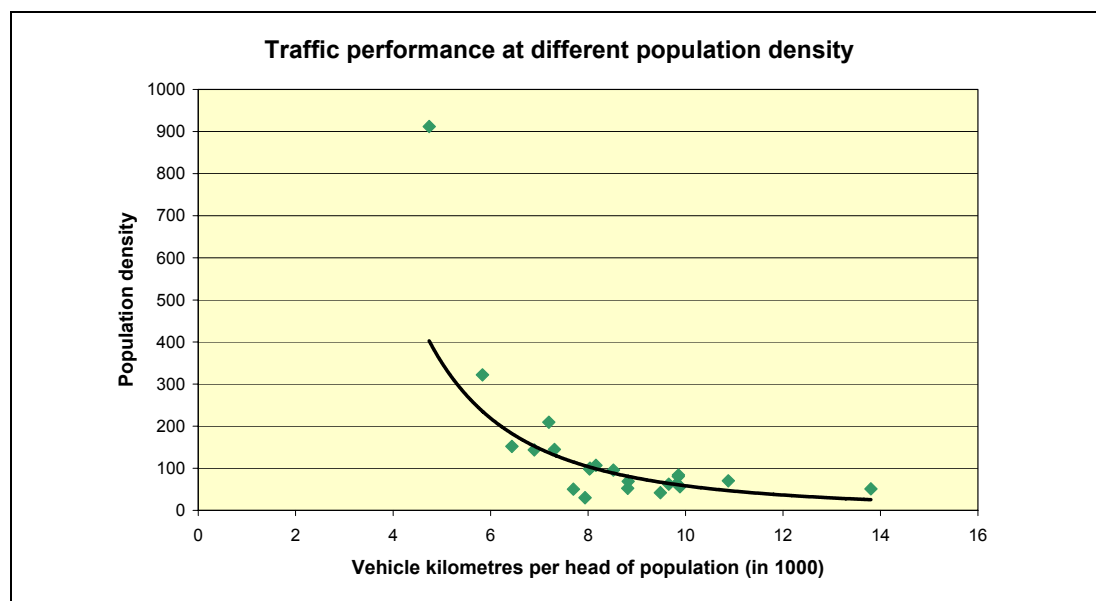
Figure 6.1. *Population density against motorized vehicle kilometres per head of population for 22 French regions in 2004*.

It can be concluded, that the best measure of safety at the regional level would be the one taking account of the real exposure of road users in road traffic, typically in terms of vehicular travel.

6.1.3.2. Performance indicators

Most European countries can only set road safety performance indicators at a national level. Detailed analysis suggests that even between a country's regions there are important differences in cultural, linguistic and economical background. For example, there are significant differences in the use of restraint systems between Swiss (Siegrist et al., 2006), or Italian regions (Taggi et al., 2006). Similarly, the prevalence of driving while intoxicated is expected to vary between for example the French, Italian and Spanish regions. As for speeding, the detailed data which allow determining the real extent of these disparities unfortunately are rarely available.

More detailed observation also shows that certain performance indicators vary for different road types or for different types of urbanization. For example, vehicle occupants are more likely to use their seatbelts on longer trips on motorways and main roads than in cities. These nuances should be accounted for when considering small administrative units, particularly cities.

Although regional or local data on casualties will generally be available, they may not allow for analysis of causal factors to the same extent as at national level and therefore it may be necessary to rely on national sample studies. Local road safety performance indicators may suffer from sampling errors, due to the limited size of

the samples used for setting sub-national indicators. Similarly, some behavioural surveys may be conducted locally, but unless local differences are anticipated and have been assessed, it may also be necessary in this case to assume that performance indicators reflect national sample surveys.

6.1.3.3. Measures and programmes

The polycentrism in road safety management is apparent in many countries which have established local road safety targets, strategies and programmes. The extent of the responsibilities and spending power of regional and local governments are the most determinative factors of their potential impact. But it is not only at this strategic and administrative level of governance that the potential differences in road safety outcomes could be conceived, as there are also significant differences in the application of concrete measures and policies.

Data on individual measures and implemented programmes can be expected to give a clearer picture of the safety outcome at the local level than when the data on the large number of individual programmes that make up measures of national activity is averaged. Differences between local areas that have implemented particular measures and those that have not can also be explored more clearly. However, the same as at the national level, information on the sub-national level of implementation is likely to be of variable quality. Analysis at city level will enable engineering measures to be related more closely to particular types of roads. Information on the expected effectiveness of different measures will still need to be based on wider studies as these will be based on larger numbers of accidents.

6.1.3.4. Structural (spatial and demographic) differences

The report on the first SUNflower project (Koornstra et al., 2002) recorded the differences in population density, road density, and percentage of vehicle kilometres on motorways in Sweden, the United Kingdom and the Netherlands. Population density, road density and motorway traffic percentage were highest in the Netherlands and lowest in Sweden. Within the UK, England has a population density similar to the Netherlands. The average annual traffic flow in Britain is higher than in the Netherlands, and the average traffic flows in Sweden are only a third or quarter of that in the other two countries. The report states that the car occupant risk could therefore be expected to be highest in Sweden. Cyclist and pedestrian safety could be considered large problems in the Netherlands and in Britain, respectively, when these modes of transport are also taken into account. If these increased risks do not occur, specific road safety measures for the protection of these particular road user groups have probably been taken in these countries.

Koornstra et al. (2002) showed that although the overall fatality rates in the three countries were similar, the rates for individual transport modes differed, with the fatality rate for car occupants being highest in Sweden, while the rates for pedestrians and cyclists were highest in Great Britain. This was largely as expected, except that despite the large cycle flows cyclist fatality rates were low in the Netherlands. The large flows induced many risk reducing countermeasures, for example cycle facilities such as cycle tracks. The report of the extensive analysis of the three original SUNflower countries (Lynam et al., 2005) includes an estimate of the likely effects of traffic flow on the national accident rates for individual transport modes and road types. Quantifying these effects is not easy, but based on average activity rates for the different transport modes in each country; the report suggests

that they might explain up to half the difference in car occupant fatality rates and most of the difference in pedestrian fatality rates. But the report concludes that much more detailed data and analyses are required to explore these effects properly.

Lynam et al. (2005) also considered the role of town size and of the presence of economically disadvantaged groups in explaining differences in pedestrian fatality rates between the three SUN countries. There are indications that both these factors have an effect on pedestrian fatality rates, although the role of economically disadvantaged groups mainly appeared to be important in Britain (Broughton & Buckle, 2005). However, the role of these factors was not quantified in any detail, and for comparison at the sub-national level, a much more in-depth analysis would be justified.

It is likely that data collected locally on these issues will be more relevant to safety outcomes than approximation of this data to national outcomes. Analysis at sub-national level, therefore, offers the potential to make real advances in understanding the role of policy, process and organizational structure in safety outcomes. Such data may require questionnaire surveys, and in some cases in-depth interviews with relevant regional or municipal officials to more fully understand the decision-making processes, and the approaches used to gain acceptance of policies.

6.1.3.5. Cultural differences

In previous descriptions of the safety pyramid, structural and cultural issues have been grouped together in the lowest level of the pyramid. Both are important to understanding the subsequent levels, but they act in different ways, and it can be argued that they might be defined as separate levels.

Many regions and towns were built upon a common cultural background. This could potentially influence road user behaviour and, consequently, the way in which road safety is managed at the sub-national level. Here, culture is regarded as reflecting values and norms in their social sense. A set of consistent values and measures together form the *value system*, which is subjective and varies across populations. Types of value include ethical/moral values, ideological, social and aesthetic values, and it may be argued that all of them have an effect on behavioural attitudes of road users, which in turn manifests itself in different road safety outcomes. Concrete values such as the value of a human life, respect for each other's rights, etc., are directly reflected in road safety provisions, such as those related to casualty reduction targets. *Norms* refer to the rules that are socially enforced. Social sanctioning is what distinguishes them from values. They can be viewed as reference standards, or statements that regulate behaviour and act as informal social controls. The most typical example is society's drink-driving attitude, which differs significantly among countries, but may also vary between regions.

It can be argued that national borders only partly reflect cultural differences between European citizens. Conflicts and political ideologies have produced some national border adjustments which do not reflect historical and cultural backgrounds. The Trentino-Alto Adige/Südtirol region, for example, was part of the Austria-Hungary Empire until its annexation by Italy in 1919 and German speakers still represent more than a third of the population. Another obvious example of cultural variation is Switzerland with its three language communities. Hence national cultural characteristics cannot be expected to be common to all regions within a country.

However, these differences seem to have a rather limited effect on road safety outcomes.

One aspect which potentially transcends the proposed division between 'structure' and 'culture' is the structure of the organizations that are to develop and implement safety policy. Organizational structure can be regarded as the result of management actions, and as such becomes part of the development of effective safety policies and programmes. But organizational structure at the sub-national level will inevitably be affected by national governmental structures that will be influenced by national cultural characteristics. In comparison with middle and south European countries, for example, Anglo-Saxon countries have a long tradition in accountability. This leads to a broader application of results and performance auditing, potentially influencing the effectiveness of policies. The extent to which effective organizations are present at the sub-national level will also be depend on the values espoused by local safety champions.

Of all the pyramidal levels, those addressing structure in both physical and organizational sense deserve particular attention when applying the SUNflower approach at a regional level. The substantial effect of physical structure on road safety at sub-national level is discussed in Section 6.2 below. Knowledge on the mechanisms and impacts of organizational features of road safety management is much more limited, but this is briefly discussed in Section 6.3.

6.2. Role of (physical) structural differences

A more detailed analysis of road safety outcomes at sub-national level unveils the existence of significant differences in risk indicators between regions. They are of the same order as the differences in risk between European countries (Eksler et al., 2008a). Given the fact that the number of factors influencing road safety outcomes at a sub-national level is limited compared to those at the national level, it is straightforward to assume that structural differences between regions may explain part of the variation in road safety outcomes.

The classification indicators for EU regions were developed in the ESPON[3] project, and one of the indicators was settlement structure. Settlement structure typology was established by Schmidt-Seiwert (1997) based on the two criteria population density and size of centres. They distinguish agglomerations, urbanized areas, and rural areas and these area types are used to define the following six types of regions (see Table 6.1).

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[3] ESPON – European Spatial Planning Observation Network, www.espon.eu

Region type		Centre size	Population density
1	Agglomerated region	>300,000	> 300/km^2
2			150-300/km^2
3	Urbanized region	150,000-300,000	150-300/km^2 [or <150/km^2 with a bigger centre >300,000]
4			<150/km^2
5	Rural region	> 125,000	<100/km^2
6		< 125,000	

Table 6.1. *Settlement structure typology versus population and density (ESPON)*.

A generalized linear model (GLM) was run, assuming road mortality to be a function of settlement type and country (to account for different levels of road safety in different countries). Data of the year 2004 for altogether 250 NUTS[4]-2 regions of 25 EU countries were considered in this analysis (Eksler, to be published). NUTS-2 regions have typically a population of 0.8 to 3.0 million and may correspond to regions (e.g. France, Italy) or provinces (the Netherlands, Belgium).

Except the one for densely populated areas with large centres, the regression coefficients for particular settlement types appear to be significant. The average road mortality ratios for the six different settlement types in relation to national and European averages are summarized in Figure 6.2.
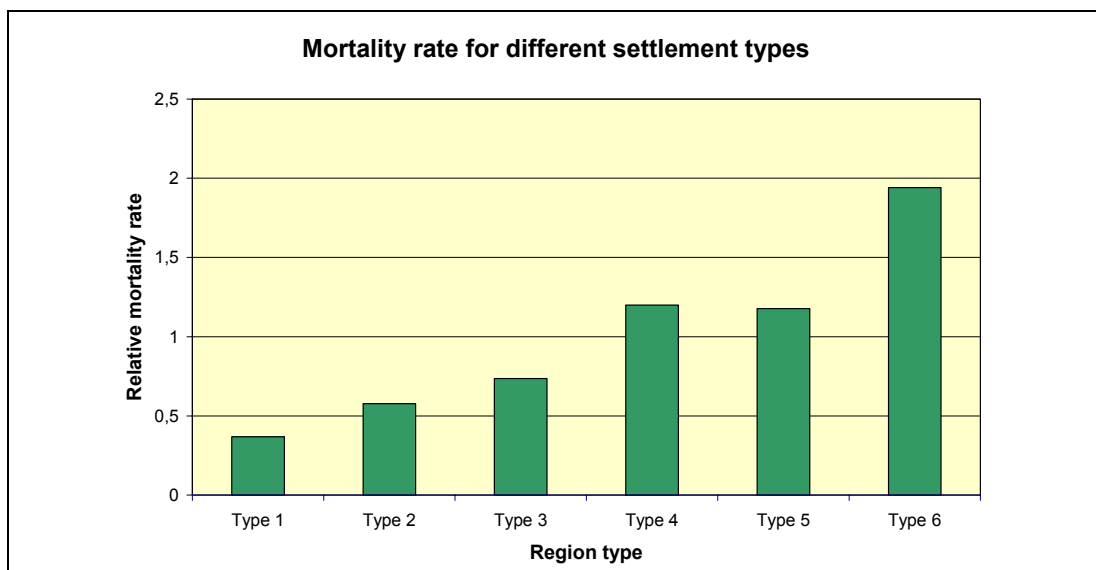
Figure 6.2. *Relative average mortality rate for different settlement types of 250 NUTS-2 regions of 25 EU countries in 2004*.

Clearly, the settlement structure has a strong influence on the registered road mortality at the regional level. Very densely populated regions with large centres have an average mortality rate which is less than half that of the average, while less

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[4] NUTS - Nomenclature of Territorial Units for Statistics (EUROSTAT). The NUTS classification is based on population criteria, with NUTS-1 regions having typically 3 to 7 million inhabitants, NUTS-2 regions 0.8 to 3.0 million, and NUTS-3 regions 0.15-0.8 million.

densely populated regions without centres, which are rural areas, have a mortality rate that is up to twice as high as average. Relatively low mortality rates in urban areas could be partly explained by larger public transport use and shorter trips which reduce exposure to risk on the one hand, and, on the other hand, by low travelling speeds due to congestion resulting in less serious injuries. High mortality rates in rural regions probably reflect high travelling speeds, often on undivided roads, and longer trips. Using vehicle kilometres instead of population as the measure of exposure significantly reduces the variance in risk between different types of region.

Since the settlement classification which is introduced above is based exclusively on population density and centre size, it may be useful to introduce a more sophisticated typology which takes functionality and morphology of area units into account. In Belgium, an urbanization classification established by Luyten & Van Hecke (2007) is widely accepted. Municipalities are subdivided on the basis of several functional and morphological variables such as population density, number of houses, and the size and date of construction of dwellings. It results in the following subdivision for each municipality: city centre, inner city area, inner suburbs, outer suburbs and rural areas. This subdivision gives a better definition of urban areas as regards habitat and road network structure than the classifications based on only one variable.

A comprehensive analysis of fatality risks (fatalities per vehicle kilometre) in 589 Belgian municipalities over the period 2001-2006 (Eksler & Lassarre, 2008, and Eksler et al., 2008b) shows that on average peri-urban municipalities register 35% higher fatality risks than core cities. The complete results which are summarized in Figure 6.3 are as follows: city centre and inner city areas have lower fatality risks (of 21% and 7% respectively) and the latter's decline at an annual rate of 22% is larger than the urban area average. In inner suburban areas, the fatality risk is falling 33% faster than average, possibly as a result of the implementation of traffic calming schemes and other measures. In outer suburban areas, on the other hand, the risk is 15% higher compared with the average and is actually going up. Rural municipalities, which are not subject to the influence of urban areas, have a 10% higher fatality risk, and the average annual risk reduction is 5% lower than average.

This analysis provides a new view of the simplified urban-rural area typology and shows that it is actually the suburbs which deserve more attention from road safety professionals rather than the rural areas. However, this may be a phenomenon that is specific for Belgium, as not all countries have had a similar degree of decentralization of manufacturing, commerce, retail and office work resulting in new waves of suburbanization (Champion, 2001).

Fatality risk for different settlement types
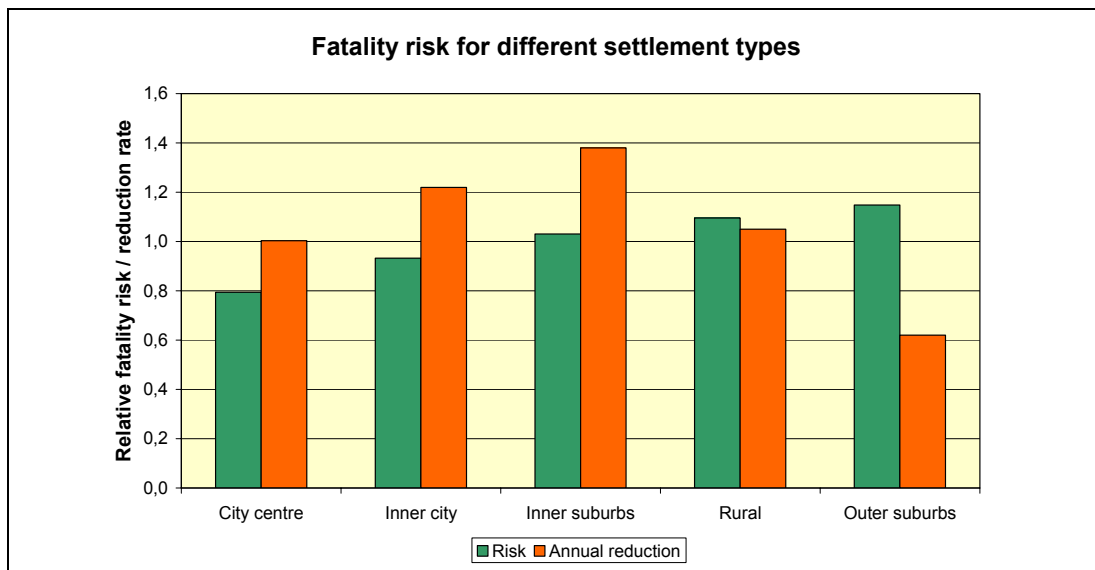
Figure 6.3. *Relative fatality risks and their relative annual reduction for different Belgian settlement types.*

One weakness of this approach is the lack of harmonization in the classification of municipalities according to their urban structure across EU countries. At the same time, this is a very promising approach, which allows classifying spatial units into more or less uniform groups for which a more reliable comparison could be made.

This simple analysis gives us a very first suggestion of the structural factors which may have an indirect impact on road safety outcomes. The review of related literature gives a rough idea of the structural factors that are to be considered in any regional comparison.

6.2.1.1. Explaining differences in risk

Eksler (2007) investigated the effect of the differing demographic structures of 25 European countries on their road mortality rates (fatalities per head of population). He found that at the national level, demographic structure, defined as the distribution of age and sex in aggregated age groups (as also used in IRTAD) had only a minor effect on mortality ratios. There can be greater effect when comparisons are made between regions. He further concluded that adjusting for the demographical structure when analysing mortality ratios could account for up to 12% of the variation in crude mortality rates.

Eksler et al. (2008a) have shown that population density is probably the single most powerful explanatory factor behind road mortality in Europe. The logarithmic relationship between road mortality and population density at the regional level is distinct in the majority of EU countries. This is illustrated in the Figure 6.4 showing the log-log relationship between both variables for 21 EU countries. For many countries, the region containing the capital city is included alongside all the other regions in the plot. Based on the data from 1,089 regions of 25 European countries, they concluded that a 10% increase in population density is linked with a 3.2% decrease in road fatalities per head of population. The level of spatial disaggregation is not crucial here, as the similar results appear at different aggregation level. Additional analysis further showed that the population density explained between 6

and 98% of the variation in road mortality registered at the level of NUTS-3 regions in different EU countries, with a 59% average. Taking account of differences in population density between European countries would thus produce a different ranking of countries in their mortality rate than that generally quoted, using fatalities per head of population.
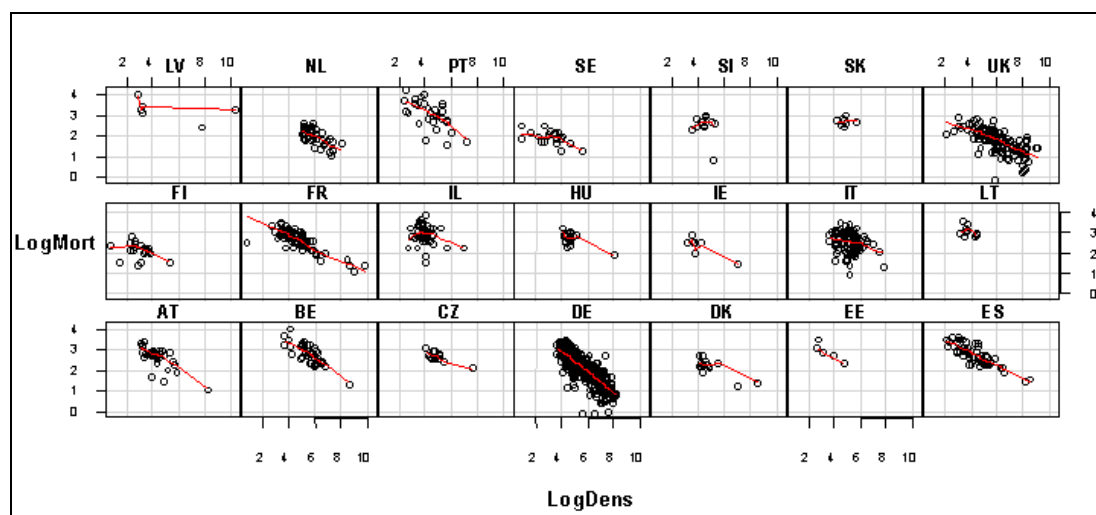
Figure 6.4. *Relationship between road mortality and population density (log-log scale) for NUTS-3 regions of 21 EU countries in 2002*.

Population density as a synthetic indicator stands for a wide range of explanatory factors influencing the occurrence of fatal injuries in road traffic. Analyses performed at the level of single countries suggest that the exposure in terms of kilometres driven by motorized vehicles is the principal partial factor behind the population density accounting for up to half of its explanatory value. This is basically because the average annual distance driven per inhabitant of rural areas is generally higher than that of urban citizens. Accident severity factors such as road environment or travelling speed account for approximately 20%. The remaining 30% can be related to the demographic, deprivation, economic and other factors (Eksler, to be published).

Similar to population density, the urbanization rate can be used as a proxy standing for a number of structural factors. In fact, both variables are strongly correlated, and this results in similar conclusions to those described earlier for the effect of population density. The differences in the definition of urbanization, however, represent a constraint to its use as explanatory factor.

Among additional socio-economic indicators claimed to explain regional variation in accident outcomes, we may find household income, employment rate, weather, or alcohol use.

Annual household income could also be considered as a possible explanatory variable behind accident outcomes at sub-national level. The effect of annual average income on fatality risk (elasticity) estimated in the model run for 589 municipalities of Belgium for the period 2001-2006 is negative and has the value of -0.239, meaning that a 10% increase in annual income per person is associated with a 2.4% reduction in fatality risk (Eksler et al., 2008b). One possible explanation for this is that people with higher household income tend to live in areas less affected

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by transit travel, use safer mode of transports and benefit from better infrastructure, which may result in lower accident severity.

Several authors have suggested that there are distinct and substantial effects on casualty rates from characteristics associated with area deprivation across diverse environments. These associations exist over and above influences arising from local environmental characteristics. Distinct dimensions of deprivation appear to affect the incidence of pedestrian and child casualties to varying degrees and sometimes in different directions. This is likely in part to be related to the higher exposure to traffic of these groups, but is also influenced by social factors (Noland & Quddus, 2004; Christie, 1995; Graham & Stephens, 2008). The role of deprivation has been widely studied in the UK, where the concept is well established, but not in other countries.

Practically all structural factors discussed above are correlated and their simultaneous use should be done with care; otherwise analyses will result in confusion rather than in understanding.

6.2.1.2. Scope for extended SUNflower analyses

The differences indicated by population density reflect a complex set of factors that are likely to be associated with this density. Examples are numbers and lengths of trips, choice of mode, and road conditions (e.g. traffic flows) faced by each mode. These in turn will also be affected by the quality and quantity of the networks provided for each mode. To gain deeper understanding of the issue, and how it might be included within SUNflower type analyses, it would be useful to explore the direct effect of changes in these factors, and to investigate their interdependency. This could be attempted at an aggregate level - for example, by adding more variables to the type of model already used by Eksler & Lassarre (2008). Alternative models, such as that used in Harland (1999) which focussed on fatalities to individual road user groups and used local car ownership data, might also be considered.

More directly, an attempt might be made to predict travel kilometres, both vehicular and pedestrian, that might arise as a result of population factors, income, and transport provision, and then relate the expected numbers of fatalities to travel kilometres taking into account network quality and road user behaviour.

There is also further potential scope for extending the previous SUNflower analyses of the effect of differences in traffic flow levels and of economically disadvantaged groups on fatality rates by obtaining detailed data for cities of different size in several countries.

6.3.   Role of cultural factors

Lassarre (in Delorme & Lassarre, 2005) attempted to explain the gap in fatality risk between France and Great Britain in terms of behavioural factors associated with policies addressing key accident causation and accident seriousness factors. These factors could be speeding, drinking and driving, and seatbelt usage, and structural factors such as urbanization and traffic patterns. He concluded that three major risk factors explain 80 to 90% of the gap in risk between France and Great Britain. He further claimed that if risk factors associated with these variables in France had the values they had in the UK, the number of fatalities in France might be reduced by

about half. This was based on the multiplicative effect of a reduction of one third in speed related fatalities, by 20% in alcohol related fatalities, by 15% in seatbelt use related fatalities and by 5% as a result of differences in urbanization. The question remains – why do these differences in behaviour occur at the national level, and are they true for all regions within a country?

Delorme (in Delorme & Lassarre, 2005) argues that it is not sufficient to address only the accident and policy outcomes; it is more important to attempt to model 'behaviour shaping mechanisms'. By example, he quotes six areas of potential difference between France and Great Britain: ranking of road safety policy on the national agenda, history of established safety cultures, well defined distribution of responsibilities between road safety 'actors', development of control and enforcement, development of public accountability, and existence of transparent goals and information, parliamentary debate and active organizations. He suggests that the stage of development of these factors was similar for the original three SUNflower countries, and thus comparisons could be made without addressing them too closely. But he argues that when extending the approach to other countries – such as France – the inclusion of these issues is desirable.

The idea that an efficient organizational/policy structure is prerequisite for the introduction and successful implementation of policies has gradually gained in popularity in recent years (see e.g. Aeron-Thomas et al., 2002; Bliss & Breen, to be published). The problem is how to consistently identify the key factors of a road safety management system and how to measure them in a way that will show their influence on safety outcomes.

Whatever approach is adopted, it is likely to need to address the influence of social norms and legal and regulatory standards on the key actors involved in both the safety policy decision-makers and the road users. This in turn will probably require addressing issues such as the appropriate balance between safety and mobility, and the public response to coercion and desire for freedom and autonomy in their choices. For many policies which involve giving up such freedoms, public belief in the credibility of the policy and the motives of the policy makers is crucial. Public willingness to spend resources on such policies, and their view of the acceptability of their allocation will also be a major factor.

6.4. Factors affecting measures and programmes

Several authors have identified setting policy targets and strong political leadership as determinative factors for effective road safety management (e.g. Wong et al., 2006; Elvik, 2001) and they can also be expected that to play an important role at the sub-national level. Policy programmes and actions with a large road safety improvement potential typically concern the national level. However, many of these policies are implemented at the sub-national level by regional and local authorities. Their commitment and professionalism are crucial for successful implementation of particular programmes and measures. Delorme & Lassarre (2005) concluded in their work on the comparison of France and Great Britain, that the work of local officers in Great Britain with designated responsibilities and allocated resources is one of the major reasons for the success in improving road safety in Great Britain.

There is sufficient evidence in success stories about the implementation of innovative policies in urban traffic planning and organization. The wide implemen-

tation of 30 km/h and 60 km/h zones had a positive impact on road safety (Wegman & Aarts, 2005). Road and traffic policies and traffic calming schemes have also a proven to have a direct effect on road safety outcomes.

Thus we may expect that the existence of regional and local road safety policies and the attribution of necessary resources for their implementation have a positive impact on road safety at the sub-national level.

6.4.1. The SUNflower approach

To gain understanding of the reasons for the observed outcomes, SUNflower used case studies of the similarities and differences in policy and the outcomes of accident groups associated with either road user groups or strategic accident causation factors. Whilst these case studies sought to explore policies, performance indicators, and casualty outcomes, they failed to establish any clear causal links between each of the 'layers' of the safety pyramid. Confounding factors include the multiplicity of safety actions contributing to the final outcomes, and the difficulty of quantifying the management actions and their effectiveness. Implementation of policies also differs between areas within each country, and any quantification of implementation at the national level can only reflect the average penetration of policies throughout the country.

Koornstra et al. (2002) included an attempt to explain the observed changes in fatality numbers over the previous 20 years in the three SUN countries in terms of the changes in exposure of the main road user groups and the trends in performance indicators reflecting the influence of vehicle design, drinking and driving, seatbelt wearing and road engineering programmes.

The SUNflower case studies also showed the extent to which different combinations of policy were associated with different final outcomes – as for example with drinking and driving in the balance between setting legal BAC levels, frequency of testing, and the level of penalty for offenders. But it was not possible to assess how far the difference in the policy combinations had contributed to the final outcome. Similarly, driver opinions from SARTRE which differed between countries were recorded, but these can only be expected to give a general impression of why different choices are made either by policymakers or in driver compliance with policies.

6.4.2. Scope for extended SUNflower analyses

Koornstra et al. (2002), in their case study on low cost infrastructure improvements, attempted to address some of the issues raised above by tracking the historical development of infrastructure improvement policies, and describing the tactical, funding and operational activities associated with them in each country. But quantifying these factors in national terms is extremely difficult. Similarly, defining at a national level the structural factors, such as transport policy, network characteristics, and traffic flows, against which the local programmes are being developed is very difficult.

It is likely that at a more local level a more coherent relationship can be developed between such structural factors, the actual level of safety policy introduced (particularly in relation to physical engineering changes) and the way in which the decisions were made and the influence of organization systems on these decisions and their effective implementation. There is likely to be much more variation

between local areas in the adoption of specific policies. Analysis at this level will also allow the influence of specific 'safety champions' to be reflected in the local outcomes, either individual or of organizations. A 'good safety outcome' might be achieved by a variety of different sources.

The SUNflower pyramid already includes a layer in which these issues can be captured and described. However, this layer needs to be substantially elaborated to include qualitative or quantitative measures of organizational structures, social norms, and public response to the issues discussed above. Innovative scientific approaches would need to be taken into account in order to deal with them consistently.

While some policies will inevitably be controlled more at the national level, engineering measures such as the implementation of 30km/h zones or the introduction of cycling facilities and enforcement or of education initiatives may differ substantially between at the sub-national level.

6.5. Regional comparisons

6.5.1. Current practices and applications

To date, much has remained unexplored across Europe in sub-national analysis of accident data. Despite the availability of local statistics in most European countries, few analyses use the data in a systematic and consistent way. More specifically, only a relatively small number of countries systematically monitor and reflect regional accident statistics in the application of local policies by authorities. This is for example done in France, Switzerland, Belgium, United Kingdom and Spain.

The EC has recently incorporated a GIS application in the CARE database, which allows mapping and monitoring of the development in road fatalities per head of population at sub-local level. The NUTS-1 to NUTS-3 regions are considered. This is a purely descriptive approach, which for the moment probably lacks an analytical and interpretation framework. Maps of crude road mortality rates, despite giving some guidance, cannot serve alone as evidence for policy actions due to the number of underlying structural factors which has an impact on both level and trend of road mortality. The variation in road mortality rates across regions in 25 EU countries in 2004 is shown in Figure 6.5 for the NUTS-2 and NUTS-3 regions. It is based on data provided by road and policy authorities of EU countries (Eksler et al., 2008a).

NUTS 2

Legend:
- 1,1 - 5,4
- 5,5 - 8,9
- 9,0 - 12,8
- 12,9 - 18,6
- 18,7 - 32,4

Canaries (ES)
Açores (PT)
Madère

Fond : RRG GIS database

NUTS 3

Legend:
- 1,06 - 3,33
- 3,34 - 8,39
- 8,40 - 14,10
- 14,11 - 24,95
- 24,96 - 32,39

Canaries (ES)
Açores (PT)
Madère

Fond : RRG GIS database
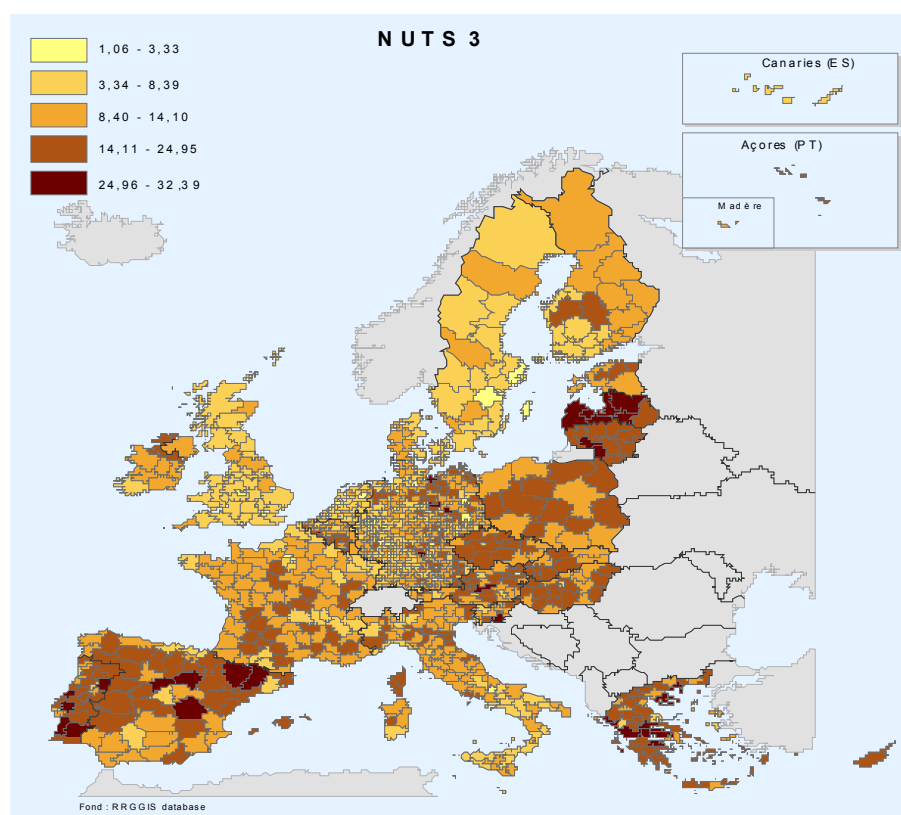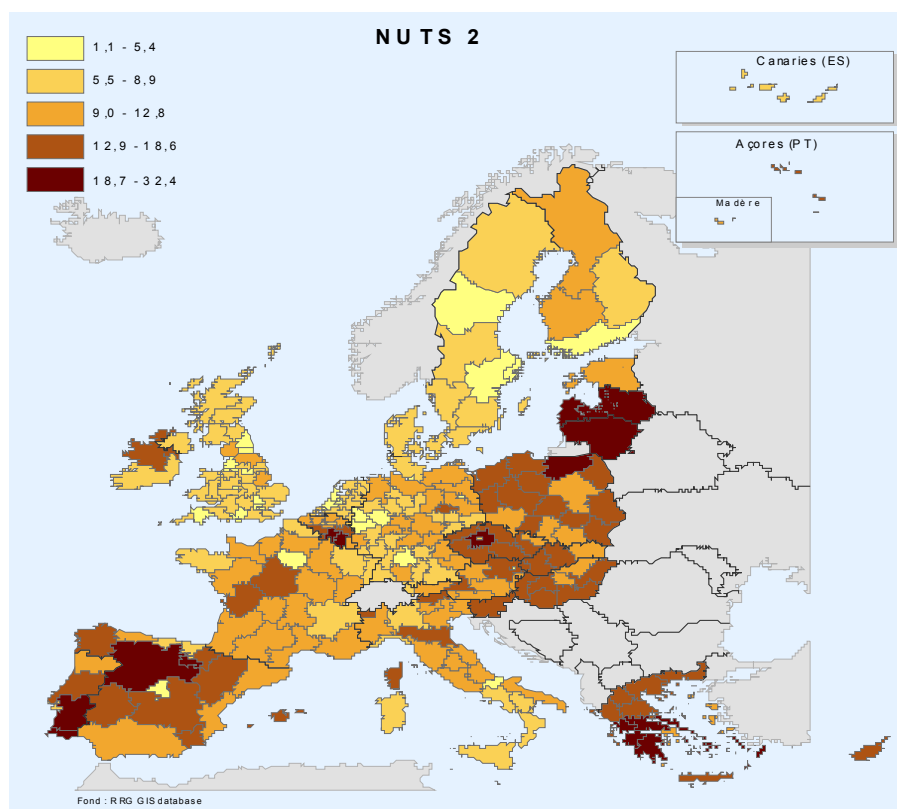
Figure 6.5. *Road mortality rates in EU-25 countries in 2004.*

In France, a local accident indicator (IAL) developed by Chapelon (2002) has recently been used for the evaluation of the effectiveness of local road safety policies. It compares the relative fatality risks of 100 French departments, defined as the average value of fatality risk per road type. This methodology is discussed in more detail in Appendix 9. Although this comparison is certainly more reliable than the one based on mortality rates, its weakness is the use of a road classification. This reflects the responsibility of authorities for its maintenance, rather than its design and passive safety characteristics.

Switzerland monitors the road safety performance of the three linguistic regions and the local policies also reflect the road safety performance indicators measured for each individual region (Siegrist et al., 2006). Also in Belgium, where the two linguistic regions have a certain authority in policies related to traffic safety, the accident statistics are analysed at a regional level. The road mortality rates are generally used for a comparison of the performance for regions. In the United Kingdom, annual data is published for each of the 87 unitary authorities in England, and for Wales, Scotland and Northern Ireland separately, enabling the calculation of fatality rates by population and by number of licensed vehicles. Fatality numbers are also recorded by road class for eleven Government Offices in England.

Broughton & Buckle (2006) also compared the casualty rates for 88 English local authority areas which had been defined as deprived areas. The fatality rates per head of population in these areas are 30% higher for adult fatalities and 60% higher for child fatalities than in other local authority areas. Population density is likely to be higher in the deprived areas, which may normally be expected to reduce the fatality rate. In the case of the deprived areas, this effect may be far outweighed by factors such as the lack of off-road playing space for children, heavier traffic volumes and the greater difficulties in child supervision due to factors such as family structure.

Harland et al. (1996) developed a model to investigate the high pedestrian casualty rate in Scotland compared with the rate in English regions. The model used was based on population, car ownership, and the amount of road space available. The results showed that when these variables were taken into account, the Scottish pedestrian casualty rate was similar to that obtained by applying the model to English regions. In Spain, the accident outcomes of Catalonia region have been subject of interest in recent years (Hayes et al., 2006).

Harland (1999) subsequently used a similar model to explore reasons for the relatively high observed casualty rate per head of the population in the North West region of England in comparison with other English regions. The analysis compared regions and also compared differences in district rates within the North West region. Observed casualty rates were compared with predicted rates for each of five road user groups to identify the situations in which the observed rates were higher than those predicted by the model.

As part of their regular monitoring of national casualty trends in relation to the national casualty target, Broughton & Buckle (2006) showed the variation between English Regions in both fatalities per head of the population and in the development of casualty trends between 1998 and 2005.

Analysis of data for Dutch regions (Figure 6.6) shows a strong link between mortality rates and population density, as indicated earlier by Eksler's analyses.
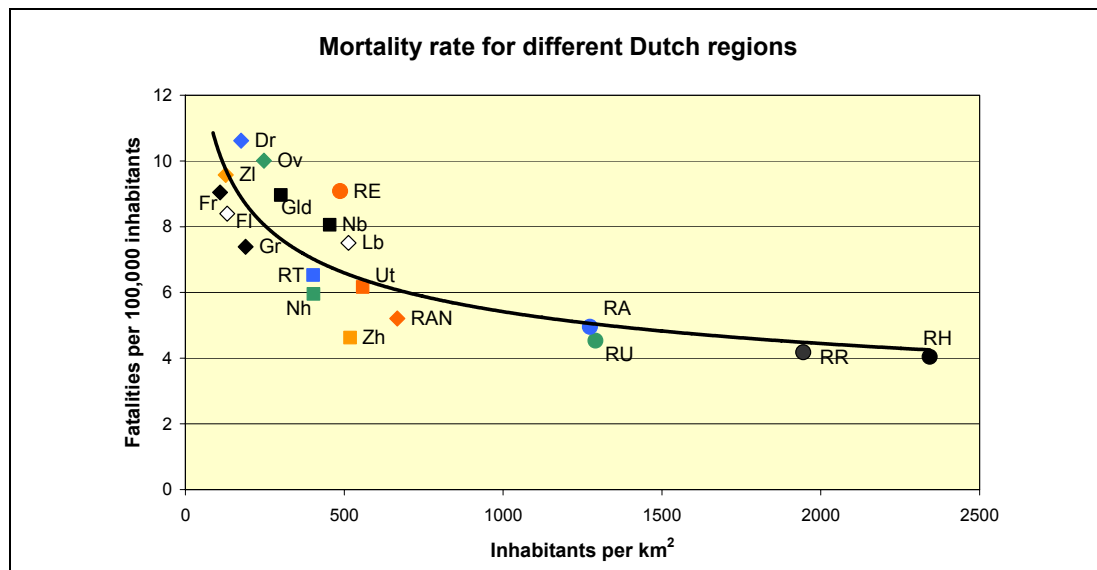
Figure 6.6. *Relations between population density and road mortality in the 19 Netherlands regions (provinces and metropolitan areas) in 2004.*

However, for the four metropolitan areas, Amsterdam (RA), The Hague (RH), Rotterdam (RR), and Utrecht (RU), which are heavily urbanized regions with population densities between 1,000 and 2,500 inhabitants per square km, there seems to be relatively little effect on the mortality rate. Also, among the regions with densities below 1,000 inhabitants, there are large differences between mortality rates of regions with similar densities, even although the effect of population density is a strong factor. This suggests additional factors need to be investigated in order to more fully explain safety performance.

In Britain, it has recently been considered whether different performance targets should be set for different regions of the national road network. Analysis of recent progress compared with casualty rates at the start of the period being assessed, and the traffic growth during the period suggested that inclusion of these factors would provide a better basis for setting different targets for each region than for simply setting the same target. For motorways (M and A(M) roads), only the starting rate was an important factor; for other main roads both starting rate and traffic growth were used to identify potential separate targets.

An overview of articles on regional analyses and their focus is presented in Appendix 10.

6.5.2. Avenues for further work

There would appear to be scope for an extension of current and past work on modelling using data from a large number of regions.

The differences indicated by population density reflect a complex set of factors that are likely to be associated with this density – e.g. numbers and lengths of trips, choice of transport mode, and road conditions (e.g. traffic flows) faced by each transport mode. These factors will in turn also be affected by the quality and quantity of the networks provided for each mode. To gain deeper understanding of the issue, and how it might be included within SUNflower type analyses, it would be useful to

explore the immediate effect of changes in these factors, and to investigate their interdependency. This could be attempted at an aggregate level - for example, by adding more variables to the type of model already used by Eksler & Lassarre, 2008). Alternative models, such as that used in Harland (1999) focussing on fatalities to individual road user groups, which used local car ownership data, could also be considered.

More directly, an attempt might be made to predict travel kilometres, both vehicular and pedestrian, that might arise as a result of population factors, income, and transport provision, and then relate the expected number of fatalities to travel kilometres, taking into account network quality and road user behaviour. This could shed some light on the impact on road safety of modal split development in time. Recent work of Stipdonk & Berends (2008) analysing road safety development in disaggregated road user groups unveils some surprising differences in safety development per transport mode which are not shown by studying only the overall trend for all road users.

Extended analysis at national and at regional level would make use of data in national databases where possible. A temporal statistical model could be run in order to investigate the development of road safety outcomes in time. A country trend could be considered at the same time. Combination of data on fatalities and injuries and the use of a Full Bayes spatiotemporal model is preferred.

A disaggregated model for different transport modes and roads (speed, allowed users), could also be considered. When thinking about the possible explanatory factors which could be introduced to an explanatory model, one should consider the relationships that exist between them. This is illustrated by the correlation matrix for road link data (Figure 6.7). Thick lines indicate 'strong' correlation ($\rho > 0.6$) and thin or no lines indicate 'weaker' correlation among variables. For example, the number of lanes and the presence of a central island correlate strongly (Greibe, 2003).
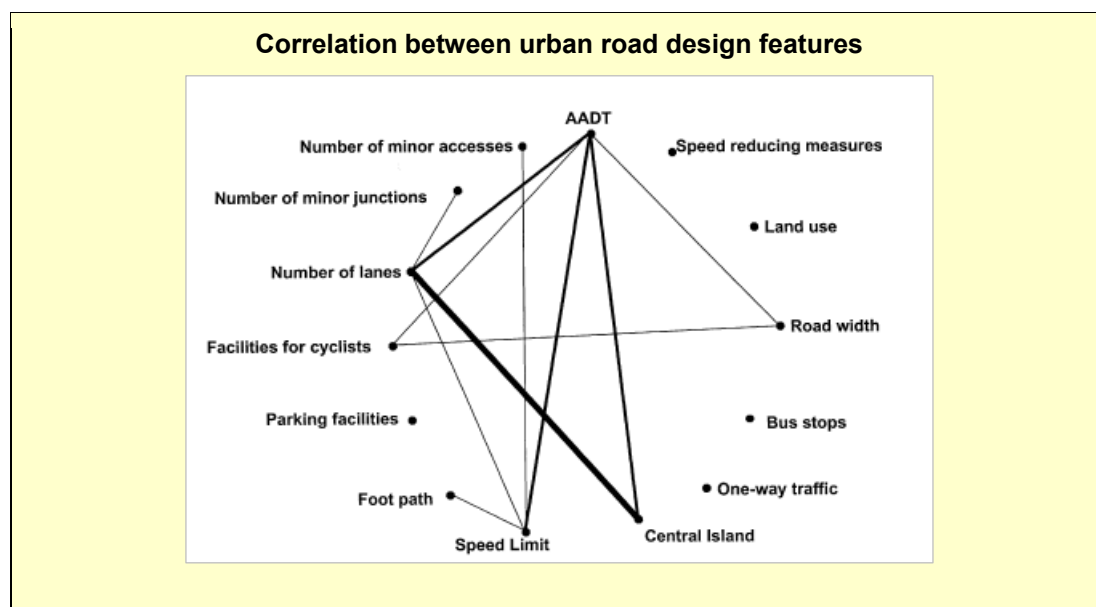
Figure 6.7. *Correlation between various factors of urban road design features.*

Modelling accidents for road links is less complicated than for junctions, probably due to a more uniform accident pattern and a simpler traffic flow exposure, or due to lack of adequate explanatory variables for junctions. Explanatory variables describing road design and road geometry proved to be significant for road link models but less important in junction models. The most powerful variable for all models was motor vehicle traffic flow (Greibe, 2003).

Recent research literature distinguishes two approaches to modelling the safety performance of individual roads (Eenink et al., 2008). Accident Prediction Models attempt to define the overall risk for particular road types in relation to traffic volumes and various road design parameters. Accident Modification Factor models aim to show more directly the extent to which changes in the design of individual road features are likely to affect accident frequencies – both in terms of individual accident types and total accident frequency. Both approaches are complementary to each other. If this approach is followed, attempts have to be made to scale up results from individual groups of roads to road networks in regions or cities.

An alternative for regions could be to develop their safety performance profile as a combination of the performance of the major cities within the region and an assessment of the performance of the main intercity road network within the region. However, the more statistical approach considered above will probably be more appropriate for comparing regions. Comparison would most fruitfully focus on regions where the regional authorities are the main planners and implementers of safety policy. Dutch data might provide a useful focus for further regional analysis.

6.6. City comparisons

6.6.1. Current practices and analyses

Analysis at the regional level allows a more controlled environment to be studied than aggregating all regions into national statistics. But most regions will still consist of a mixture of urban and rural environments, which have clearly different road user groups and traffic conditions as well as different population densities. One way of reducing these confounding factors is to limit the comparison to areas having more or less consistent characteristics, such as metropolitan regions, or to large cities.

Much work has been done on urban safety management principles, and the EC DUMAS project included inputs from several European countries (Lines, 1999). The main focus for urban safety management has been a combination of engineering and speed control measures, but in the Gloucester Safer City project (Mackie & Wells, 2003), for example, much attention was also given to the development of a safety strategy and the organizational structure required to ensure its acceptance by the public.

Earlier EC studies (ADONIS, WALCING and PROMISING) looked in depth at the physical and organizational background of improvements in the safety of vulnerable road users. ADONIS, for example, examining three major cities (Copenhagen, Amsterdam and Barcelona) concluded that lack of safety was an inhibiting factor to cycle use in Barcelona, but not in the other two cities.

Within each country there are also clear differences in the policies adopted by different cities. In Britain, London has been able to introduce transport policies, such

as congestion charging, which do not exist elsewhere. London also carried out a substantive development of cycling networks and 20mph (30km/h) zones. Other British cities, e.g. York, Hull, Cambridge are also known to have pursued more radical policies for residential areas, speed management, and provisions for vulnerable road users. Comparison of policies, safety management organization and casualty trends within these cities may yield interesting associations. Similarly Paris and other French cities have been developing and applying specific road safety policies aimed at protecting vulnerable road users and encouraging the use of ecological friendly modes of transport.

6.6.1.1. Safety of different roads within cities

Different roads within cities are designed for different traffic functions, with different road user groups using them in different ways. This usage is reflected in different total safety outcomes and different mixes of casualty type on each road type. The biggest difference in road function is between main traffic arteries carrying large volumes of motorized traffic, and residential access roads where many safety practitioners attempt to limit the flow and speed of motorized vehicles to reduce the risk for pedestrians and cyclists, particularly children, who are likely to use these roads. Roads distributing traffic between these two road categories often have mixed functions, unless their layout and use are strictly controlled.

Urban safety analyses (e.g. IHT, 1990) show that typically half of all casualties in urban areas occur on main roads, with roughly a quarter on residential roads and a quarter on distributor roads. Analyses on the basis of these road categories only tend to be available when detailed city analyses have been made; more generally data relate to road classifications. For example, in Gloucester (DTLR, 2001), 57% of casualties occurred on Class A and B roads (which made up 17% of road length), 20% of casualties were on Class C roads (11% of length) and 23% of casualties on lower class roads (72% of road length within the city).

Data from the Netherlands (Van Schagen & Janssen, 2000) illustrate the difference between the safety characteristics of urban distributor roads (including main arteries) and urban residential roads (Table 6.2).

Characteristic	Urban distributor	Urban access
Fatality risk per billion vehicle kilometres	14.5	7
Number of fatalities per year	308	60
Share of national road length (%)	13	35
Share of car kilometres (%)	18	7
Share of fatalities (%)	28	6
Share of in-patient casualties (%)	43	12

Table 6.2. *Safety related characteristics of urban roads with different functions in the Netherlands*.

Table 6.2 again shows the greater role of the larger roads in the fatality toll of the urban areas.

6.6.1.2. Modal influences

Pfundt & Meewes (1986) and Brühning (1986) both showed that pedestrian and bicycle accidents made up over 40% of the total accident cost in German towns. This proportion was relatively constant for all urban areas above 20,000 inhabitants, although the part of the total resulting from pedestrian accidents increased with town size, while that from cyclists increased with town size up to 50,000 and then decreased slightly.

Data for a selection of capital cities, averaged over 2004 to 2006, indicated that vulnerable road user deaths (pedestrian, cyclist and powered two-wheeler) accounted for between 35 and 85% of all road deaths in capital cities (Figure 6.8). The availability of public transport and dedicated infrastructure together with climatic conditions leading to differences in modal split can partly explain the recorded distribution of road user deaths.
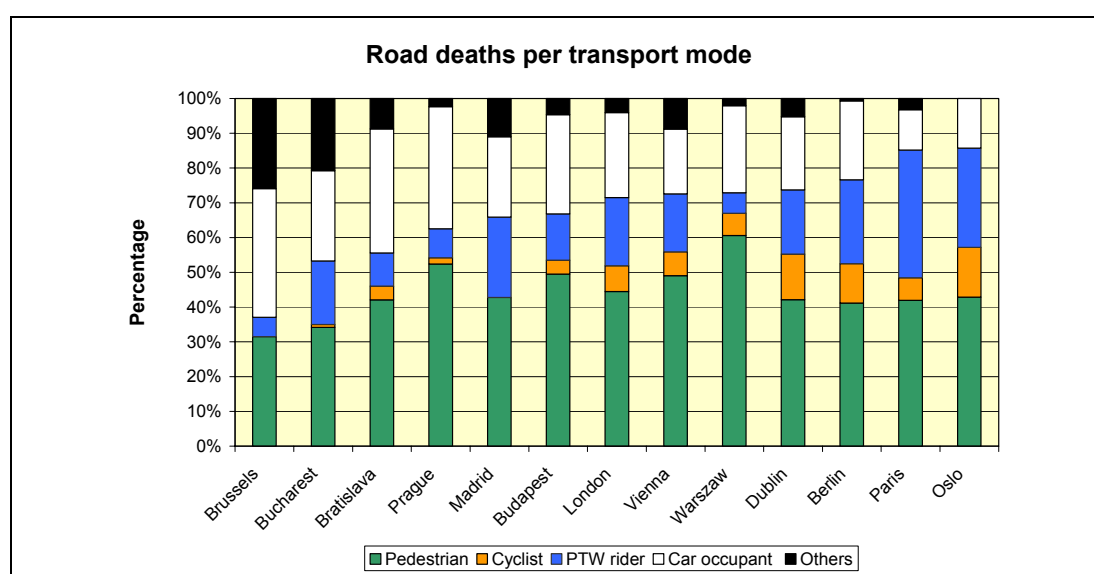
Figure 6.8. *Road user deaths as a percentage of all deaths in a sample of capital cities (ETSC, 2008)*.

6.6.1.3. Casualty rates by type of local authority area in England

Broughton (unpublished) compared casualty rates for local authority areas in England, categorized by a classification system produced by the Office of National ONS, based on a Cluster Analysis of the data collected by the 2001 Census. This identified groups of local authorities with common characteristics, as expressed by 42 Census variables. The average annual rates (casualties per thousand inhabitants) from 2000-2002 for these different types of area are compared in Figure 6.9. The categories include both different types of urban area, and more rural areas.
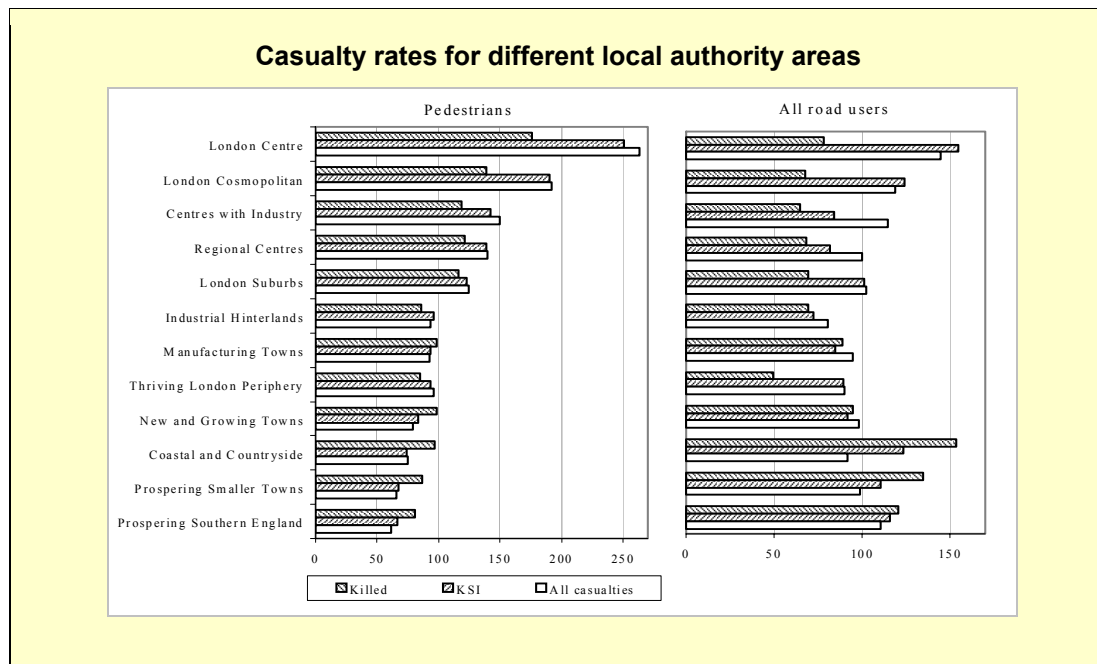
Figure 6.9. *Casualty rates for pedestrians and all road users for different local authority areas, 2000-2002 (100 = national average for each rate)*.

Although the rates for all road users vary across the whole range of area types, the rates for pedestrian casualties are more uniform, once London and major regional centres are excluded.

The extent of motorized travel within a city is likely to be affected by the prominence of the city within a region, and its proximity to good interurban road links. In the Netherlands, for example, a high proportion of vehicular travel occurs on the national network due to the relatively high density of the network.

6.6.1.4. Changes in safety performance

Changes in safety performance over the same period can differ substantially between cities. Figure 6.10 shows the percentage reduction in killed and seriously injured casualties in English urban areas averaged over the period 2004-2006 compared with that averaged over the period 1994-1998. The individual outcomes varied from a small increase in casualties to reductions of over 40%.
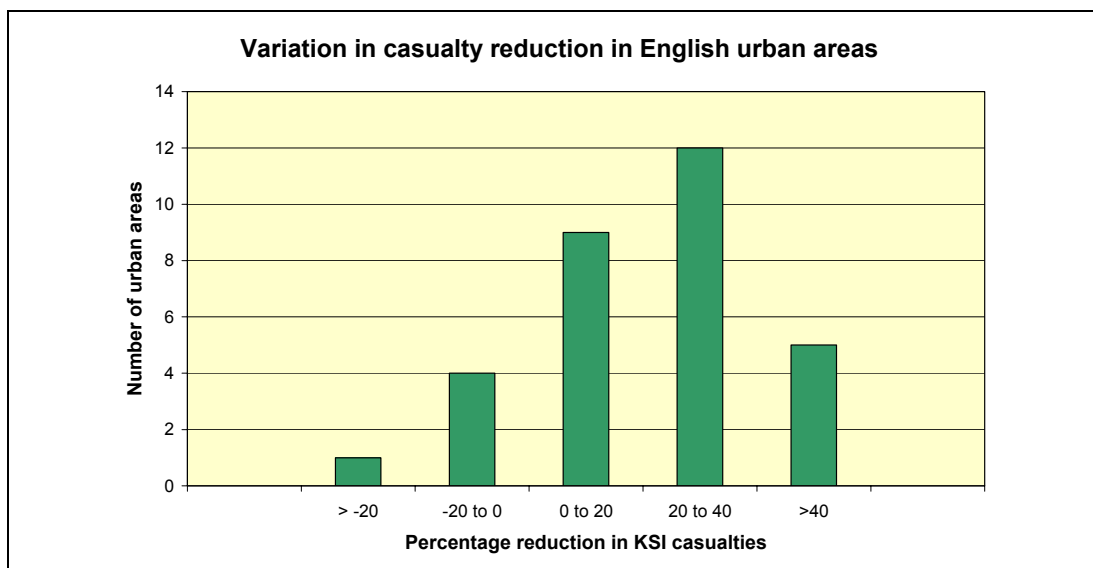
Figure 6.10. *Variation in percentage reduction in KSI casualties in English urban areas*.

Figure 6.11 suggests, however, that the percentage reduction in casualty rates may be associated with initial casualty rates in the period being considered; i.e. reductions are likely to be higher if initial rates are higher. This is consistent with the pattern for changes in major road casualty rate described in Section 6.5.1. However, in both cases, the link is relatively weak, and likely to be only one of several factors affecting the outcome.
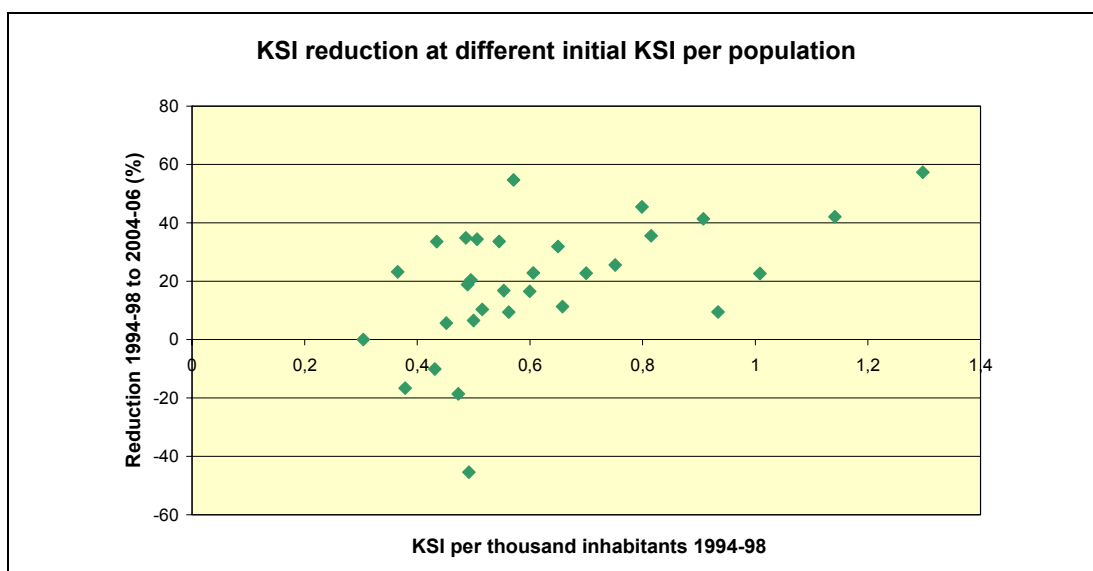
Figure 6.11. *Percentage reduction in KSI casualty rates per thousand inhabitants compared with the initial casualty rates.*

6.6.1.5. Effect of city size

Figure 6.4 suggested that at high population densities, differences in density may no longer have a major effect on mortality rates. Figure 6.12 similarly suggests city size

does not have a direct relation with the total KSI casualty rates, although it does appear to have an impact on the exposure and road safety performance of particular road user groups.
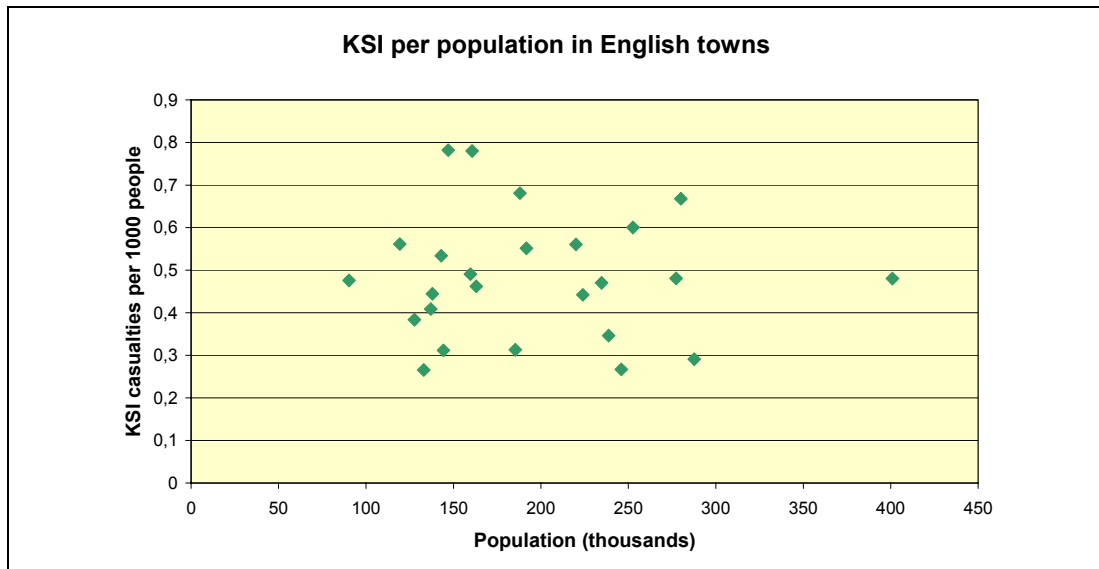
Figure 6.12. *Variation in total KSI casualties per head of population (averaged 2004-2006) with urban population in English towns*.

Consistent with the data for German towns in Section 6.6.1.2, a relation between pedestrian and cycle casualty rates and town size can be seen both in English data and Dutch data (Figure 6.13). However, the Dutch data suggests that the effect is different for different casualty severities. While rates increase continuously for all pedestrian injuries as urban area size increases (Figure 6.13a), for the more severe injuries, rates initially rise with town size but then decrease for the larger cities (Figure 6.13b).
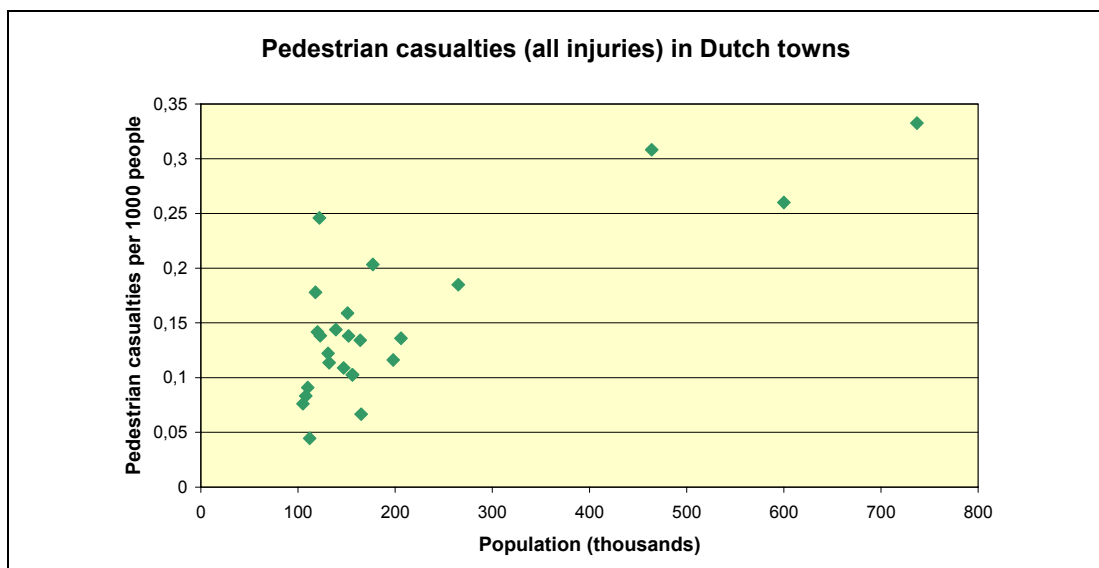
Figure 6.13a. *Variation in Dutch pedestrian casualty (all injury) rates with town size*.
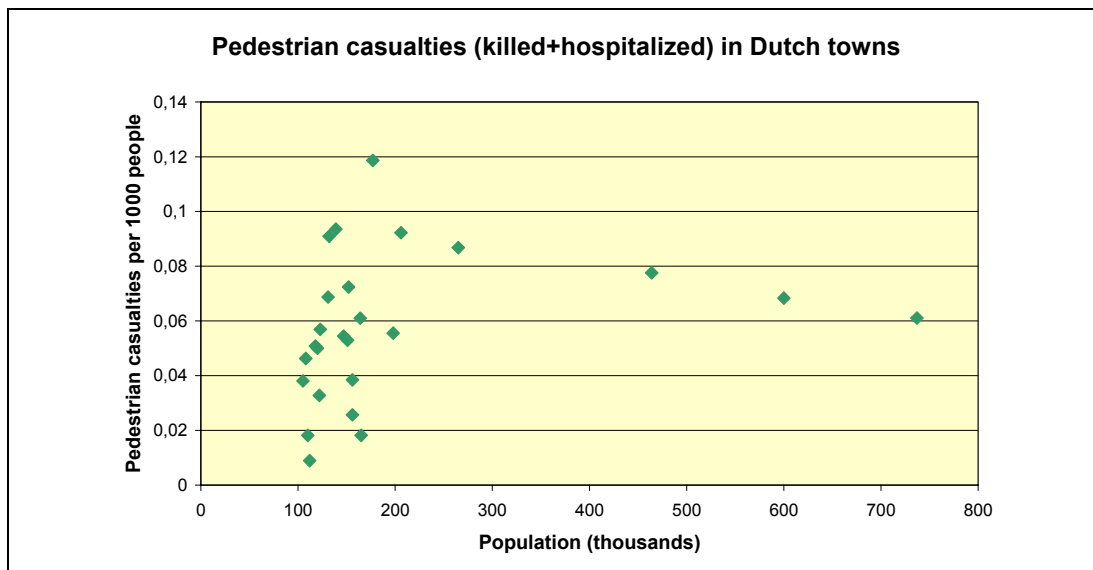
Figure 6.13b. *Variation in Dutch pedestrian casualty (killed and hospitalized only) rates with town size*.

6.6.2. Avenues for further work

There would appear to be opportunities for comparison between cities both within countries and between similar-sized cities in different countries. The former would aid the development of an effective ranking system within a country, while the latter would further extend understanding of what factors contribute to a good safety performance.

It is proposed that the process of comparison should include:
- casualty numbers by road type and road user group;
- length of road and average traffic volumes by road type;
- speed limits by road type and length;
- transport and traffic policies and modal split;
- any local information on behaviours such as seatbelt wearing, speeding, alcohol involvement in accidents;
- road safety measures implemented over at least a 10 year period by road type (engineering and behavioural);
- typical frequency and types of junctions by road type;
- town population, population density, and possibly economic indicators of activity;
- road safety plans, policies and programmes;
- organization and funding of road safety programmes.

The primary task would be to select a set of cities with well-documented road safety policies and compare 1) how these inputs have developed over the last 10-20 years, and 2) how the safety outputs have changed over the same period.

It can be expected that the safety performance in a city will be influenced both by transport and traffic policies, and by safety policies. In turn, traffic policies will affect, and be affected by, the spatial layout of the town, the road network provided, and the demand for travel by different modes and within different corridors within the city. In the past, transportation models and urban safety management models have

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analysed this situation for each major link in the road network. For the work suggested here, it is suggested the city is defined in terms of the average conditions in each road category. Some safety policies, such as enforcement, will be applied across the whole city, although they might focus on specific problem areas, but different engineering and speed control measures are likely to be applied to different types of road within the city.

A starting point for defining performance is thus likely to be to assess separately the roads serving different traffic functions – residential access roads, distributor roads and arterial roads. The balance between safety and mobility, and the demographics of the population at risk, will be different for each of these road types, and thus safety policies will have a different focus for each road type. The overall demand for travel on each road type, reflected by the average person and vehicle flows, will affect the impact on mobility of any changes to the road environment, and the degree of acceptability of such policies. Both the quantification of the traffic problem (as AADT of different modes) and of the implementation of safety related programmes (e.g. % of roads treated as 30km/h zones, % of road length with cycle lanes) can be linked directly with the length of road of each type. Wider policies (enforcement, education) can be applied across all roads, but may be targeted at user groups (e.g. children) that are more likely to use a particular road types.

Data should be sought across all levels of the safety pyramid used in SUNflower. Data on safety outcomes should be readily available, providing the boundaries of the area being assessed can be defined. Many large cities include large peri-urban developments; these are likely to perform differently than the more central city areas and should either be excluded from the comparison or considered separately. As far as road safety outcomes are concerned, both fatalities and injuries (injury accidents) are of interest, due to the scarcity of fatal injury at the level of cities.

Data on safety performance indicators is likely to be less available unless local surveys have been made. It may be possible to carry out small scale surveys of specific kind of behaviour such as speeding, seatbelt wearing, compliance with traffic signals etc. If this cannot be done, regional or national data will need to be assumed. Differences in transport patterns and in implementation of policies and programmes are likely to be fairly well known. But differences in safety management structures and 'behaviour shaping mechanisms' are not likely to be known unless explored through in-depth surveys.

The existence of safety 'champions' and an environment in which they can strongly influence delivery of safety schemes has been shown to be important (Peden et al. 2004 and Bliss & Breen, to be published). The most noteworthy recent example is the presidential intervention in France to put road safety high on the national agenda. But there are many local examples where safety programmes have been driven by the actions of individuals or groups. The DUMAS project, particularly in the example of Gloucester Safer City, also demonstrated the role that efficient local communication groups can play in interacting with the public and winning acceptability for safety policies. Data that would be useful to collect include the existence of a local safety strategy, the executive responsibilities of local managers, the availability of funds, and the extent of local safety analysis and scheme implementation skills. Much of this type of information may need to be obtained through questionnaires and in-depth Interviews, and a safety management interview process will need to be developed. Face to face interviews could be made in

participant countries, but there may also be scope for postal questionnaires to cover cities in a wider range of countries.

Output will aim to:
- illustrate differences in safety management and safety outcomes;
- show how these are affected by the factors above;
- show how decisions are influenced by social norms/national policies;
- show how public respond to policies implemented;
- propose ways in which data on important factors might be collected more generally to allow comparison across a wider group of sub-national areas.

It would be of interest to compare both the factors affecting the performance of cities of similar size in different countries, and also the factors affecting the performance of cities of differing size within the same country. The SUNflower study showed that Britain contained a much wider number and range of city sizes than the Netherlands or Sweden, and could provide a useful basis for within country comparisons. Given the large number of cities within Britain, this comparison could encompass both similar-sized and different-sized cities.

Among the most populous cities within administrative city limits in Europe (as opposed to urban or metropolitan areas), there are six cities with populations over 2 millions and 16 cities with populations over 1 million. A sample of cities from these groups would illustrate the factors affecting the implementation of successful safety programmes in national capital cities. However, these cities are likely to each have its own distinctive character, and both a 'safety ranking process' and a transfer of experience might be less important than in smaller towns.

The conditions in smaller free-standing cities are likely to be very different, and the study should seek to focus on comparing a sample of cities with populations from 100,000 to 250,000. The final choice of cities may be dictated by the availability of good data across the range of factors discussed above. It may be possible to collect more limited data for a larger sample of cities for some population groups.

7.   Conclusions and recommendations

The SafetyNet project can be considered as a start-up of the European Road Safety Observatory, paying attention to three different areas: collecting and analysing data at a *macroscopic level* (CARE, risk exposure data and safety performance indicators), *in-depth-data* (independent and in-depth accident investigation) and *data application* (EU safety information system and data analysis and synthesis).

In the course of the present SafetyNet project it was decided to include the SUNflower approach in SafetyNet in an attempt to integrate different components of the two projects. This report reflects the work that has been done to accomplish this task.

The aim of the SUNflowerNext project is to develop a knowledge-based framework for comprehensive benchmarking of road safety performances and developments for a country or sub-national jurisdictions.

The SUNflowerNext study attempts to link the different components of the road safety target hierarchy (information from the five layers of the SUNflower pyramid) and to use this to create a composite index for road safety for benchmarking the road safety performance of countries. This composite index is aimed to present the safety performance of countries in a valid and meaningful manner and, in addition, can be used to identify how countries can learn from each other.

This study has made use of existing data that was relatively easily available. This ensured that the study could be carried out in a relatively short time. On the other hand, one important concession needed to be made. Because this study is an innovative approach using existing data only, and it turned out that relevant data was not always available, it was decided to do the research in such a way that all the steps required for benchmarking a country's performance have been taken. As a result it was decided to refrain from presenting the actual results of the benchmark, as they are considered not always to be of sufficient quality. The experiences gained from this study are such that SUNflowerNext's ambition – benchmarking the safety performance of countries – is realistic after detailing indicators, have them accepted by the road safety community, and when reliable data becomes available. Therefore, it is recommended to carry out this task in Europe in the near future, to widely spread the results of this benchmarking, for example on an annual basis, and to consequently make use of them for policy making in the European Member States.

7.1.   Benchmarking of road safety performances

Benchmarking is a process in which countries or sub-national jurisdictions (states, provinces, 'länder', etc.) evaluate various aspects of their performance in relation to other, and to so-called 'best in class' practices. The benchmark results enable countries or jurisdictions to learn from others as a basis for developing measures and programmes with the aim of improving their own performance.

In the SUNflowerNext project we concluded that it is better not to make comparisons between all European countries, but to attempt grouping comparable countries and to then compare the countries within a specific group.

Different approaches have been used in this study, in Chapters 3 and 4 these approaches are presented. We recommend identifying the pros and cons of these approaches taking data availability explicitly into account, and based on this, making a final decision on how to best carry out this grouping of countries.

Three procedures have been used to find out whether meaningful groups could be made: safety experts were asked to group countries, countries were grouped based on road safety outcome indicators (grouping obtained with a Singular Value Decomposition (SVD) of the annual fatality rates in the years 1980-2003 of countries), and, thirdly, countries were grouped using general statistic data about a country in the most recent years based on a Multiple Correspondence Analysis (MCA).

The results of the three methods have many points of agreement. The results are presented in the table below with some reservation, for reasons which are given before. Further effort is recommended to improve the quality of this grouping and by adding more countries to this grouping.

Group 1	Group 2	Group 3	Group 4
Denmark Finland Great Britain Iceland The Netherlands Norway Sweden	Austria Belgium France Germany Ireland Italy Luxemburg Switzerland	Czech Republic Hungary Poland Slovakia Slovenia	Greece Portugal Spain

Table 7.1. *Indicative grouping of countries based on three different procedures to be used in further benchmarking of road safety performances.*

7.2. Indicators for road safety

SUNflowerNext decided to develop an integral and comprehensive set of indicators to measure the road safety performance of a country including all information as proposed in the SUNflower pyramid. SUNflowerNext distinguishes three types of indicators: *the road safety performance indicator, the implementation performance indicator, and the policy performance indicator.*

The first indicator captures the quality of road safety in a country. It has been named **Road safety performance indicator**. Other names such as outcome indicators and product indicator are also used. In SUNflower the three top layers of the SUNflower-pyramid are included: final outcomes (numbers of killed and injured), intermediate outcomes (such as the safety performance indicator), and social costs.

For a meaningful comparison of countries, numbers of people killed or injured are typically 'normalized', resulting in fatality rates, e.g. fatalities per inhabitant, vehicle type, or kilometre travelled. Besides, the comparison may specifically concern more vulnerable groups of road users, e.g. pedestrians, cyclists, motorized two-wheelers.

The second type of indicator specifies the quality of the implementation of road safety policies: the **Implementation performance indicator.** For this implementation quality indicator the term process indicator can also be used. Basically, this

indicator follows a vertical line in the pyramid linking 'safety measures and programmes', safety performance indicators and numbers of killed and injured people.

Implementation performance, in general, can deal with different components of causal relationships between the (three) different layers of the safety pyramid: between the policy changes ('safety measures and programmes') and the changes in safety performance indicators (SPIs), and between the changes in safety performance indicators and changes in the number of casualties. However, although much progress was made in the development of safety performance indicators within the SafetyNet project, it was necessary to conclude that the possibilities for a systematic and comprehensive measurement of all these relationships are still limited. Further research is needed on this indicator, both in terms of definitions, concept development and data collection.

The third type of indicator deals with the quality of policies to improve road safety: the **Policy performance indicator.** This indicator sometimes is called a policy output indicator. Here SUNflowerNext distinguishes two components: the quality of conditions (strategies, programmes, resources, coordination, institutional settings, etc.) and the quality of action plans and individual (counter)measures) in the perspective of the ambitions expressed in road safety targets

Policy performance is about the quality of road safety strategy, more specifically about the quality of road safety plans and the conditions for successfully implementing road safety measures and programmes. Examples are institutional arrangements, budget, quality of professionals, application of evidence-based knowledge, sound analysis and diagnosis of road safety problems, vertical cooperation between different tiers of government, etc. Different international studies summarize the demands for the effective development and implementation of national road safety policies. However, it must be concluded that as yet only little information from European countries is available, and it is strongly recommended to include this type of information in international data collection systems, such as the European Road Safety Observatory. A good understanding of why European countries are making road safety progress is impossible without information on Policy performance.

7.3.   Towards a composite road safety performance index

There are several reasons why it is attractive to combine all information in one indicator, a so-called composite index. A composite index includes all components of the SUNflower pyramid, more specifically the three types of indicators.

The pros and cons of working with composite indices are rather well known and are discussed in this report. Three words can summarize the main characteristics: 'simplification, quantification and communication'. Road safety will not be the first policy field to successfully attempt capturing performance in one single value. To mention a few: the Human Development Index, the Environmental Sustainability Index and the Overall Health System Index. Based on these examples it was decided to also explore the opportunities for a composite index for road safety.

The purpose of SUNflowerNext is to explore a composite road safety performance index and to research the similarities in the behaviour of basic indicators and

countries. The composite index will enable a ranking of countries according to their safety performance.

The choice of indicators and their definitions has a preliminary character. As was mentioned earlier, the choice of indicators used was influenced by the direct availability of data. In addition, the assessments that were carried out suggest that the final results that are presented are not the main value of its exercise. This study makes clear along which lines a composite index can be designed.

Weights based on statistical models were used to combine the basic indicators into a composite one. Both Principal Component Analysis (PCA) and Common Factor Analysis (FA) weighting were examined. Both methods group together indices that are collinear to form a composite index that captures as much of common information among sub-indicators as possible. The analysis was made on the data collected for 27 European countries. Five trials of creating a composite index were performed, where each trial produced a combined safety indicator, and clusters/ groups of countries with similar values of the combined indicator. The composite indicator enables us to rank the countries in accordance with their safety performance.

The purpose of our analysis was to create a composite road safety performance index and, concurrently, to explore the similarities in the behaviour of basic indicators and countries. It was demonstrated that both tasks cab be realized by means of the statistical weighting methods applied. The composite indices, estimated by several methods, enabled us to rank the countries according to their safety performance.

The analysis revealed that the countries' ranking based on a composite index is not necessarily similar to the traditional ranking of countries based on mortality rates or fatality rates/risks only. We believe that adding information on policy performance and implementation performance to the ranking process improves the results beyond the traditional methods and makes them more comprehensible. Furthermore, it was observed that the indicators belonging to the final outcomes and intermediate outcomes, both part of the road safety performance indicator, are not uniform in their behaviour. Indicators which were found to be more consistent and termed 'core set of basic indicators' are recommended for future uses.

The general conclusion is that the design of a composite road safety performance index in which relevant information from the different components of the road safety pyramid has been captured and weighted is realistic and meaningful. In addition, such an index gives a more enriched picture of road safety than a ranking only based on data on mortality or fatality rates, which is normal practice at present. Grouping countries in this process is promising and seems to be preferable to simply ranking countries. Before defining the *SUNflower road safety performance index* and actually applying the results to policy making, two improvements should be made: develop indicators for the Implementation performance indicator and develop procedures to make available high quality and comparable data for EU Member States. Finally, it is recommended to develop a standardized terminology for road safety indicators and a composite index.

7.4. Time series analyses

Analyses of safety developments are interesting because they may give us a better insight in the underlying forces for these developments and, hopefully, also in the effectiveness of road safety interventions. Different approaches were used in this part of the study, among which state space modelling. The first attempt to compare developments in fatality rates (fatalities per 10,000 motorized vehicles) and mortality rates (fatalities per 100,000 inhabitants) was made at a macroscopic level. Although European countries do have a remarkably different history when it comes to the development of fatality rate vs. mortality rate, our data suggests that all countries seem to be moving to the same position. However, leading countries in the field of road safety generally keep ahead of the other countries, albeit with decreasing advantage.

Three types of disaggregate developments are compared (age, traffic mode and road type). For this comparison countries were firstly grouped. Inspecting the results of the analyses, we may conclude that, although all European countries tend towards the same aggregated or macroscopic level of road safety, there are important differences between the individual countries as well as between groups of similar countries in terms of how they reach this level of road safety when considering their focus on avoiding special types of accidents. In other words, the general policies of improving road safety in different countries ultimately seem to move towards the same safety level, but for different countries that level of road safety is achieved at a different pace and in different ways.

Time series analysis methods have been available for many years. More advanced methods are being developed as of recently. These methods offer new opportunities and more reliable results; however they require a good insight. It is recommended to introduce these methods in road safety research by developing menu-based applications for these methods and by organizing training courses.

7.5. SUNflower at regional or city level?

SUNflower analyses to date have focussed on national comparisons and the lessons that could be learned by individual countries from comparing their road safety policies and resulting performance with that of other countries. A similar scope exists for comparison of programmes and performance at the sub-national level. In principle, such comparisons can be made at any level where an authority has the possibility to pursue its own safety programme and policies or where developments in motorization or in economic activity result in changes in mobility levels of different transport modes, resulting in changes in safety outcomes.

There is potential for innovation in terms of knowledge and road safety improvements which can be reached by the application of the SUNflower method at sub-national level, which has so far been left unexplored. The potential beneficiaries are not just the local administrations who prepare and apply the programmes and policies at the local level, but national administrations also benefit by improved understanding of structural factors influencing the application and results of road safety policies. The application at sub-national level may however require a rethink and an adjustment of the method applied so far at the national level. This part of the study was intended to explore the potential for comparisons of safety performance at a sub-national level and to propose methods allowing reliable comparison.

There are two basic reasons for comparing safety performance of sub-national jurisdictions. In the first place, a ranking of relative performance of each area will be very useful for comparison within countries. To ensure a meaningful process, factors that could enable safety practitioners to achieve similar safety improvements need to be included within the ranking process. This might be done by developing a model of safety outcomes that includes these factors. The second reason is to provide better understanding of the factors affecting safety improvement, so that safety practitioners can achieve more effective programmes. This requires greater focus on understanding how the effects of programmes are modified by the nature of the safety problems faced by each area. Lessons can not only be learned from comparison between areas within countries, but also from comparison between similar areas in different countries. This can probably be more effectively achieved by case studies comparing small groups of areas, than by attempts to model a wide range of areas.

There are two ways to make any statistical sub-national comparison meaningful and reliable. One is to compare areas that are similar in terms of their physical structure such as road network configurations, climate, relief, mobility patterns, modal split, and attitudes towards road safety. The second is to try to adjust for as many of these factors as possible. The first way limits the number of areas that can be used for comparison, the second is sensitive to data reliability and availability, and implies the use of sophisticated statistical methods. This could make the comparison less understandable for a broader public and might bring about the risk of the use of inappropriate and confounding factors.

An alternative approach, consistent with the SUNflower case studies, is to explore the factors that are present or absent in situations with a good or a poor safety performance. This approach allows factors that may be difficult to define in numerical terms, such as organizational efficiency or the presence of constraints on the implementation of safety policy, to be considered alongside the numerical characteristics of an area. The outcome of such an approach will be less quantitative but allows a potentially wider range of factors to be considered.

Analysis at a regional level allows a more controlled environment to be studied than aggregating all regions into national statistics. However, most regions will still contain a mixture of urban and rural environments, which have clearly different road user groups and traffic conditions as well as different population densities. One way of reducing these confounding factors is to limit the comparison to areas that have more or less consistent characteristics, such as metropolitan regions or to large cities.

The results of this sub-national comparisons are considered that interesting that it is recommended to continue this work in an international/European project. In addition, it is also recommended to use a different approach for studies at both the regional and the urban level.

For regions

The SUNflowerNext study of applying the SUNflower methodology on regions clearly illustrates the added value of this new work. Different research questions have been addressed and important factors influencing the safety performance of regions have been identified. More attention seems to be required for factors and

developments that are captured in the bottom layer of the pyramid: 'structure and culture'. We recommend a statistical approach. Practically all structural factors are mutually correlated and if they are used simultaneously this should be done with care: otherwise analyses could result in confusion rather than in understanding.

For cities

We recommend further studies for comparison between cities both within countries and between similar-sized cities in different countries. The first type of comparison will aid the development of an effective ranking system within a country, while the latter will further increase our understanding of what factors produce a good safety performance. The primary task of this study would be to select a set of cities with well-documented road safety policies and compare how these inputs have developed over the last 10-20 years, and how the safety outputs have changed over the same period. For this comparison we recommend to use a case-study approach.

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Appendix 1. Final data set with initial and imputed values of basic indicators

For data imputations, the SAS 9.2 MI procedure was applied using the MCMC method for imputation. At present, only continuous variables can be used for the MCMC imputation. This imputation assumes multivariate normality of variables. We used SAS macro %bctrans to find a Box-Cox transformation in order to achieve marginal normality of each of the continuous variables. (Details about %bctrans can be found in LaLonde, 2005.) Due to the relatively small number of observations with respect to the number of variables (basic indicators), the imputation was carried out separately for groups of variables. All the data transformations and imputations were done for the data set without Malta. Then, the missing value among Malta's single observation was imputed using a monotone imputation. The final dataset of basic indicators is as follows in the tables below.

Obs	Country	Code	B1	B2	B3	B4	B5	B6
1	Austria	AT	88.138	174.605	99.697	54.6356	0.15068	0.06575
2	Belgium	BE	101.347	216.072	96.160	38.4602	0.11413	0.08606
3	Cyprus	CY	111.320	236.238	167.478	31.0814	0.22093	0.02326
4	Czech Republic	CZ	103.514	263.532	145.756	20.8043	0.19003	0.10348
5	Denmark	DK	56.278	153.588	55.802	17.6569	0.19608	0.10131
6	Estonia	EE	151.837	389.390	175.258	12.6716	0.27219	0.04142
7	Finland	FI	63.802	136.146	53.034	20.0595	0.11873	0.11346
8	France	FR	76.753	153.140	63.912	17.0544	0.11361	0.03844
9	Germany	DE	61.802	109.886	57.312	64.4243	0.13966	0.09546
10	Great Britain	UK	54.385	115.697	47.645	58.8902	0.20953	0.04556
11	Greece	EL	148.630	374.626	174.421	9.7707	0.16113	0.01267
12	Hungary	HU	129.000	446.044	271.176	16.0990	0.22717	0.11742
13	Ireland	IE	86.348	211.119	129.577	18.6033	0.18991	0.02967
14	Italy	IT	96.180	162.053	73.805	42.0046	0.12622	0.04835
15	Latvia	LV	177.889	520.308	256.459	10.5700	0.38000	0.06000
16	Lithuania	LT	223.625	498.111	190.550	8.9236	0.34000	0.05130
17	Luxembourg	LU	76.168	115.759	54.111	21.1667	0.09677	0.01613
18	Malta	MT	24.606	46.435	48.780	84.1000	0.35294	0.00000
19	The Netherlands	NL	44.659	101.938	48.425	33.5986	0.09436	0.18288
20	Norway	NO	52.200	116.000	62.848	32.7479	0.14463	0.03306
21	Poland	PL	137.463	407.642	234.859	8.9407	0.32256	0.11076
22	Portugal	PT	91.550	228.269	130.769	36.8215	0.15996	0.04128
23	Slovakia	SK	107.393	439.060	214.986	13.7962	0.09300	0.05500
24	Slovenia	SI	130.552	270.037	112.659	44.3511	0.13688	0.05323
25	Spain	ES	93.027	200.748	117.211	24.3126	0.15308	0.01846
26	Sweden	SE	49.006	106.509	44.724	40.7146	0.12360	0.05843
27	Switzerland	CH	49.600	95.000	42.131	58.0946	0.20541	0.09459

Obs	B7	C1	C2	C3	C4	C5	C6	C7
1	0.18356	0.05990	83.0000	52.0000	20.5429	7.5148	0.12353	0.06974
2	0.15529	0.04408	71.0000	23.8853	21.3000	6.6500	0.05975	0.11133
3	0.29070	0.22549	79.6000	36.2805	20.6755	9.3018	0.07589	0.21735
4	0.10913	0.05521	72.0000	13.0000	20.7000	11.0000	0.15113	0.09018
5	0.14706	0.22961	85.0000	63.0000	20.6679	7.3150	0.06746	0.18655
6	0.04142	0.28402	74.0000	30.0000	21.6626	12.7269	0.01895	0.13972
7	0.09499	0.23483	87.9760	78.0000	20.4537	9.1340	0.10471	0.11638
8	0.23487	0.28808	97.0000	70.0000	20.7287	8.3166	0.06420	0.13726
9	0.17678	0.05074	96.0000	89.0000	20.1000	6.0000	0.10466	0.05077
10	0.17506	0.17495	90.0000	84.0000	20.6000	5.0000	0.03731	0.10656
11	0.29994	0.10676	79.4106	28.0234	20.7000	8.0000	0.17236	0.17438
12	0.10054	0.08764	67.0000	34.0000	20.6000	8.0000	0.03671	0.12531
13	0.16320	0.14937	86.0000	46.0000	20.6434	5.1358	0.01613	0.14726
14	0.23816	0.02366	71.0000	21.2961	20.9538	7.8561	0.20493	0.08670
15	0.04000	0.21719	77.0000	22.5190	21.3000	10.0000	0.03725	0.12225
16	0.11585	0.11842	60.0000	13.0348	22.6350	14.4799	0.01442	0.07663
17	0.00000	0.00000	80.0000	60.0000	20.7793	4.4223	0.10008	0.07960
18	0.17647	0.24980	96.3000	28.0000	18.6000	9.0000	0.04441	0.16429
19	0.18385	0.15333	90.0000	64.0000	20.2000	6.0000	0.06450	0.11309
20	0.15289	0.30837	91.0000	83.0000	21.0000	8.0000	0.09362	0.17036
21	0.03857	0.09827	77.7000	23.2381	20.5527	11.7991	0.04711	0.14375
22	0.24149	0.11424	86.0000	45.0000	20.7379	9.6747	0.09035	0.21346
23	0.07400	0.11964	76.2848	24.3845	20.9679	7.0002	0.03654	0.11904
24	0.20532	0.32171	86.8500	30.0000	21.1468	4.9922	0.04812	0.06341
25	0.17650	0.12129	74.3500	51.0000	20.6213	7.6014	0.14563	0.16712
26	0.15730	0.34000	92.0000	73.0000	22.6000	7.0000	0.09584	0.09239
27	0.21622	0.19315	82.0000	53.0000	20.5469	7.2542	0.12499	0.06449

Obs	N_A1	N_A2	N_A3	N_A4	N_A5	D1	D2
1	1.00000	3.00000	2.00000	2.00000	1.00000	506.689	98.92
2	2.00000	2.00000	2.00000	2.00000	2.00000	470.147	347.05
3	1.39650	2.27384	1.92987	1.75805	1.37147	478.943	83.76
4	2.00000	3.00000	2.00000	2.00000	2.00000	399.391	130.38
5	1.00000	2.00000	2.00000	2.00000	2.00000	370.843	126.38
6	2.00000	3.00000	2.00000	2.00000	1.00000	412.700	29.69
7	1.00000	2.00000	2.00000	2.00000	2.00000	474.808	15.61
8	1.00000	1.00000	2.00000	1.00000	1.00000	503.789	113.12
9	1.00000	2.00000	2.00000	1.00000	2.00000	565.750	230.57
10	1.00000	2.00000	2.00000	1.00000	1.00000	471.095	249.30
11	1.00000	2.00000	2.00000	2.00000	2.00000	406.652	84.64
12	1.00000	3.00000	2.00000	2.00000	2.00000	293.432	108.24
13	2.00000	2.00000	2.00000	1.00000	2.00000	417.682	61.38
14	3.00000	4.00000	3.00000	3.00000	4.00000	596.931	196.25
15	2.00000	3.00000	2.00000	2.00000	2.00000	360.325	35.31
16	2.00000	3.00000	2.00000	2.00000	2.00000	470.397	51.92
17	1.37723	3.63131	2.43701	1.90550	2.00012	660.913	183.08
18	1.00000	3.00000	2.00000	2.00000	2.00000	534.938	1360.00
19	1.00000	1.00000	2.00000	1.00000	1.00000	441.997	394.17
20	2.00000	1.00000	1.00000	2.00000	2.00000	445.233	14.44
21	2.00000	3.00000	2.00000	2.00000	2.00000	351.057	121.92
22	2.00000	3.00000	2.00000	2.00000	2.00000	404.752	115.33
23	2.00000	3.00000	2.00000	2.00000	2.00000	247.282	110.53
24	2.00000	3.00000	2.00000	2.00000	2.00000	487.601	99.01
25	1.00000	3.00000	2.00000	2.00000	2.00000	464.011	87.90
26	1.00000	1.00000	1.00000	1.00000	1.00000	461.137	20.25
27	1.00000	1.00000	1.00000	2.00000	1.00000	519.384	181.82

Appendix 2.   Detailed results of the five analyses

A2.1. PCA in which all variables are analysed together (PCA-all)

Using the PCA, Eigenvalue>1 served as a criterion for choosing the number of factors. As a result, five factors were chosen providing 76.3% of cumulative explained variance. Then we used orthogonal rotation of the five factors. Scores were calculated for each country for each factor. Then the five scores of each country were weighted according to the weights created by the 'explained by each factor' variance divided by the sum of the five variances.

Table A2.1 provides the rotated factor pattern received in this analysis, which makes it possible to see which variables (basic indicators) contributed most to each one of the factors built. The behaviours of major variables (with coefficients over 0.5), which compose the factor, enable interpreting the 'safety-desirable' behaviour of the factor. For example, for basic indicators C5 (median age of passenger cars), B1-B3 (number of fatalities per population, vehicles, passenger kms travelled), B5 (share of pedestrian fatalities): the lower the values, the better the safety situation of the country. Similarly, for indicators C2-C3 (safety belt wearing rates in front and rear seats): the higher the values, the better for safety. These two groups of indicators make a major contribution to Factor 1 (see Table A2.1), with positive and negative coefficients, accordingly. Therefore, a better safety situation overall is associated with lower values of Factor 1.

In Table A2.1 arrows indicate 'safety-desirable' behaviour of each basic indicator. Based on this information and each factor's composition, the factor interpretations will be as follows:
- Factor 1 mainly reflects the safety 'product', car fleet's age and seatbelt use, and for better safety it should aim at a lower value. Therefore, we can write: Factor 1 → min;
- Similarly, Factor 2 mainly reflects the 'strategy' indicators, but also includes a negative correlation with C1 (share of drink-driving accidents). Therefore: Factor 2 → min;
- Factor 3 reflects the share of bicyclist fatalities, EuroNCAP scores for cars, and population density. Therefore: Factor 3 → min;
- Factor 4 reflects the share of motorcycles in the vehicle fleet and the share of motorcyclist fatalities. Therefore: Factor 4 → min;
- Factor 5 reflects the share of HGVs in the fleet, the number of injury accidents per fatality, and the motorization level of the country, therefore the 'desirable' value of this factor is unclear, but will probably be a minimum.

The tools produced by this analysis for the estimation of each country's score, i.e. the factors' scoring coefficients, factors' weights, means and variances of the variables to estimate the standardized values, are given in Appendix 3.

Table A2.2 provides the country scores estimated in this trial, where the combined indicator is presented by WF (weighted index' value).

Basic indicator and its 'safety-desired' behaviour		Factor1	Factor2	Factor3	Factor4	Factor5
C5	↓	**0.82281**	-0.05114	-0.13990	0.03258	0.07188
B2	↓	**0.81377**	0.22390	-0.07361	-0.35261	0.27504
B1	↓	**0.80847**	0.29893	-0.21667	-0.23356	0.04940
B3	↓	**0.74577**	0.23969	0.00297	-0.30388	0.42035
B5	↓	**0.73546**	-0.08223	-0.07773	-0.28072	0.06914
C2	↑	**-0.75692**	-0.49112	-0.07181	0.00379	0.07170
C3	↑	**-0.77094**	-0.47782	-0.01486	-0.01698	-0.06163
N_A3	↓	-0.06187	**0.86337**	0.11585	-0.12262	0.07379
N_A2	↓	0.32897	**0.83821**	-0.10312	-0.14772	-0.04356
N_A5	↓	0.10671	**0.78628**	-0.10678	0.24352	0.01832
N_A4	↓	0.48346	**0.57833**	-0.11082	0.40171	-0.02498
N_A1	↓	0.38289	**0.55035**	-0.28421	-0.00448	-0.12514
C1	↓	-0.01846	**-0.70457**	-0.48939	-0.07028	0.10070
B6	↓	0.09152	-0.22500	**0.83410**	-0.09091	-0.08257
D2	↓	-0.34390	0.16389	**0.72886**	0.03552	-0.23342
C4	↑	0.49951	-0.17503	**-0.54151**	-0.17143	-0.41491
C6	↓	-0.19535	0.27701	0.03949	**0.81482**	-0.13549
B7	↓	-0.24746	-0.15919	-0.04603	**0.72856**	0.14163
C7	↓	0.03620	-0.07892	-0.25342	0.19072	**0.84957**
B4	↓	-0.48078	-0.17521	0.21314	0.33466	**-0.52502**
D1	↑	-0.49118	0.18357	-0.16747	0.25852	**-0.63870**

Table A2.1. *Rotated factor pattern received by the PCA in which all variables are analysed together*.

Obs	Country	Code	Factor1	Factor2	Factor3	Factor4	Factor5	WF
1	Austria	AT	-0.18750	0.03685	0.50396	0.52196	-0.87198	-0.03163
2	Belgium	BE	0.20785	0.49670	1.11582	0.14418	-0.88384	0.25906
3	Cyprus	CY	0.20292	-0.36392	-0.69144	1.03772	1.26982	0.17758
4	Czech Republic	CZ	1.06053	0.46159	1.03482	0.71011	-0.32119	0.68559
5	Denmark	DK	-0.45927	-0.33758	0.29466	0.11332	1.21670	-0.04707
6	Estonia	EE	1.21917	-0.35021	-1.09404	-1.14521	-0.18884	0.02856
7	Finland	FI	-0.57484	-0.29836	-0.00991	0.09103	0.21920	-0.24463
8	France	FR	-1.10061	-0.96531	-0.76079	-0.25846	0.63887	-0.69691
9	Germany	DE	-1.41318	0.00544	1.09739	-0.24937	-1.01914	-0.51574
10	Great Britain	UK	-1.35379	-0.52159	0.31356	-0.96782	-0.39620	-0.74990
11	Greece	EL	0.44094	0.19936	-0.32738	1.69338	1.55771	0.57649
12	Hungary	HU	1.01982	0.22930	1.43842	-0.78585	1.07992	0.64505
13	Ireland	IE	-0.98623	0.29825	-0.79932	-1.25632	0.94042	-0.42463
14	Italy	IT	-0.11862	2.87298	-0.39783	2.03147	-1.21513	0.76132
15	Latvia	LV	1.47182	0.11570	-0.46289	-1.30890	0.28562	0.36030
16	Lithuania	LT	2.52497	-0.03205	-0.76131	-0.68984	-1.62858	0.50048
17	Luxembourg	LU	-1.71519	1.89584	-0.65024	-1.44137	-1.11003	-0.52814
18	Malta	MT	-1.10104	0.63562	4.22576	0.44586	-0.22985	0.35854
19	The Netherlands	NL	-0.82933	-0.90707	2.69329	-0.30286	0.13467	-0.19797
20	Norway	NO	-0.44158	-1.14757	-1.49153	0.89052	0.30156	-0.49961
21	Poland	PL	1.28805	0.26680	0.94963	-0.81912	0.77487	0.64385
22	Portugal	PT	-0.12295	0.37701	-0.41458	0.95944	1.21851	0.27370
23	Slovakia	SK	0.22268	0.72877	0.14052	-1.14595	1.00259	0.26355
24	Slovenia	SI	-0.22471	0.25272	-0.92202	-0.33291	-0.92573	-0.29356
25	Spain	ES	-0.31602	0.54563	-0.48487	0.83210	0.75748	0.16589
26	Sweden	SE	-0.22992	-2.19453	-1.35911	0.04294	-1.41079	-0.99941
27	Switzerland	CH	0.41497	-1.66474	1.04518	1.63581	-1.42649	-0.11224

Table A2.2. *Country scores estimated by the PCA in which all variables are analysed together*.

Based on the weighted index (WF) and using a WARD clustering procedure, the countries can be classified into similar groups as presented in Figure A2.1. The number of groups varies depending on the level of 'distances' between the countries, which is selected as a threshold for countries in the same group. For example, with a threshold value of 0.05, the countries are divided into four groups.
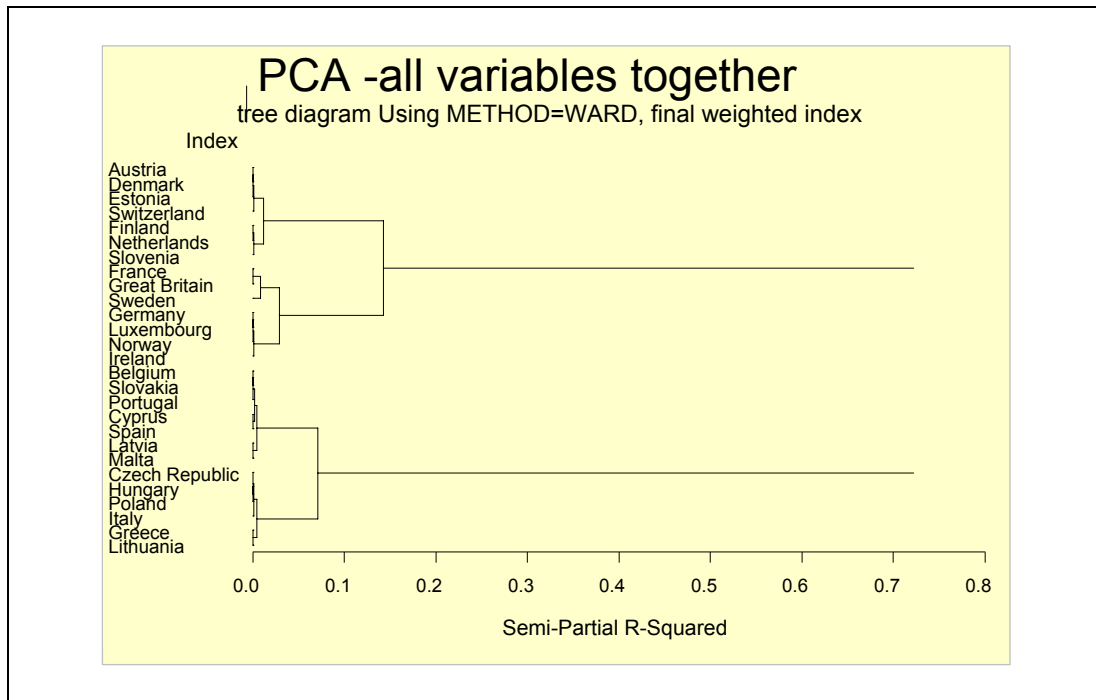
Figure A2.1. *Similar groups of countries based on the PCA-all variables analysis*.

Furthermore, we can recognize similarities in the behaviour of separate indicators when they are plotted against the factors. For example, Figure A2.2 illustrates the indicators' behaviour on the dimensions of Factor 1 and Factor 2, where similar behaviour can be noted for variable groups of B1-B2-B3, A1-A4, A2-A3-A5, C2-C3. The same groups of variables were relatively stable when they were plotted against other factors, whereas other variables behaved differently on different dimensions.
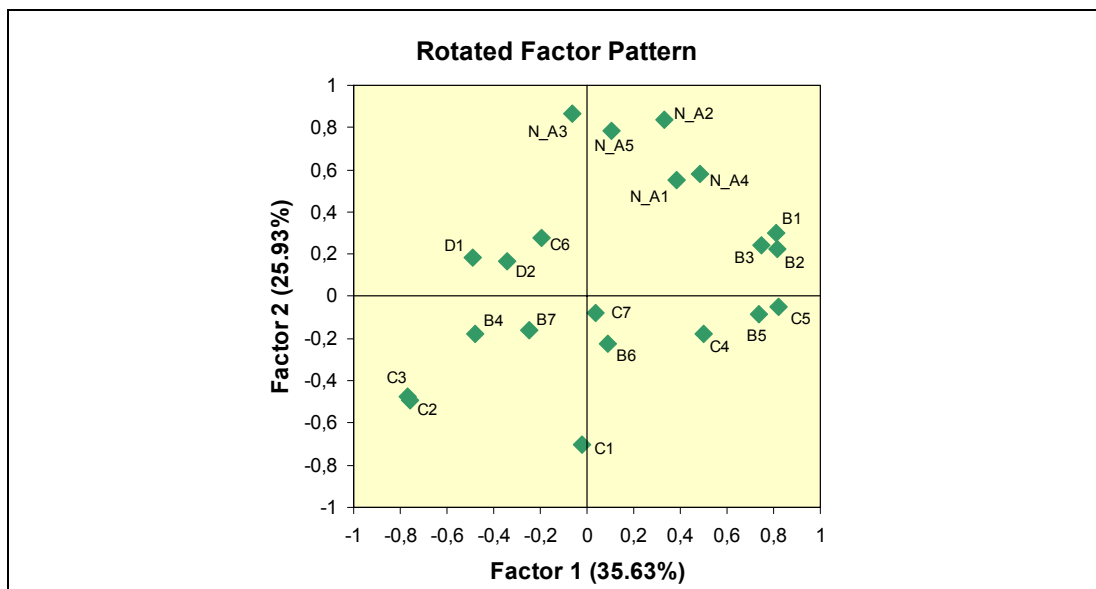
Figure A2.2. *Basic indicators plotted versus Factor 1 and Factor 2 (PCA-all analysis)*.

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A2.2. PCA by groups of indicators (PCA-groups)

In this analysis we carried out the PCA for each group of indicators separately, namely for the A, B, C and D groups of basic indicators. Initially, one combined factor is fitted for each group. If more than one factor is obtained for a group, then the factors are weighted to get one combined index (factor) for this group. The four resulting combined factors are then subjected to another PCA, where the final composite index is generated by using the weights attained from this second analysis.

The eigenvalue>1 criterion was first used for choosing the number of factors for each group of variables and next for the final combined indicator.

For the A-group indicators one factor was chosen which provided 64.42% of the cumulative explained variance. According to the factor pattern received in this analysis (Table A2.3a), each variable of the group contributes positively to the factor value. As lower values of A1-A5 indicators are preferable (stating higher quality of the national safety program), a lower value of the A-group factor is 'safety-desirable'.

The tools produced by the analysis of the A-group (and further, by the analyses of B, C and D groups of indicators) for the estimation of each country's score, i.e. the factors' scoring coefficients, factors' weights (if more than one factor received), means, and variances of the variables (to estimate the standardized values), are given in Appendix 3. Table A2.4 gives the country scores estimated for the A-group (and for other groups) of indicators, where the countries' clustering into similar groups (using the results of group analyses) is presented in Figure A2.3.

For the B-group indicators two factors were chosen providing 74.46% of cumulative explained variance. According to the factor pattern received in this analysis (Table A2.3b), variables B1-B2-B3-B5 contribute positively to the Factor 1 value, whereas B4 (injury accidents per fatality) contributes negatively to the same factor; overall, a lower value of Factor 1 can be considered as 'safety-desirable'. Two basic indicators contribute to Factor 2: B6 (share of bicyclist fatalities) and B7 (share of motorcyclist fatalities) but with opposite coefficients; overall, a lower value of Factor 2 can be considered preferable for safety.

Exploring the C-group indicators (SPIs), low communalities with others were observed for C6, C7 indicators (the percentages of motorcycles and HGVs in the vehicle fleet, accordingly), which, consequently, were excluded from the analysis. For the remaining indicators, two factors were chosen, providing 80.11% of cumulative explained variance. According to the factor pattern obtained from this analysis (Table A2.3c), variable C2-C3 (seatbelt wearing rate) contributes positively to the Factor1 value, whereas C5 (median age of passenger cars) contributes negatively to the same factor. Therefore, overall, a higher value of Factor 1 is 'safety-desirable'. Two basic indicators contribute to Factor 2: C1 (share of drink-driving accidents) and C4 (average EuroNCAP score). However, as both indicators contribute positively to Factor 2 (whereas minimum C1 and maximum C4 values are 'safety-desirable'), a preferred safety value cannot be given for Factor 2. In total, having weighted both factors, a higher value of the C-group factor can be considered safety-desirable.

For the D-group indicators (background characteristics), one factor was chosen providing 63.2% of the cumulative explained variance. According to the factor

pattern received in this analysis (Table A2.3d), each variable of the group contributes positively to the factor value. According to different sources, a higher motorization level of the country and a lower population density are probably more favourable for safety, therefore, the combined D-group factor appears to be safety-indifferent.

As mentioned above, the tools produced by each group analysis for the estimation of each country's score are given in Appendix 3, and the country scores estimated for each group of indicators and the results of the countries' clustering into similar groups are presented in Table A2.4 and Figure A2.3, respectively.

Indicators	Factor1
N_A2	0.86565
N_A5	0.85723
N_A4	0.78888
N_A1	0.75598
N_A3	0.73698

a)

Indicators	Factor1	Factor2
B2	**0.96666**	0.04130
B1	**0.92452**	-0.15173
B3	**0.92295**	0.04515
B5	**0.76317**	0.11852
B4	**-0.73632**	-0.14349
B6	-0.19054	**0.84533**
B7	-0.41192	**-0.68164**

b)

Indicators	Factor1	Factor2
C2	**0.95273**	0.03179
C3	**0.90504**	-0.02923
C5	**-0.64819**	0.47955
C1	0.48383	**0.80142**
C4	-0.36733	**0.78461**

c)

Indicators	Factor1
D2	0.79499
D1	0.79499

d)

Table A2.3. *Factor patterns obtained from the PCA of different groups of indicators.*

Obs	Country Code	FA (for A-group)	FB (final for B-group)	FC (final for C-group)	FD (for D-group)	Factor1 (combined analysis)	Factor2 (combined analysis)	WF (combined index)
1	AT	-0.21719	-0.53442	-0.32169	0.22792	0.06605	0.48602	0.25715
2	BE	0.30616	-0.25555	-0.85012	1.59920	1.01047	1.29614	1.14046
3	CY	-0.28273	-0.19814	0.02848	-0.07009	-0.20786	0.05011	-0.09048
4	CZ	0.61473	0.40384	-1.08416	-0.33203	1.06280	-0.31133	0.43752
5	DK	-0.10865	-0.17253	0.50540	-0.56240	-0.54665	-0.31531	-0.44138
6	EE	0.19761	1.05701	0.16487	-0.89934	-0.00478	-1.22661	-0.56076
7	FI	-0.10865	-0.20836	0.69176	-0.54804	-0.67990	-0.30154	-0.50774
8	FR	-1.33540	-0.60246	1.14367	0.30066	-1.49940	0.34913	-0.65826
9	DE	-0.60972	-0.83857	0.33765	1.51628	-0.38600	1.41396	0.43304
10	UK	-1.02683	-0.79988	0.68791	0.96286	-0.93618	0.96575	-0.07074
11	EL	-0.10865	0.15535	-0.47386	-0.58107	0.18987	-0.43585	-0.09485
12	HU	0.19992	1.21408	-0.87098	-1.23510	0.67905	-1.44325	-0.28666
13	IE	-0.19491	-0.04414	0.09534	-0.65524	-0.29888	-0.42234	-0.35506
14	IT	3.23882	-0.69045	-1.04289	1.51336	2.48709	1.75650	2.15465
15	LV	0.61473	1.80568	-0.10091	-1.23674	0.45282	-1.84347	-0.59206
16	LT	0.61473	1.50049	-0.85989	-0.34069	1.10238	-1.00584	0.14307
17	LU	0.75099	-0.25851	-0.45167	1.88401	1.00693	1.48082	1.22257
18	MT	0.19992	-1.03913	0.10246	8.72656	1.55859	6.29741	3.71491
19	NL	-1.33540	-0.54444	0.30569	1.70799	-0.62884	1.30439	0.25084
20	NO	-0.56783	-0.63929	1.23492	-0.76714	-1.40353	-0.26825	-0.88694
21	PL	0.61473	1.48981	-0.69580	-0.73316	0.90901	-1.26910	-0.08210
22	PT	0.61473	-0.38430	-0.09778	-0.39272	0.22289	0.03745	0.13850
23	SK	0.61473	0.65575	-0.48412	-1.54988	0.45084	-1.31034	-0.35055
24	SI	0.61473	-0.24852	0.70083	0.09214	-0.21273	0.19466	-0.02735
25	ES	0.19992	-0.25197	-0.34574	-0.14963	0.26371	0.10458	0.19130
26	SE	-1.90082	-0.77338	1.62685	-0.61521	-2.32385	-0.23058	-1.37135
27	CH	-1.39975	-0.83708	0.15625	0.86407	-0.77530	0.94428	0.00716

Table A2.4. *Country scores resulting from the PCA for groups of indicators*.
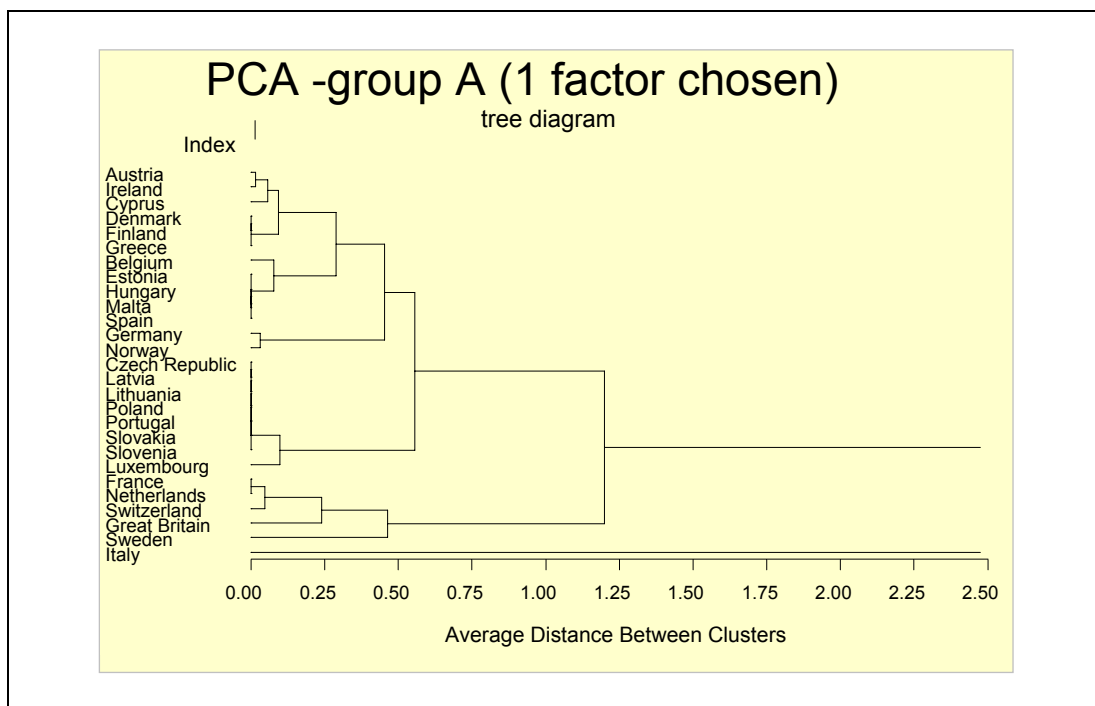
a) based on the A-group of indicators.
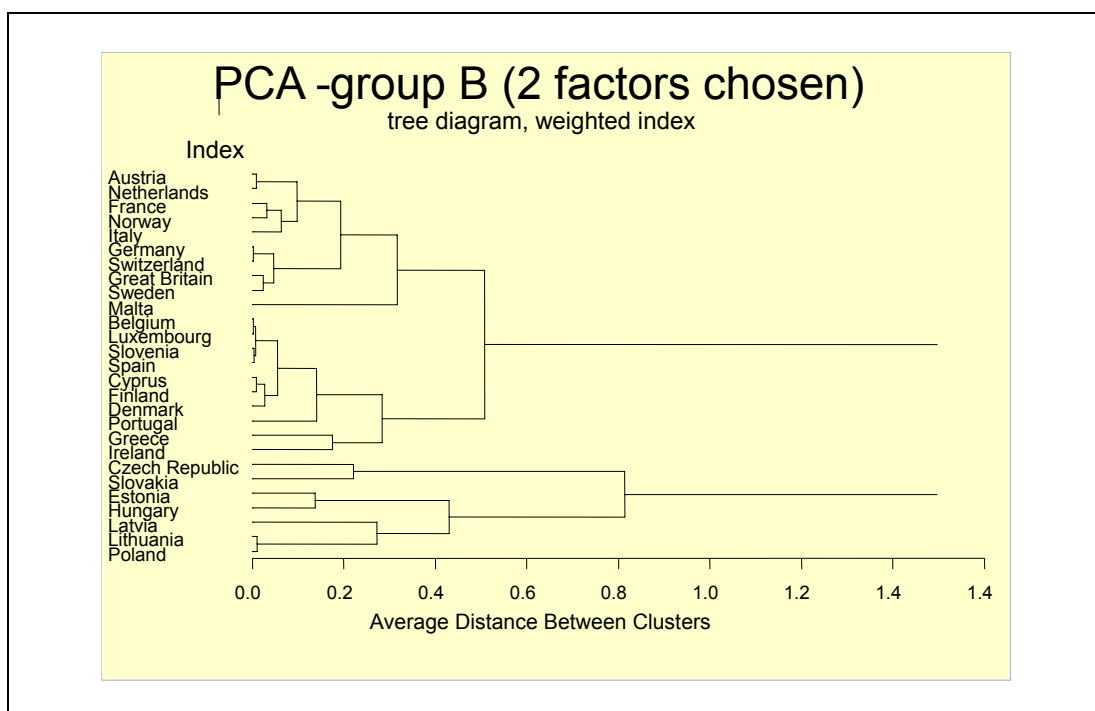
b) based on the B-group of indicators.

Figure A2.3. *Similar groups of countries based on the 'PCA-by groups' analysis.*

PCA -group C, no c7 c6 (2 factors chosen)
tree diagram, weighted index
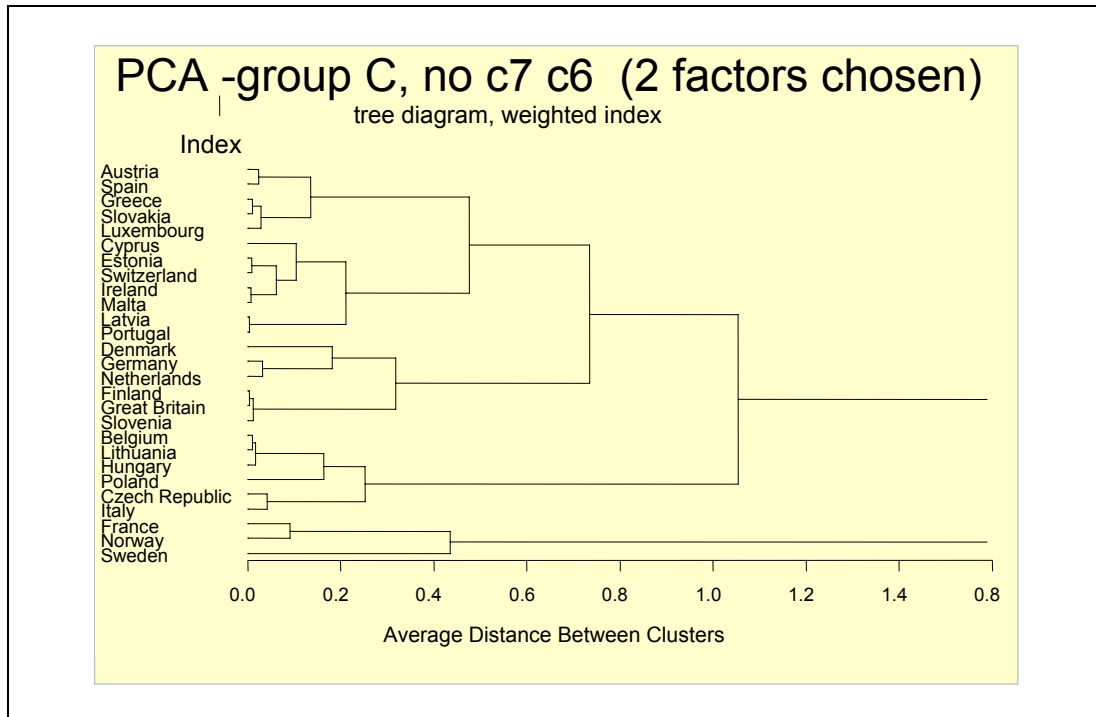
c) based on the C-group of indicators.

PCA -group D (1 factor chosen)
tree diagram
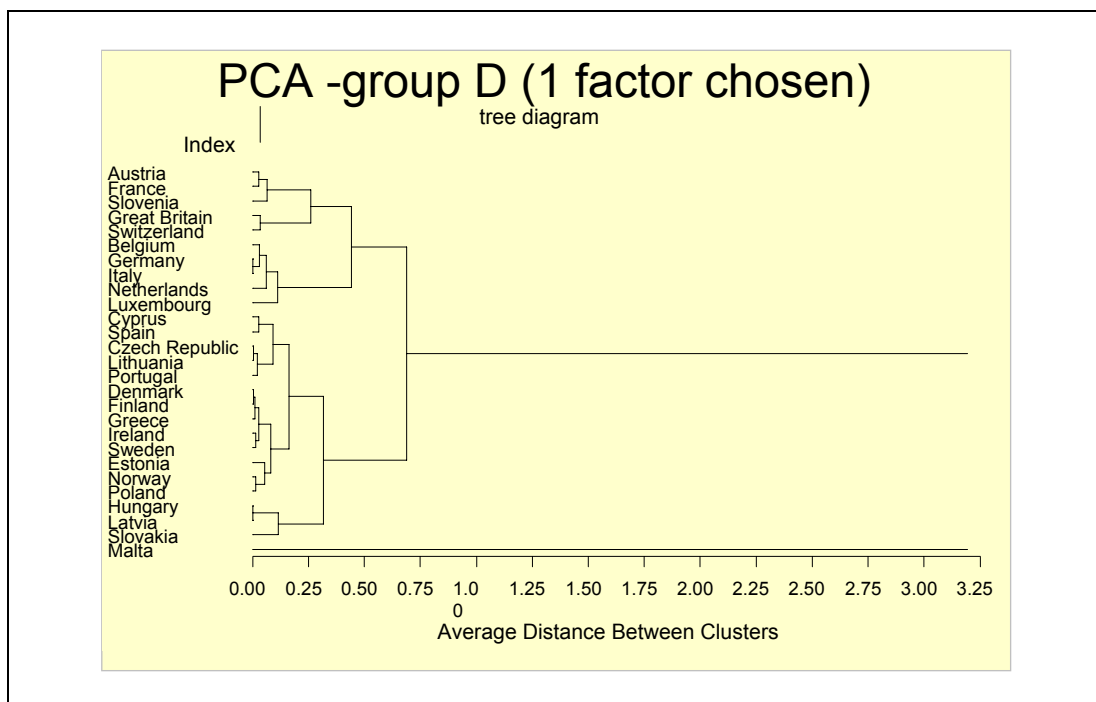
d) based on the D-group of indicators.

Figure A2.3. (cont.) *Similar groups of countries based on the 'PCA-by groups' analysis.*

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At the second step of the analysis, the factors obtained for each group (i.e. FA, FB, FC, FD in Table A2.4) were subjected to another PCA, to provide the final composite index. At this step, two factors were chosen, providing 86.27% of cumulative explained variance.

According to the factor pattern obtained from this analysis (Table A2.5), factors FA and FC compose the Factor 1, where FD and FB compose Factor 2. Discussion of previous interpretations of components of the group factors, has shown that it is safer to have lower values of FA and FB factors and a higher value of the FC factor. Therefore, we can state that a lower value of the combined Factor 1 is 'safety-desirable', whereas for the combined Factor 2 we should probably prefer a higher value.

The tools produced by the estimation of the final safety indicator in this case, i.e. the factors' scoring coefficients, factors' weights, means and variances, are discussed in Appendix 3. The last three columns of Table A2.4 contain the country scores estimated for each factor of the combined analysis and the final composite index, whereas the countries' clustering into similar groups, using the final indicator, is presented in Figure A2.4.

Rotated Factor Pattern		
Indicator (group factor)	Factor1	Factor2
FA	**0.89253**	-0.05656
FC	**-0.92977**	0.08105
FD	0.13049	**0.94526**
FB	0.45004	**-0.81670**

Table A2.5. *Factor patterns received by the PCA for four indices (FA, FB, FC, FD).*
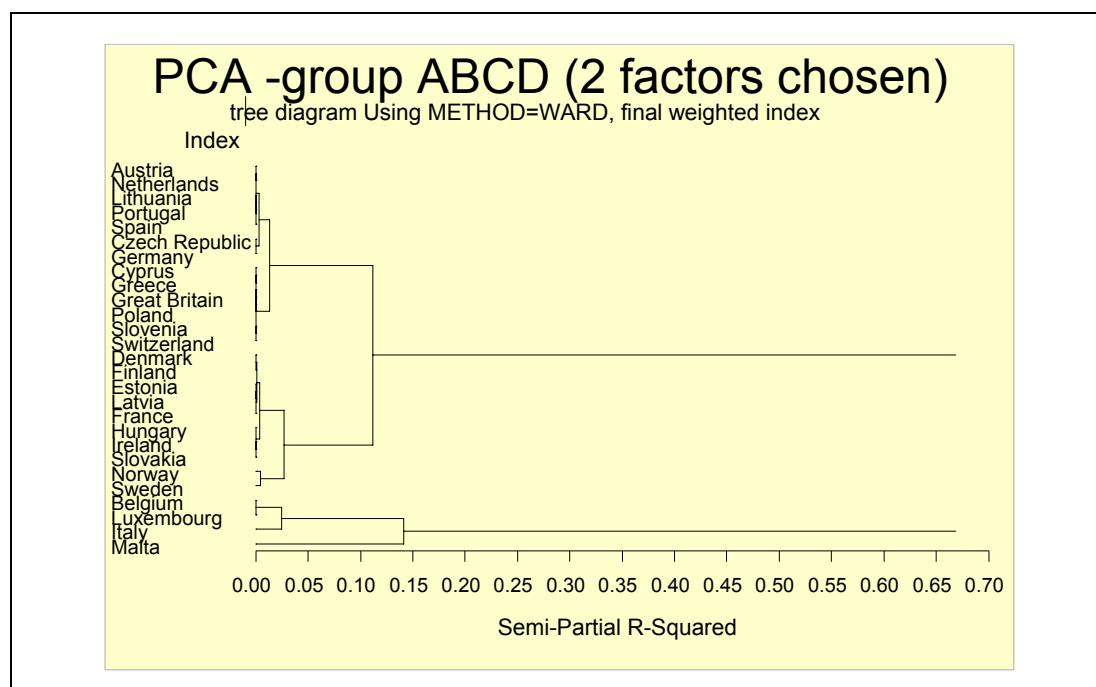
Figure A2.4. *Countries' clustering into similar groups, using the final indicator of the PCA-by groups' analysis.*

A2.3. Common factor analysis with four factors (FA-4Factors)

General comment

A preliminary examination of all variables together revealed a low value of the overall KMO statistics (0.45), and the lowest values of the KMO statistics for such variables as B6 (0.131), B7 (0.309), and C7 (0.136). Once the indicators B6, B7, and C7 were excluded, the overall KMO statistics increased to 0.63, making it possible to proceed with the Common Factor Analysis (FA). Therefore, the coming three trials of creating the composite index by means of FA consider 18 variables (basic indicators), without B6 (share of bicyclist fatalities), B7 (share of motorcyclist fatalities), and C7 (percentage of HGVs in fleet).

To determine the number of factors required, the variance explained criterion is applied. At this point, two approaches are possible. Some researchers use the rule of keeping enough factors to account for certain share (e.g. 90% or 80%) of the variation. Conversely, if the researcher's goal emphasizes parsimony (explaining variance with as few factors as possible), the criterion could be as low as 50%. In our case, the variation was taken to be the sum of the eigenvalues of the reduced correlation matrix. It was found that four factors explain more than 80% of the variation.

Furthermore, examining the solution for four factors demonstrated that C4 variable (average EuroNCAP score) is nearly identical to one of the factors. Moreover, excluding C4 resulted in two factors being responsible for 71% of the variation. Hence, we decided to explore the results of three trials:

FA-4Factors – FA with all variables (except for B6, B7, C7 as explained before) and four factors.
FA-2Factors-noC4 – FA with the same variables excluding C4 and two factors.
FA-2factors – FA with the above variables, including C4, and two factors.

The FA-2Factors results can be conveniently displayed, and give insight into the data.

FA-4Factors

In this case, the average of the eigenvalues of the reduced correlation matrix was 0.87. Four factors explained 84% of cumulative variance.

Table A2.6 provides the rotated factor pattern obtained from this analysis, which shows which variables (basic indicators) contributed more to each one of the factors built. The behaviours of major variables (with coefficients over 0.5), which compose the factor, make it possible to interpret the 'safety-desirable' behaviour of the factor.

As discussed previously, for basic indicators B1-B3 (number of fatalities per population, vehicles, passenger kms travelled), B5 (share of pedestrian fatalities), C5 (median age of passenger cars), lower values are safety-preferable. Similarly, for indicators C2-C3 (safety belt wearing rates in front and rear seats), higher values are better for safety. Concerning B4 (injury accidents per fatality), a lower value is safety-desirable, whereas for D1 (number of passenger cars per population) a higher value is probably associated with better safety. All these indicators make a major contribution to Factor 1 (see Table A2.6). Accounting for the basic indicators'

effect on Factor 1's value (positive or negative coefficients), we can conclude that a better safety situation is associated with a lower value of Factor 1.

Factor 2 (see Table A2.6) mainly reflects the behaviour of 'safety strategy' indicators A1, A2, A4, A5 and C6 (percentage of motorcycles in the vehicle fleet), for which lower values are safety-preferable. Hence, lower value of Factor 2 should be seen as safety-preferable.

Factor 3 consists of the C4 indicator only (average EuroNCAP score) which should be higher from a safety point of view.

Factor 4 reflects the behaviour of D2 (population density), A3 (quality of economic basis of safety program) and C1 (share of drink-driving accidents). For increased safety, all three variables should have lower values. Accounting for their coefficients in the Factor 4 composition, the safety-desirable behaviour of Factor 4 is not obvious, but a lower value is probably preferable.

To sum up the factors' interpretation and characterize the safety-desirable factors' behaviour, we can give the following summary:
Factor 1 → min; Factor 2 → min; Factor 3 → max; Factor 4 → min (not obvious).

Rotated Factor Pattern					
Basic indicator and its 'safety-desired' behaviour		Factor1	Factor2	Factor3	Factor4
B3	↓	**0.93114**	0.16237	0.16430	0.09886
B2	↓	**0.90113**	0.15766	0.34291	0.07174
B1	↓	**0.68637**	0.24702	0.59423	0.11426
B5	↓	**0.60411**	-0.03942	0.45413	-0.06381
C5	↓	**0.52698**	0.20849	0.46343	-0.23475
C2	↑	**-0.50146**	-0.49013	-0.43328	-0.28767
C3	↑	**-0.58789**	-0.47246	-0.41165	-0.25516
B4	↓	**-0.70392**	-0.17008	-0.09415	0.14029
D1	↑	**-0.82127**	0.13857	0.19451	0.17435
N_A4	↓	0.18750	**0.85028**	0.13938	-0.01902
N_A5	↓	0.02815	**0.81876**	-0.00825	0.19648
N_A2	↓	0.31802	**0.65628**	0.22076	0.41407
C6	↓	-0.45550	**0.58664**	-0.30691	-0.05497
N_A1	↓	0.15967	**0.55971**	0.44619	0.10842
C4	↑	0.09648	-0.00215	**0.77306**	-0.32513
D2	↓	-0.36120	-0.19337	-0.16500	**0.71500**
N_A3	↓	0.09619	0.48215	-0.01314	**0.65940**
C1	↓	-0.02361	-0.40141	0.13150	**-0.73881**

Table A2.6. *Rotated factor pattern for FA-4Factors' trial*.

The tools obtained from this analysis for the estimation of each country's score, i.e. the factors' scoring coefficients, factors' weights, means, and variances of the variables to estimate the standardized values, are given in Appendix 4.

Table A2.7 provides the country scores estimated in this trial, where the composite index is presented by WF-4F (weighted index' value).

Obs	Country	Code	Factor1	Factor2	Factor3	Factor4	WF-4F (combined index)
1	Austria	AT	-0.51333	0.11212	-0.36543	0.30850	-0.18372
2	Belgium	BE	-0.61693	-0.10196	0.86891	1.48278	0.12586
3	Cyprus	CY	0.28024	-0.16952	0.05955	-0.19428	0.04165
4	Czech Republic	CZ	0.32629	0.98406	-0.00322	0.25801	0.43665
5	Denmark	DK	-0.11726	0.11485	-1.07465	-0.67545	-0.31372
6	Estonia	EE	0.92728	-0.34931	1.61377	-0.53938	0.46403
7	Finland	FI	-0.32609	0.52476	-1.06877	-1.25634	-0.37508
8	France	FR	-0.27240	-1.23411	-0.44444	-0.53126	-0.60764
9	Germany	DE	-1.03623	-0.74971	-0.72937	1.06208	-0.56560
10	Great Britain	UK	-0.76593	-1.72859	-0.02897	1.00974	-0.61245
11	Greece	EL	0.81396	0.60818	-0.73238	-0.31280	0.30160
12	Hungary	HU	2.08833	-0.08571	-1.10172	0.59256	0.68627
13	Ireland	IE	0.17444	-0.64890	-0.16791	0.26594	-0.09682
14	Italy	IT	-1.30599	3.26270	0.21343	0.90846	0.56986
15	Latvia	LV	1.77916	-0.00079	0.64996	-0.26562	0.76263
16	Lithuania	LT	0.79314	0.01150	3.34107	0.18876	0.93474
17	Luxembourg	LU	-1.33076	0.61825	0.11757	1.32288	-0.11329
18	Malta	MT	-1.80332	-1.89677	0.01888	5.67029	-0.30215
19	The Netherlands	NL	-0.54731	-1.69909	-0.76365	1.34816	-0.59562
20	Norway	NO	-0.81465	0.19592	-0.11620	-2.37984	-0.66613
21	Poland	PL	1.49531	0.21653	-0.19155	0.27671	0.64975
22	Portugal	PT	-0.05081	0.56496	-0.27798	-0.10442	0.06860
23	Slovakia	SK	1.73187	0.15183	-0.95102	0.26927	0.58770
24	Slovenia	SI	-0.48375	0.20160	1.05057	-0.15750	0.02878
25	Spain	ES	-0.16303	0.72902	-0.40731	-0.08646	0.04986
26	Sweden	SE	-1.09173	-1.08386	0.61912	-2.09179	-0.94661
27	Switzerland	CH	-0.97385	-0.44472	-0.10937	-0.69870	-0.63127

Table A2.7. *Country scores estimated by FA with four factors' solution*.

Based on the final weighted index (WF-4F) and using a WARD clustering procedure, the countries can be classified into similar groups, as presented in Figure A2.5a (the countries' clustering based on the results of other two FA trials are presented in the same figure). As usual, the number of groups can vary depending on the level of the

'distance' between the countries in the same group, which is selected as a threshold. For example, with a threshold value of about 0.02, five groups of countries can be distinguished.
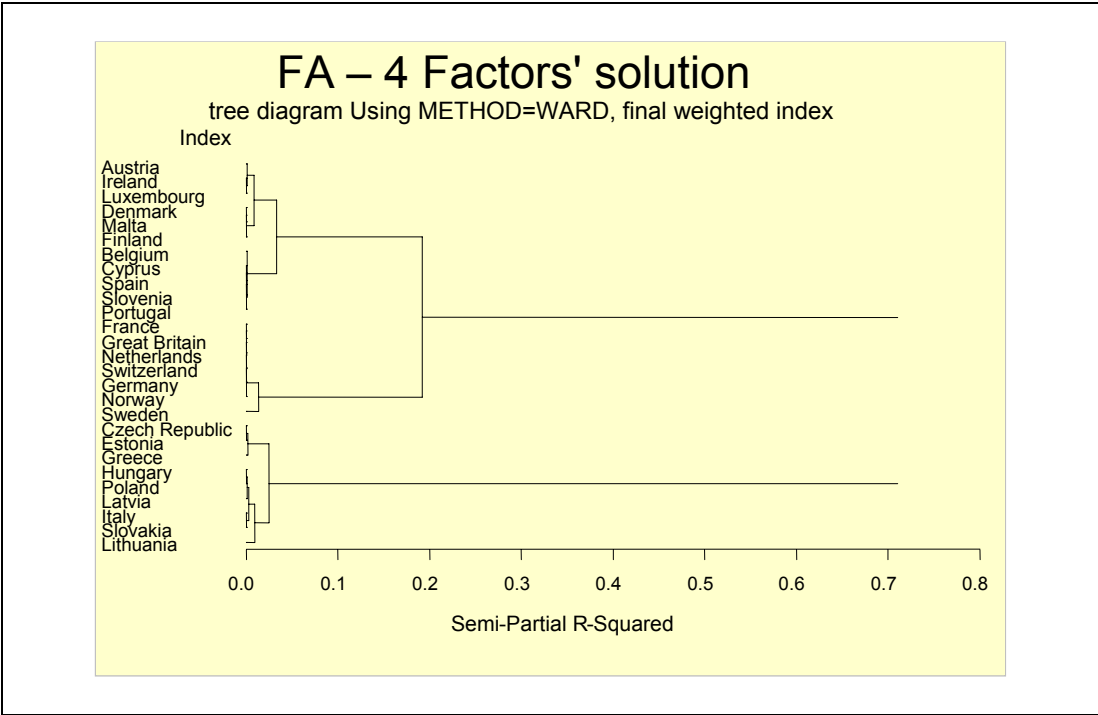
a) FA with four factors' solution.
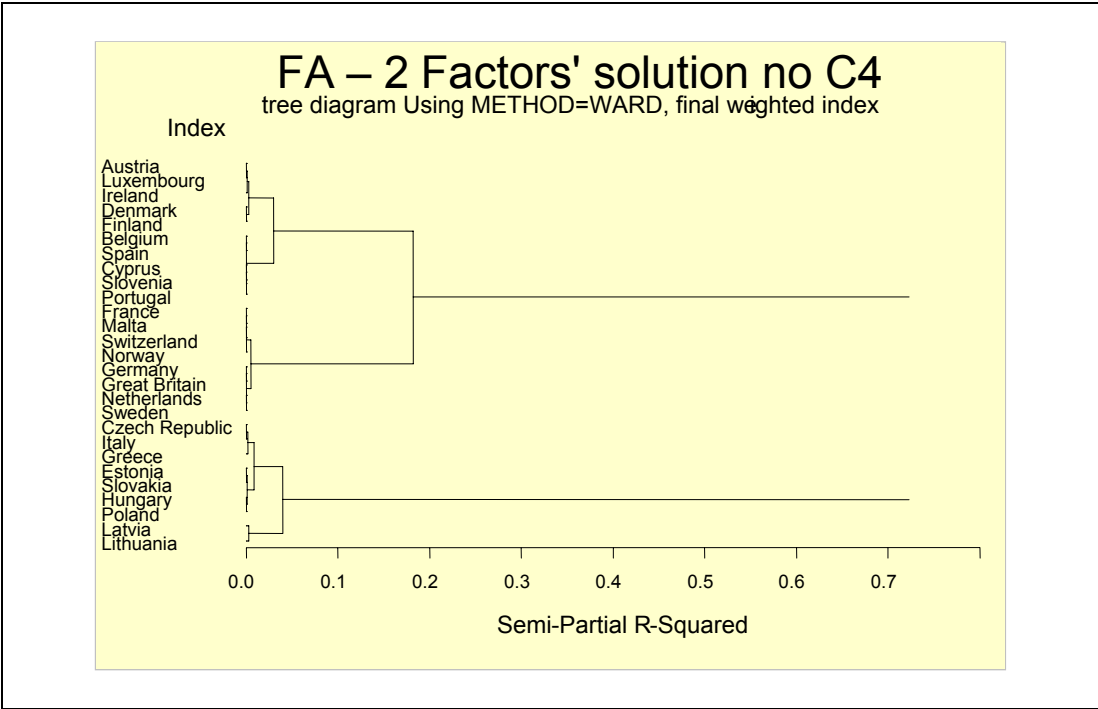
b) FA with two factors' solution (C4 excluded).

Figure A2.5. *Countries' clustering into similar groups based on FA analyses*.

FA – 2 Factors' solution with C4
tree diagram Using METHOD=WARD, final weighted index
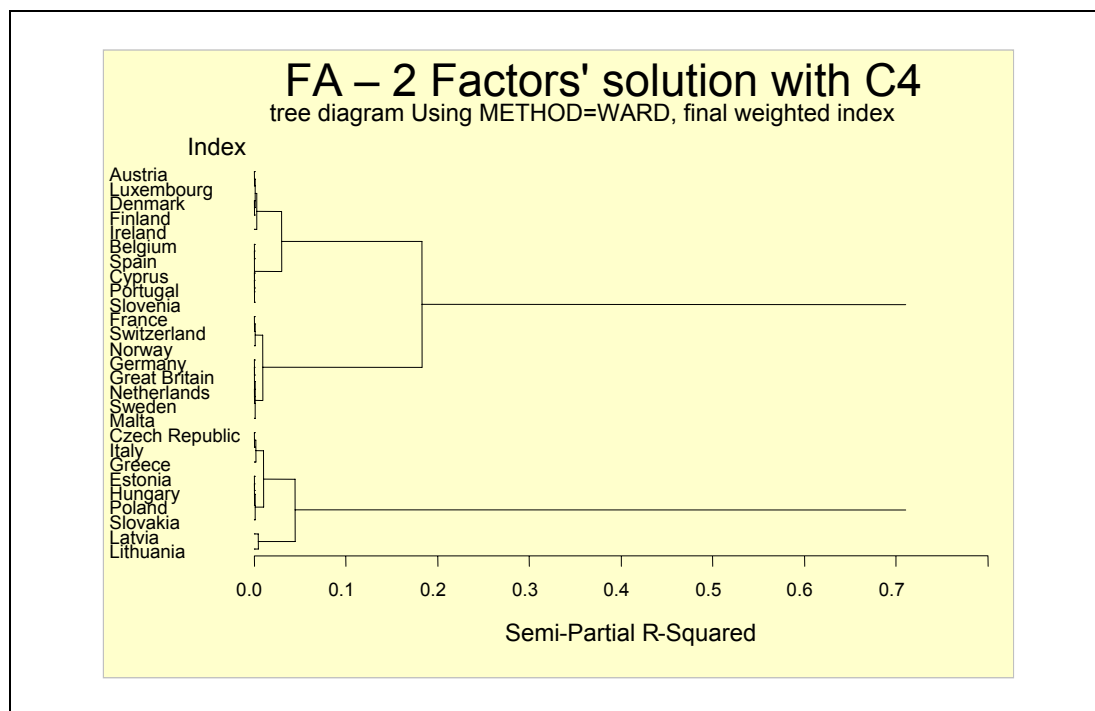
c) FA with two factors' solution (C4 included).

Figure A2.5. (cont.) *Countries' clustering into similar groups based on FA analyses*.

A2.4. Common factor analysis with two factors, C4 excluded (FA-2Factors-noC4)

In this analysis, the average of the eigenvalues of the reduced correlation matrix was 0.85. Two factors explained 71.8% of cumulative variance.

Table A2.8 provides the rotated factor pattern received in this analysis. It can be seen that Factor 1 mainly reflects the behaviour of B1-B5 indicators ('safety product'), D1-D2 ('background characteristics'), C5 (median age of passenger cars), and C6 (percentage of motorcycles in the vehicle fleet). For all these variables, except for D1, lower values are safety-preferable. Accounting for the indicators' correlations with the Factor 1 value (see Table A2.8), a lower value of this factor can be considered as safety-preferable (although, an 'opposite contribution' to Factor 1 or a 'moderating effect' is expected from the B4, C6, and D2 indicators).

Factor 2 (see Table A2.8) mainly reflects the behaviour of 'safety strategy' indicators A1-A5, C2-C3 (seatbelt use) and C1 (share of drink-driving accidents). For A1-A5 and C1 lower values are safety-preferable, whereas for C2-C3 higher values are desirable. Hence, a lower value of Factor 2 should be considered safety-preferable (with a 'moderating effect' expected from C1 indicator).

To sum up the factors' interpretation and to characterize the safety-desirable factors' behaviour, we can write:
Factor 1 $\rightarrow$ min; Factor 2 $\rightarrow$ min.

Rotated Factor Pattern			
Basic indicator and its' safety-desirable' behaviour		Factor1	Factor2
B2	↓	**0.91349**	0.31392
B3	↓	**0.86582**	0.30533
B1	↓	**0.81085**	0.42604
B5	↓	**0.74210**	0.05929
C5	↓	**0.70113**	0.17389
D2	↓	**-0.53665**	0.14608
C6	↓	**-0.53827**	0.36909
B4	↓	**-0.68467**	-0.15757
D1	↑	**-0.69604**	0.15062
N_A2	↓	0.25093	**0.82875**
N_A5	↓	-0.06048	**0.79124**
N_A3	↓	-0.08222	**0.74827**
N_A4	↓	0.19439	**0.73048**
N_A1	↓	0.26819	**0.61014**
C3	↑	-0.60687	**-0.65187**
C2	↑	-0.52413	**-0.67475**
C1	↓	0.20785	**-0.69421**

Table A2.8. *Rotated factor pattern for FA 2factors' trial (C4 excluded)*.

The tools obtained from this analysis for the estimation of each country's score, i.e. the factors' scoring coefficients, factors' weights, means and variances of the variables to estimate the standardized values, are given in Appendix 4.

Table A2.9 provides the country scores estimated in this trial, where the composite index is presented by WF (weighted index' value).

Similarities and differences in the behaviours of separate indicators can be considered when they are plotted against the factors (Figure A2.6). As Figure A2.6 illustrates, groups of indicators with similar behaviour are: B1-B2-B3-B5-C5 ('road safety performance indicator' and 'median age of cars'), A1-A2-A3-A4-A5 ('policy performance indicator'), C2-C3 (use of seatbelts), D1-D2-C6 ('background characteristics' and percentage of motorcycles in fleet), where C1 (share of drink-driving accidents) and B4 (injury accidents per fatality) demonstrate 'individual' behaviour.

Obs	Country	Code	Factor1	Factor2	WF
1	Austria	AT	-0.58748	0.06590	-0.28994
2	Belgium	BE	-0.53285	0.75390	0.05312
3	Cyprus	CY	0.35085	-0.23072	0.08601
4	Czech Republic	CZ	0.15384	1.01263	0.54492
5	Denmark	DK	-0.35010	-0.42282	-0.38322
6	Estonia	EE	1.58534	-0.26214	0.74402
7	Finland	FI	-0.44325	-0.45957	-0.45068
8	France	FR	-0.22973	-1.40723	-0.76595
9	Germany	DE	-1.40834	-0.27982	-0.89442
10	Great Britain	UK	-0.84980	-1.02428	-0.92926
11	Greece	EL	0.50645	0.30152	0.41313
12	Hungary	HU	1.25743	0.28024	0.81243
13	Ireland	IE	0.05364	-0.44329	-0.17266
14	Italy	IT	-1.44082	3.11863	0.63550
15	Latvia	LV	1.92435	0.15291	1.11766
16	Lithuania	LT	1.95693	0.71593	1.39180
17	Luxembourg	LU	-1.46607	1.10102	-0.29704
18	Malta	MT	-2.80077	1.68566	-0.75770
19	Netherlands	NL	-1.02611	-0.88366	-0.96124
20	Norway	NO	-0.24445	-1.22666	-0.69174
21	Poland	PL	1.25358	0.44864	0.88702
22	Portugal	PT	-0.09297	0.37697	0.12104
23	Slovakia	SK	1.03545	0.31605	0.70784
24	Slovenia	SI	-0.00394	0.22419	0.09995
25	Spain	ES	-0.37206	0.49854	0.02440
26	Sweden	SE	-0.30211	-1.81707	-0.99200
27	Switzerland	CH	-0.72780	-0.90981	-0.81068

Table A2.9. *Country scores estimated by FA with two factors' solution (C4 excluded).*
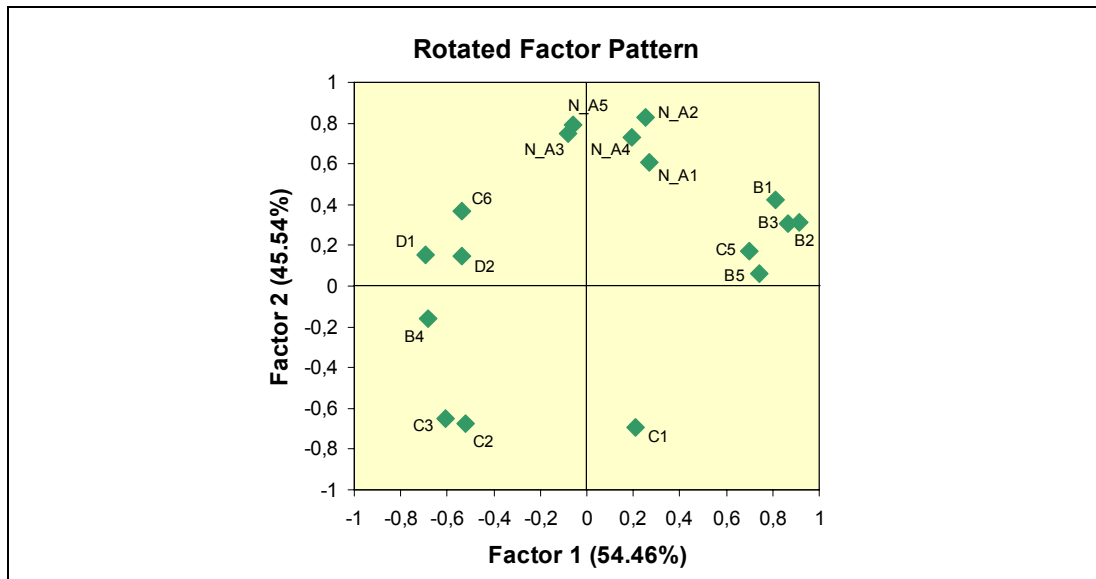
Figure A2.6. *Basic indicators plotted versus factors, according to FA with two factors' solution (C4 excluded)*.

Based on the final weighted index (WF) of this trial, the countries can be classified into similar groups, as presented in Figure A2.5b. For example, with a threshold value of 0.025, five groups of countries can be recognized. Figure A2.7 presents the countries' subdivision into five groups, where the country positions are plotted using the weighted index (WF) and Factor 1 values. It can be seen that: the countries with the best safety level (first group) are Sweden, the Netherlands, Great Britain, Germany, Switzerland, France, Malta and Norway. The second group includes Finland, Denmark, Austria, Luxembourg and Ireland. The third group consists of Spain, Belgium, Cyprus, Slovenia and Portugal. The fourth group consists of Greece, Czech Republic, Italy, Hungary, Estonia, Slovakia and Poland, and the fifth group consists of Latvia and Lithuania.

Figure A2.7 shows that Malta, Italy and Luxembourg (to a less extent) behave as 'outsiders' of their groups (similar to the results of FA with four factors – see Section A2.3). These three countries are characterized by much lower values of Factor1 (in general, and especially in comparison with the countries of their groups, i.e. with similar level of the composite index) but by high positive values of Factor 2.

Figure A2.7. *Countries plotted using WF values and Factor 1 values (FA with two factors', C4 excluded).*
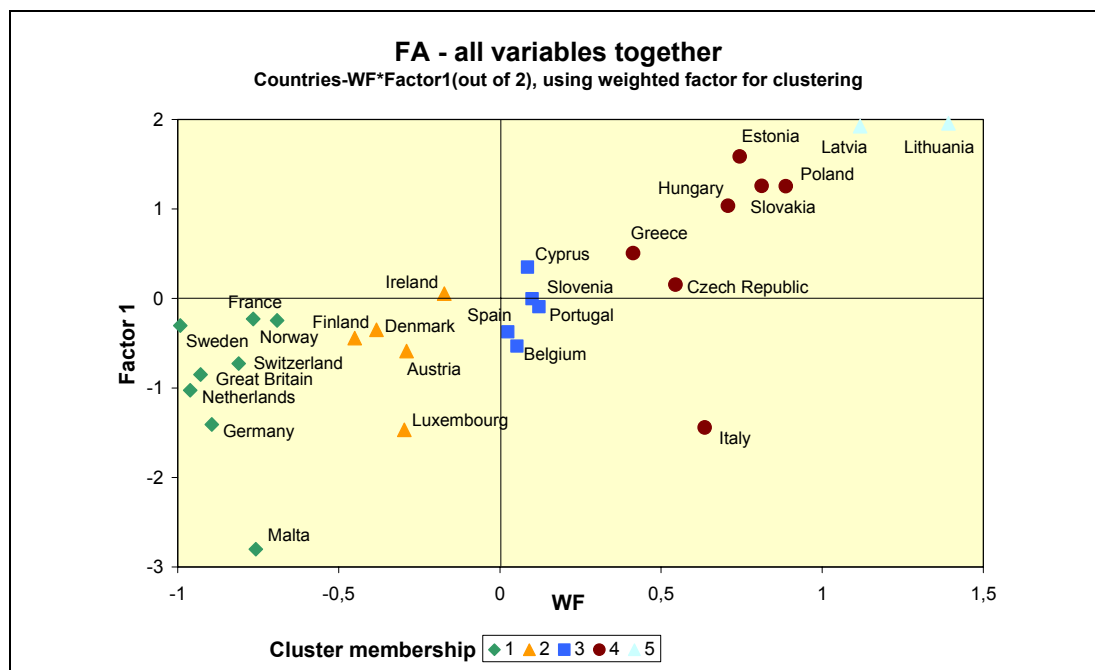

A2.5 Common factor analysis with two factors, C4 included (FA-2Factors)

In this analysis the average of the eigenvalues of the reduced correlation matrix was 0.87. Two factors explained 68.7% of cumulative variance.

Table A2.10 provides the rotated factor pattern received in this analysis. It is clear that Factor 1 mainly reflects the behaviour of B1-B5 indicators ('safety performance indicator – final outcome'), D1-D2 ('background characteristics'), C4 (average EuroNCAP score), C5 (median age of passenger cars) and C6 (percentage of motorcycles in vehicle fleet). For the majority of these variables, except for D1 and C4, lower values are safety-preferable. Accounting for the indicators' correlations with Factor 1 (see Table A2.10), lower value of this factor can be considered as safety-preferable (although, an 'opposite contribution' to Factor 1 or a 'moderating effect' is expected from C4, C6, D2, and B4 indicators).

Factor 2 (see Table A2.10) reflects mostly the behaviour of 'policy performance indicators' A1-A5, C2-C3 (safety belt use) and C1 (share of drink-driving accidents) indicators. For A1-A5 and C1 lower values are safety-preferable, whereas for C2-C3 higher values are desired. Hence, lower value of Factor 2 should be seen as safety-preferable (with a 'moderating effect' expected from the C1 indicator).

We can summarize the factors' interpretation and characterize the safety-desirable factors' behaviour as follows: Factor 1 → min; Factor 2 → min. In general, this FA solution is similar to that received in the previous trial (see Section A2.4).

Rotated Factor Pattern			
Basic indicator and its 'safety-desired behaviour'		Factor1	Factor2
B2	↓	**0.89030**	0.35273
B3	↓	**0.82662**	0.35248
B1	↓	**0.80647**	0.44793
B5	↓	**0.73794**	0.08673
C5	↓	**0.70792**	0.19072
C4	↑	**0.52185**	-0.05787
C6	↓	**-0.54598**	0.34493
D2	↓	**-0.56129**	0.13888
D1	↑	**-0.66133**	0.10334
B4	↓	**-0.66607**	-0.18853
N_A2	↓	0.21927	**0.83801**
N_A5	↓	-0.08187	**0.78293**
N_A3	↓	-0.13059	**0.75847**
N_A4	↓	0.17631	**0.73949**
N_A1	↓	0.27601	**0.60189**
C3	↑	-0.58845	**-0.66931**
C2	↑	-0.51539	**-0.69034**
C1	↓	0.26249	**-0.70695**

Table A2.10. *Rotated factor pattern for FA 2factors' trial (C4 included)*.

The tools produced by this analysis for the estimation of each country's score, i.e. the factors' scoring coefficients, factors' weights, means and variances of the variables to estimate the standardized values, are given in Appendix 4.

Table A2.11 provides the country scores estimated in this trial, where the composite index is presented by WF (weighted index' value).

Based on the final weighted index (WF) of this trial, the countries can be classified into similar groups, as presented in Figure A2.5c. For example, with a threshold value of 0.03, the same five groups of countries can be recognized as in Figure A2.7.

Obs	Country	Code	Factor1	Factor2	WF (combined index)
1	Austria	AT	-0.69070	0.12768	-0.31567
2	Belgium	BE	-0.51748	0.71218	0.04603
3	Cyprus	CY	0.32665	-0.19086	0.08949
4	Czech Republic	CZ	0.14626	0.99895	0.53702
5	Denmark	DK	-0.41520	-0.41776	-0.41637
6	Estonia	EE	1.68690	-0.21917	0.81341
7	Finland	FI	-0.45790	-0.41664	-0.43899
8	France	FR	-0.21657	-1.39872	-0.75831
9	Germany	DE	-1.44982	-0.31614	-0.93030
10	Great Britain	UK	-0.82861	-1.01949	-0.91608
11	Greece	EL	0.40200	0.36988	0.38728
12	Hungary	HU	1.11044	0.42401	0.79588
13	Ireland	IE	0.03856	-0.39053	-0.15808
14	Italy	IT	-1.44760	2.99680	0.58911
15	Latvia	LV	1.87350	0.22088	1.11617
16	Lithuania	LT	2.14449	0.66436	1.46620
17	Luxembourg	LU	-1.46473	1.01450	-0.32859
18	Malta	MT	-2.92575	1.13839	-1.06330
19	Netherlands	NL	-1.07151	-0.87796	-0.98281
20	Norway	NO	-0.11523	-1.23237	-0.62717
21	Poland	PL	1.09063	0.53270	0.83495
22	Portugal	PT	-0.17575	0.36781	0.07334
23	Slovakia	SK	0.95011	0.41402	0.70444
24	Slovenia	SI	0.10026	0.14407	0.12033
25	Spain	ES	-0.34440	0.47855	0.03273
26	Sweden	SE	-0.01460	-2.08592	-0.96381
27	Switzerland	CH	-0.65969	-0.90085	-0.77020

Table A2.11. *Country scores estimated by FA with two factors (C4 included)*.

Appendix 3.   Tools produced by Principle Component analyses for the estimation of country scores

A3.1. PCA with all variables together

The FACTOR Procedure
Rotation Method: Varimax

Scoring coefficients estimated by regression

Standardized Scoring Coefficients		Factor1	Factor2	Factor3	Factor4	Factor5
C5	C5	0.25408	-0.13566	0.04206	0.19032	-0.05939
B2	B2	0.11246	0.00784	0.03175	-0.08294	0.06772
B1	B1	0.13104	0.01431	-0.04654	-0.03323	-0.05776
B3	B3	0.09164	0.02078	0.07020	-0.05871	0.16271
B5	B5	0.17343	-0.09751	0.04047	-0.02016	-0.05770
C2	C2	-0.18502	-0.02891	-0.10493	-0.10049	0.09878
C3	C3	-0.17300	-0.03140	-0.08181	-0.11654	0.02552
N_A3		-0.17408	0.29537	-0.01147	-0.18716	0.09944
N_A2		-0.06459	0.23706	-0.08035	-0.13818	-0.02020
N_A5		-0.05376	0.21097	-0.07532	0.07340	0.04606
N_A4		0.13841	0.06425	-0.00165	0.27847	-0.03116
N_A1		0.01334	0.12693	-0.14181	-0.01587	-0.09111
C1	C1	0.01272	-0.17374	-0.22246	0.00030	0.00650
B6	B6	0.16643	-0.13471	0.46687	0.05460	-0.05344
D2	D2	-0.00532	0.03961	0.33310	-0.01545	-0.06712
C4	C4	0.12877	-0.10057	-0.23687	-0.03588	-0.32222
C6	C6	0.08565	0.00763	0.03975	0.44775	-0.02143
B7	B7	0.07552	-0.09037	0.01519	0.43406	0.11479
C7	C7	-0.06784	0.01158	-0.09112	0.13671	0.47712
B4	B4	0.03136	-0.06600	0.07723	0.14156	-0.24407
D1	D1	-0.08177	0.07762	-0.16170	0.01309	-0.29788

Proportion of variance explained by each factor

Obs	Factor1	Factor2	Factor3	Factor4	Factor5	k	sumF
1	5.7106158	4.1566576	2.1129504	2.0627407	1.9850024	1	16.0280

Factors' weights

Obs	w1	w2	w3	w4	w5
1	0.35629	0.25934	0.13183	0.12870	0.12385

Means and variances of variables

Obs	_TYPE_	B1	B2	B3	B4	B5	B6
1	MEAN	98.5564	240.058	120.029	29.0867	0.18001	0.065286
2	STD	44.0645	135.296	71.095	16.9387	0.07688	0.040203

Obs	B7	C1	C2	C3	C4	C5	C6	C7
1	0.15433	0.15846	81.2374	46.5639	20.9006	8.08366	0.082161	0.12250
2	0.07748	0.09822	9.1263	23.4846	0.6053	2.44772	0.049863	0.04579

Obs	N_A1	N_A2	N_A3	N_A4	N_A5	D1	D2
1	1.52976	2.38097	1.93719	1.79475	1.78352	449.344	126.575
2	0.56578	0.87092	0.40464	0.48876	0.63802	87.989	95.598

A3.2. PCA with groups of indicators

A-group

Scoring coefficients estimated by regression

Standardized Scoring Coefficients	
	Factor1
N_A2	0.26874
N_A5	0.26612
N_A4	0.24491
N_A1	0.23469
N_A3	0.22879

Means and variances of variables

Obs	_TYPE_	N_A1	N_A2	N_A3	N_A4	N_A5
1	MEAN	1.52976	2.38097	1.93719	1.79475	1.78352
2	STD	0.56578	0.87092	0.40464	0.48876	0.63802

B-group

Scoring coefficients estimated by regression

		Standardized Scoring Coefficients	
		Factor1	Factor2
B2	B2	0.24452	-0.01739
B1	B1	0.24397	-0.17287
B3	B3	0.23316	-0.01193
B5	B5	0.18850	0.05646
B4	B4	-0.18033	-0.07828
B6	B6	-0.09334	0.70073
B7	B7	-0.06907	-0.53512

Proportion of variance explained by each factor

Obs	Factor1	Factor2	k	sumF	w1	w2
1	3.9715847	1.2406149	1	5.21220	0.76198	0.23802

Means and variances of variables

Obs	_TYPE_	B1	B2	B3	B4	B5	B6	B7
1	MEAN	98.5564	240.058	120.029	29.0867	0.18001	0.065286	0.15433
2	STD	44.0645	135.296	71.095	16.9387	0.07688	0.040203	0.07748

C-group

Scoring coefficients estimated by regression

		Standardized Scoring Coefficients	
		Factor1	Factor2
C2	C2	0.38485	0.07494
C3	C3	0.36226	0.03083
C5	C5	-0.23377	0.28935
C1	C1	0.23942	0.57131
C4	C4	-0.10376	0.51224

Proportion of variance explained by each factor

Obs	Factor1	Factor2	k	sumF	w1	w2
1	2.5159608	1.4897073	1	4.00567	0.62810	0.37190

Means and variances of variables

Obs	_TYPE_	C1	C2	C3	C4	C5
1	MEAN	0.15846	81.2374	46.5639	20.9006	8.08366
2	STD	0.09822	9.1263	23.4846	0.6053	2.44772

D-group

Scoring coefficients estimated by regression

Standardized Scoring Coefficients		Factor1
D2	D2	0.62894
D1	D1	0.62894

Means and variances of variables

Obs	_TYPE_	D1	D2
1	MEAN	449.344	126.575
2	STD	87.989	95.598

Combined indicator

Scoring coefficients estimated by regression

Standardized Scoring Coefficients	Factor1	Factor2
FA	0.49023	0.07950
FC	-0.50778	-0.06804
FD	0.19696	0.64838
FB	0.14362	-0.48625

Proportion of variance explained by each factor

Obs	Factor1	Factor2	k	sumF	w1	w2
1	1.8806542	1.5702955	1	3.45095	0.54497	0.45503

Means and variances of variables

Obs	_TYPE_	FA	FB	FC	FD
1	MEAN	0	0.00000	0.00000	0
2	STD	1	0.79829	0.72994	1

Appendix 4.   Tools produced by common factor analyses for the estimation of country scores

A4.1. FA with four factors' solution

Scoring coefficients estimated by regression

		Factor1	Factor2	Factor3	Factor4

Standardized Scoring Coefficients					
		Factor1	Factor2	Factor3	Factor4
B3	B3	0.28284	0.03886	-0.47369	-0.04605
B2	B2	0.83187	-0.19123	-0.34775	0.20168
B1	B1	-0.43343	-0.07134	0.96965	0.03006
B5	B5	0.01655	-0.05018	0.05501	-0.01055
C5	C5	0.09078	0.05955	0.04620	-0.10329
C2	C2	-0.08465	0.04512	-0.33210	-0.20254
C3	C3	-0.06120	-0.16283	0.08725	-0.09027
B4	B4	-0.04864	-0.05139	0.04067	0.10191
D1	D1	-0.10739	0.02804	0.12406	0.13266
N_A4		-0.04051	0.37078	-0.23965	-0.28150
N_A5		-0.02689	0.32963	-0.13568	-0.05602
N_A2		-0.12188	0.14262	0.26336	0.16829
C6	C6	-0.06311	0.22161	-0.08883	-0.14550
N_A1		-0.08813	0.03893	0.34375	0.01278
C4	C4	-0.14834	0.00998	0.21873	-0.15999
D2	D2	-0.10885	-0.17951	0.14318	0.41278
N_A3		0.13289	0.04168	-0.28114	0.24323
C1	C1	0.03043	-0.04445	0.14917	-0.24055

Proportion of variance explained by each factor

Obs	Factor1	Factor2	Factor3	Factor4	k	sumF
1	5.0795326	3.5812942	2.3264115	2.1078804	1	13.0951

Obs	w1	w2	W3	w4
1	0.38790	0.27348	0.17765	0.16097

Means and variances of variables

Obs	_TYPE_	B1	B2	B3	B4	B5
1	MEAN	98.5564	240.058	120.029	29.0867	0.18001
2	STD	44.0645	135.296	71.095	16.9387	0.07688

Obs	C1	C2	C3	C4	C5	C6
1	0.15846	81.2374	46.5639	20.9006	8.08366	0.082161
2	0.09822	9.1263	23.4846	0.6053	2.44772	0.049863

Obs	N_A1	N_A2	N_A3	N_A4	N_A5	D1	D2
1	1.52976	2.38097	1.93719	1.79475	1.78352	449.344	126.575
2	0.56578	0.87092	0.40464	0.48876	0.63802	87.989	95.598

A4.2. FA with two factors' solution (C4 excluded)

Scoring coefficients estimated by regression

Standardized Scoring Coefficients		Factor1	Factor2
B2	B2	0.45090	-0.01603
B3	B3	0.11485	-0.00612
B1	B1	0.06441	0.00304
B5	B5	0.06424	-0.03844
C5	C5	0.11670	0.02916
D2	D2	-0.13370	0.11491
C6	C6	-0.09095	0.10344
B4	B4	-0.04894	-0.00145
D1	D1	-0.10158	0.10990
N_A2		-0.08341	0.29142
N_A5		-0.10388	0.27347
N_A3		-0.02490	0.10401
N_A4		-0.01382	0.08241
N_A1		0.04763	0.04050
C3	C3	-0.00070	-0.21626
C2	C2	-0.08587	-0.09107
C1	C1	0.08981	-0.11036

Proportion of variance explained by each factor

Obs	Factor1	Factor2	k	sumF	**w1**	**w2**
1	5.6841616	4.7529446	1	10.4371	0.54461	0.45539

Means and variances of variables

Obs	_TYPE_	B1	B2	B3	B4	B5
1	MEAN	98.5564	240.058	120.029	29.0867	0.18001
2	STD	44.0645	135.296	71.095	16.9387	0.07688

Obs	C1	C2	C3	C5	C6
1	0.15846	81.2374	46.5639	8.08366	0.082161
2	0.09822	9.1263	23.4846	2.44772	0.049863

Obs	N_A1	N_A2	N_A3	N_A4	N_A5	D1	D2
1	1.52976	2.38097	1.93719	1.79475	1.78352	449.344	126.575
2	0.56578	0.87092	0.40464	0.48876	0.63802	87.989	95.598

A4.3. FA with two factors' solution (C4 included)

Scoring coefficients estimated by regression

Standardized Scoring Coefficients		Factor1	Factor2
B2	B2	0.50258	0.03286
B3	B3	0.03320	-0.00930
B1	B1	0.07194	0.01471
B5	B5	0.04495	-0.03731
C5	C5	0.12206	0.01495
C4	C4	0.01664	-0.07078
C6	C6	-0.06819	0.08515
D2	D2	-0.12681	0.07048
D1	D1	-0.07156	0.09227
B4	B4	-0.04687	0.00885
N_A2		-0.03669	0.22140
N_A5		-0.08943	0.22104
N_A3		-0.08365	0.14676
N_A4		-0.09034	0.12082
N_A1		0.07652	0.06959
C3	C3	0.02205	-0.18024
C2	C2	-0.17152	-0.12543
C1	C1	0.16108	-0.13926

Proportion of variance explained by each factor

Obs	Factor1	Factor2	k	sumF	w1	w2
1	5.7984077	4.9049874	1	10.7034	0.54174	0.45826

Means and variances of variables

Obs	_TYPE_	B1	B2	B3	B4	B5
1	MEAN	98.5564	240.058	120.029	29.0867	0.18001
2	STD	44.0645	135.296	71.095	16.9387	0.07688

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Obs	C1	C2	C3	C4	C5	C6
1	0.15846	81.2374	46.5639	20.9006	8.08366	0.082161
2	0.09822	9.1263	23.4846	0.6053	2.44772	0.049863

Obs	N_A1	N_A2	N_A3	N_A4	N_A5	D1	D2
1	1.52976	2.38097	1.93719	1.79475	1.78352	449.344	126.575
2	0.56578	0.87092	0.40464	0.48876	0.63802	87.989	95.598

Appendix 5. Singular Value Decomposition (SVD)

A description of the singular value decomposition (SVD) of a matrix can be found in any basic text book on linear algebra (see for example Lay, 1994). In this appendix only a very short overview will be given.

The SVD of a matrix A involves two orthogonal matrices and a matrix containing the singular values of A. Therefore, the definitions of orthogonality and singular values are given before the SVD is introduced.

Firstly, a matrix U is called orthogonal if it is a square matrix with orthonormal columns. With other words, its columns form an orthogonal set of unit vectors. From the definition it immediately follows that an $n \times n$ orthogonal matrix U satisfies the equality $U^T U = UU^T = I_n$ where I_n is the $n \times n$ identity matrix.

Secondly, the singular values of an $m \times n$ matrix A are the square roots of the eigenvalues of $A^T A$. A scalar λ is by definition an eigenvalue of $A^T A$ if there exists a non-zero n-dimensional vector x such that $A^T A x = \lambda x$. Each $n \times n$ matrix has exactly n eigenvalues (counting multiplicities), from which is follows that each $m \times n$ matrix has exactly n singular values (also counting multiplicities).

Although the two definitions above are sufficient to define the SVD of an $m \times n$ matrix A, it is helpful to introduce some notation first. The singular values of A will be denoted by $\sigma_1 \geq \sigma_2 \geq ... \geq \sigma_r > 0 = \sigma_{r+1} = ... = \sigma_n$, so A has exactly r strictly positive singular values. The matrix D will be the $r \times r$ diagonal matrix with the strictly positive singular values of A on the diagonal and Σ will be the $m \times n$ matrix given by

$$\Sigma = \begin{pmatrix} D & 0 \\ 0 & 0 \end{pmatrix}.$$

It follows that Σ has m-r rows containing only zeros and n-r columns containing only zeros.

The matrix Σ plays an important role in the SVD of an $m \times n$ matrix A. Indeed, the SVD of A is given by

$$A = U\Sigma V^T. \tag{1}$$

where U is an $m \times m$ orthogonal matrix and V an $n \times n$ orthogonal matrix. There always exist orthogonal matrices U and V such that equality (1) holds. Moreover, they are not unique For each choice of U and V such that the previous equation holds, the columns of U are called the left singular vectors of A, whereas V are called the right singular vectors of A.

Because Σ possibly contains zero columns and rows, the SVD can be reduced to the following expression:

$$A = U_r D V_r^T,$$

where U_r and V_r are the matrices consisting of the first r columns of U and V respectively. Working out this expression shows that A can be written as the following sum of matrices:

$$A = A_1 + A_2 + \ldots + A_r, \text{ where } A_i = u_i \sigma_i v_i^T.$$

Here u_i and v_i are the i-th columns of U_r and V_r respectively. The matrix A_i is called the i-th component of the SVD. Each component A_i can be written out explicitly:

$$A_i = \sigma_i \begin{pmatrix} u_{i1}v_{i1} & u_{i1}v_{i2} & \cdots & u_{i1}v_{in} \\ u_{i2}v_{i1} & u_{i2}v_{i2} & \cdots & u_{i2}v_{in} \\ \vdots & \vdots & \ddots & \vdots \\ u_{im}v_{i1} & u_{im}v_{i2} & \cdots & u_{im}v_{in} \end{pmatrix}, \tag{2}$$

where u_{ij} and v_{ij} denote the j-th element of u_i and v_i respectively. It follows that the rows of A_i are multiples of the row vector v_i^T and the columns of A_i are multiples of the vector u_i.

The singular value σ_i is a measure of the contribution of matrix A_i to A. Because the singular values are in decreasing order, A_1 contributes the most to A, i.e., it explains most of the variance in the values of A. The cumulative percentage of explained variance of the k-th component, denoted by $CPEV_k$, is the variance of A explained by $A_1 + \ldots + A_k$. It is computed as

$$CPEV_k = 1 - \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(A_{(i,j)} - \left(A_1 + \ldots + A_k\right)_{(i,j)}\right)^2}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(A_{(i,j)}\right)^2}.$$

If the $CPEV_k$ is very large, then A is reasonably well approximated by $A_1 + \ldots + A_k$.

In this report the SVD is used to study the similarities and dissimilarities between the development of the fatality rates over the years 1970 up to 2003 for the nine countries. The matrix A represents in this case a table with in its (i,j)-entry the fatality rate of country i in year j.

If A is reasonably well approximated by A_1, then the development over time of the fatality rate in the nine countries is similar. In other words, for each country the 34-dimensional row vector containing the fatality rates over the years is equal to the row vector $\sigma_1 v_1^T$ multiplied with a scalar. For country j this scalar is u_{1j}. The row vector v_1^T is called the general trend of the SVD and the scalars u_{1j} the country weights of the first component. Analysing the country weights gives an idea of the road safety in a country. Countries with larger weights perform worse than countries with smaller weights.

The terminology introduced above can be extended if more components are added to the approximation of A. The row vector v_j^T is called the trend of the j-th component and the scalar u_{ij} is called the country weight of country i of the j-th component. Adding more SVD components to the approximation of A makes it possible to study in which way a country deviates from the general trend. If country i has the highest country weight (in absolute value) of component j, then the trend of component j primarily represents the deviations of the combined trend of the first j-1 components for country i.

Appendix 6.   The latent risk model

For each country a bivariate local linear trend model called the latent risk model was used to estimate macroscopic trends and forecasts for the developments of road safety and exposure. Whereas in a classical regression model the intercept and the regression coefficient of the linear regression of a dependent variable on time are fixed and do not change over time, in a local linear trend model these two parameters are typically allowed to change from time point to time point. In this context the time-varying intercept and regression weight are called the level and the slope component, respectively.

The latent risk model is a special case of the state space methods for the analysis of time series (Harvey, 1989; Durbin & Koopman, 2001; Commandeur & Koopman, 2007). In matrix algebra, all state methods can very generally be written as

$$y_t = Z_t \alpha_t + \varepsilon_t, \qquad\qquad \varepsilon_t \sim NID(0, H_t) \qquad\qquad (1)$$

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t, \qquad\qquad \eta_t \sim NID(0, Q_t) \qquad\qquad (2)$$

for t = 1, ..., n, where $\varepsilon_t \sim NID(0, H_t)$ is a short-hand notation for: the errors or disturbances ε_t are assumed to be normally and independently distributed with means equal to zero and a variance structure equal to H_t. The latent risk model for evaluating the developments in road safety is a bivariate local linear trend model. Specifically, let

$$y_t = \begin{pmatrix} y_t^{(1)} \\ y_t^{(2)} \end{pmatrix} = \begin{pmatrix} \log M_t \\ \log F_t \end{pmatrix},$$

where M_t are the observed annual mobility figures and F_t are the observed annual fatality figures at time points t = 1, ..., n.

Defining

$$\alpha_t = \begin{pmatrix} \mu_t^{(1)} \\ v_t^{(1)} \\ \mu_t^{(2)} \\ v_t^{(2)} \end{pmatrix}, \quad \eta_t = \begin{pmatrix} \xi_t^{(1)} \\ \zeta_t^{(1)} \\ \xi_t^{(2)} \\ \zeta_t^{(2)} \end{pmatrix}, \quad T = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad Z = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \end{bmatrix},$$

$$H_t = \begin{bmatrix} \sigma^2_{\varepsilon^{(1)}} & \mathrm{cov}(\varepsilon^{(1)}, \varepsilon^{(2)}) \\ \mathrm{cov}(\varepsilon^{(1)}, \varepsilon^{(2)}) & \sigma^2_{\varepsilon^{(2)}} \end{bmatrix}, \text{ and}$$

$$Q_t = \begin{bmatrix} \sigma^2_{\xi^{(1)}} & 0 & \mathrm{cov}(\xi^{(1)}, \xi^{(2)}) & 0 \\ 0 & \sigma^2_{\zeta^{(1)}} & 0 & \mathrm{cov}(\zeta^{(1)}, \zeta^{(2)}) \\ \mathrm{cov}(\xi^{(1)}, \xi^{(2)}) & 0 & \sigma^2_{\xi^{(2)}} & 0 \\ 0 & \mathrm{cov}(\zeta^{(1)}, \zeta^{(2)}) & 0 & \sigma^2_{\zeta^{(2)}} \end{bmatrix}$$

and writing out (1) in scalar notation yields the following two observation equations:

$$\begin{aligned} y_t^{(1)} &= \mu_t^{(1)} + \varepsilon_t^{(1)} \\ y_t^{(2)} &= \mu_t^{(1)} + \mu_t^{(2)} + \varepsilon_t^{(2)} \end{aligned} \tag{3}$$

while working out (2) in scalar notation results in the following four state equations:

$$\begin{aligned} \mu_{t+1}^{(1)} &= \mu_t^{(1)} + v_t^{(1)} + \xi_t^{(1)} \\ v_{t+1}^{(1)} &= v_t^{(1)} + \zeta_t^{(1)} \\ \mu_{t+1}^{(2)} &= \mu_t^{(2)} + v_t^{(2)} + \xi_t^{(2)} \\ v_{t+1}^{(2)} &= v_t^{(2)} + \zeta_t^{(2)} \end{aligned} \tag{4}$$

Since $\mu_t^{(1)}$ and $\mu_t^{(2)}$ are the trends for the exposure and the risk, respectively, and the mobility and fatality figures are modelled in their logarithms, the second equation in (3) can be written as

$$\log F_t = \log(\text{trend Exposure}) + \log(\text{trend Risk}) + \log(\text{error}) \tag{5}$$

and therefore as

$$\log F_t = \log[(\text{trend Exposure})(\text{trend Risk})(\text{error})], \tag{6}$$

since $\log a + \log b = \log(ab)$.

Finally, taking the exponent of (6) yields the following multiplicative model

$$\text{Traffic Safety} = (\text{trend Exposure})(\text{trend Risk})(\text{error}). \tag{7}$$

When all disturbances in (4) are fixed on zero, the latent risk model collapses to a bivariate linear regression model:

$$\log M_t = a^{(1)} + b^{(1)}t + \varepsilon_t^{(1)}$$
$$\log F_t = a^{(1)} + b^{(1)}t + a^{(2)} + b^{(2)}t + \varepsilon_t^{(2)}$$

$$(8)$$

with t = 1, …, n.

As (7) clearly indicates, in the latent risk model the development of road safety is assumed to be the product of the developments of two latent, unobserved factors: exposure and risk, see also Bijleveld et al. (2008). The model requires the estimation of thirteen parameters: three for the disturbance variances of the mobility and fatality figures including their covariance, another three for the disturbance variances of the level components of exposure and risk including their covariance, yet another three for the disturbance variances of the slope components of exposure and risk including their covariance, and finally four parameters for the initial values of the two level and the two slope components.

In all cases the annual total number of road fatalities in each country was used as an indicator for road safety. Whenever available the annual total number of motor vehicle kilometres driven was used as an indicator for the exposure in a country; if not available the annual figures for the total number of motor vehicles in a country were used for this purpose instead.

Appendix 7.   Fatality trends for individual countries

Observed and predicted fatality numbers for 20 European countries, using motor vehicle kilometre figures (unless otherwise stated) and fatalities in Harvey's structural time series model.
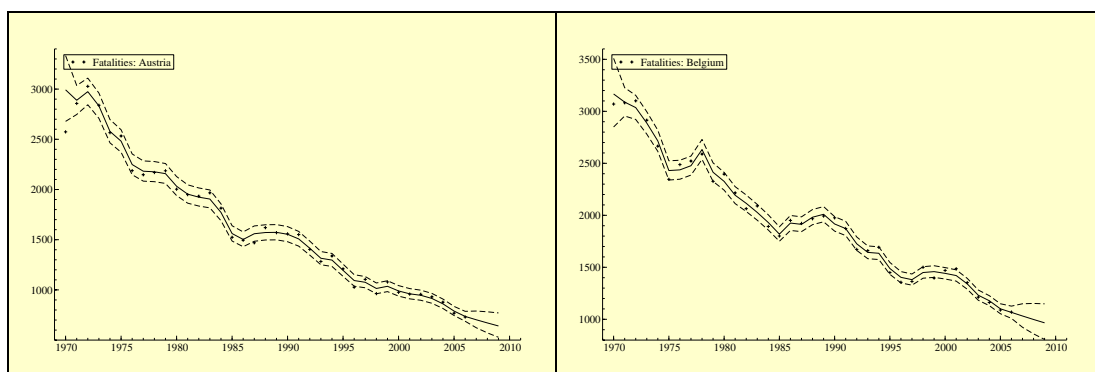
Austria

Belgium
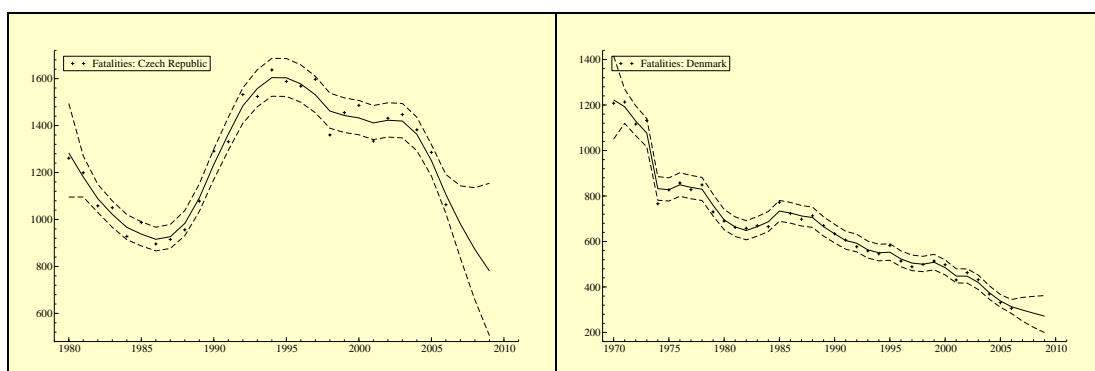
Czech Republic: with vehicle fleet as indicator for exposure.

Denmark: with mv-kms missing for 2003, 2005, and 2006.
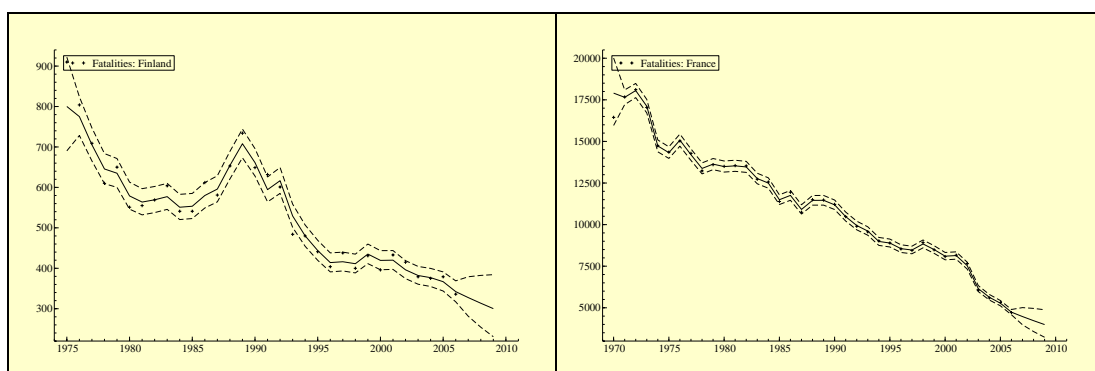
Finland

France
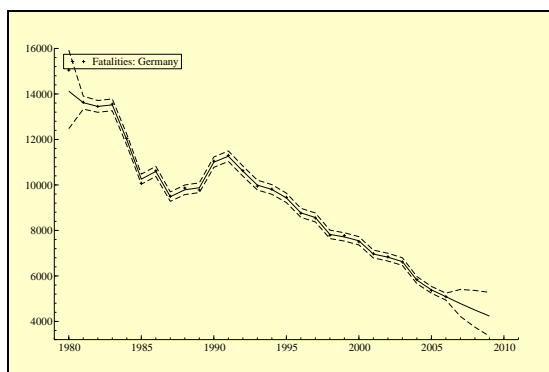
Germany
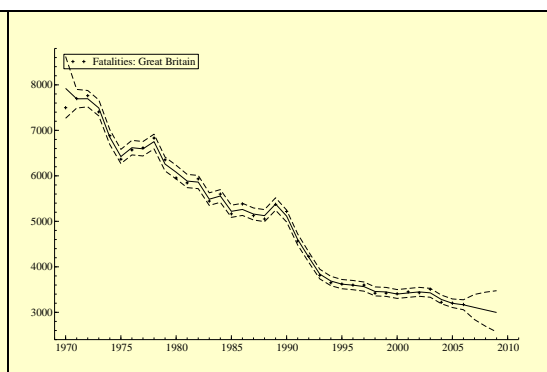
Great Britain
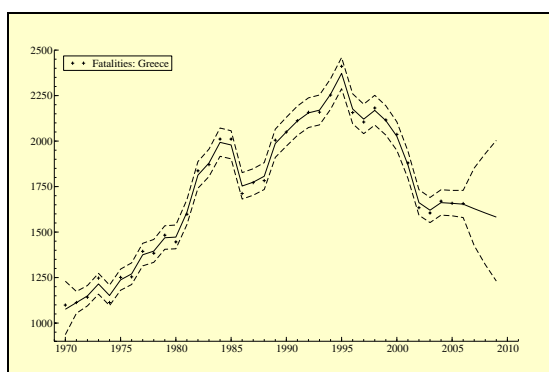
Greece: with vehicle fleet as indicator for exposure (missing in 1992).
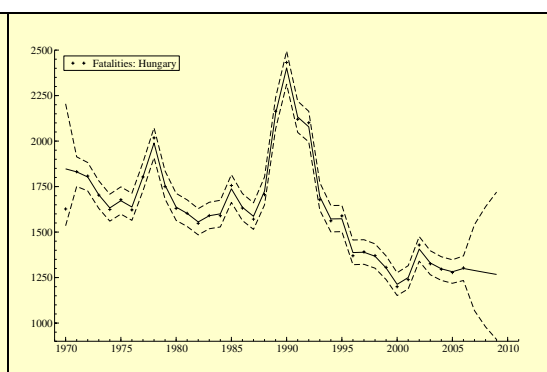
Hungary: with vehicle fleet as indicator for exposure.
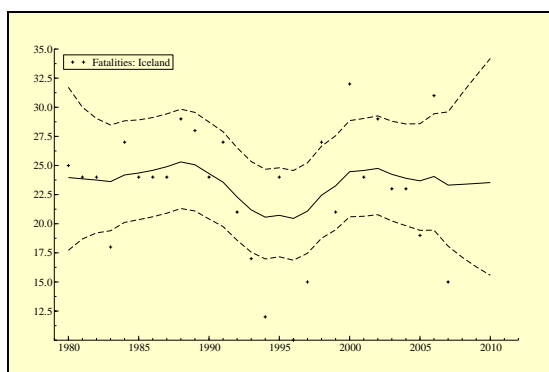
Iceland: mv-kms missing for 2001, 2002, 2003, 2004, and 2005.
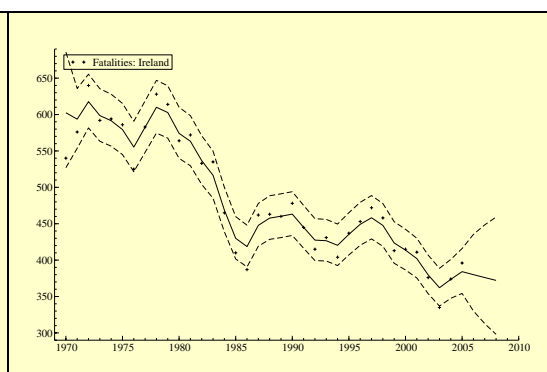
Ireland: with vehicle fleet as indicator for exposure.
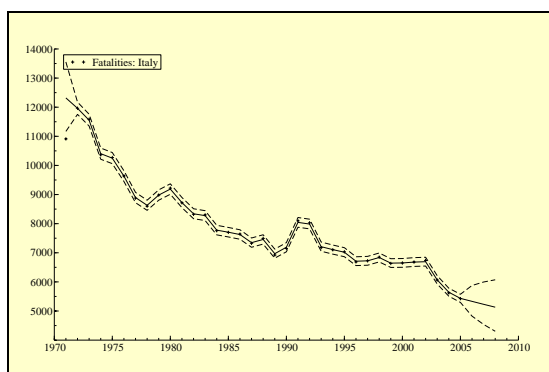
Italy: with vehicle fleet as indicator for exposure (and 2005 missing).
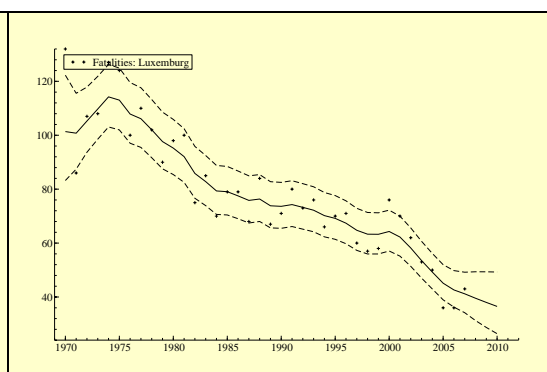
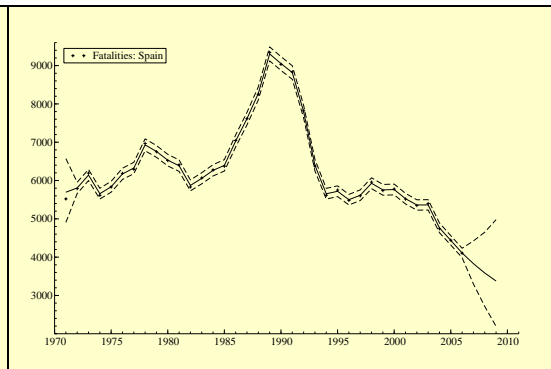Luxemburg: with vehicle fleet as indicator for exposure.
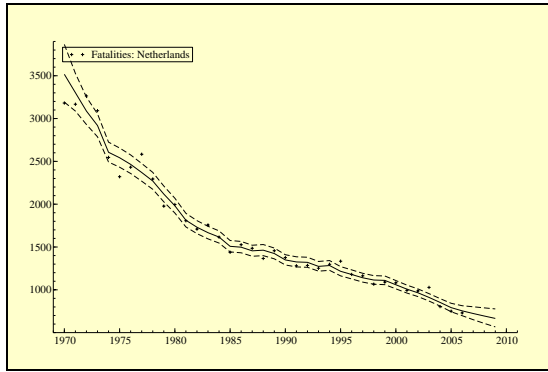
The Netherlands
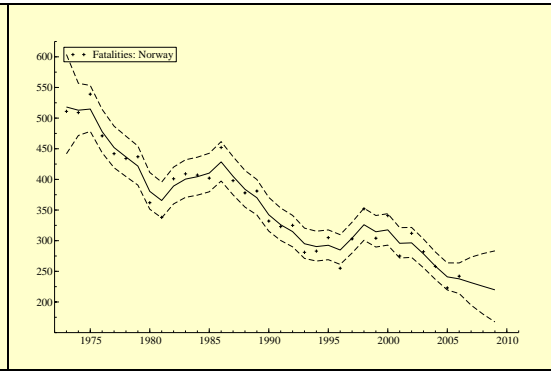
Norway

Poland: with vehicle fleet as indicator for exposure.
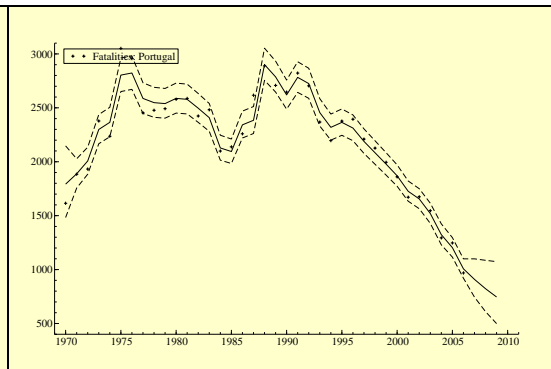
Portugal: mv-kms missing for 2004, 2005, and 2006.
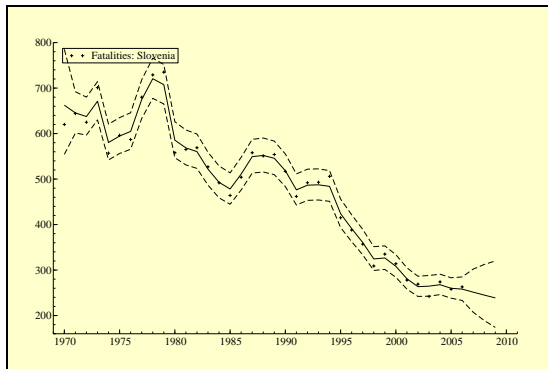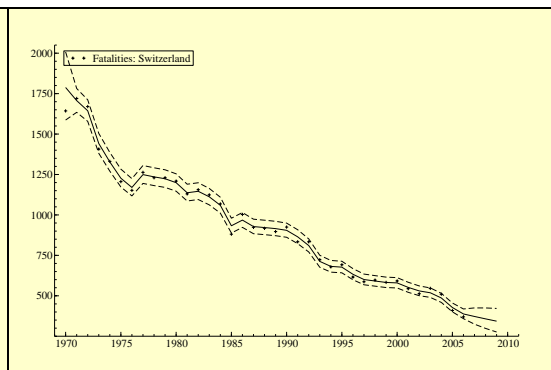

Slovenia

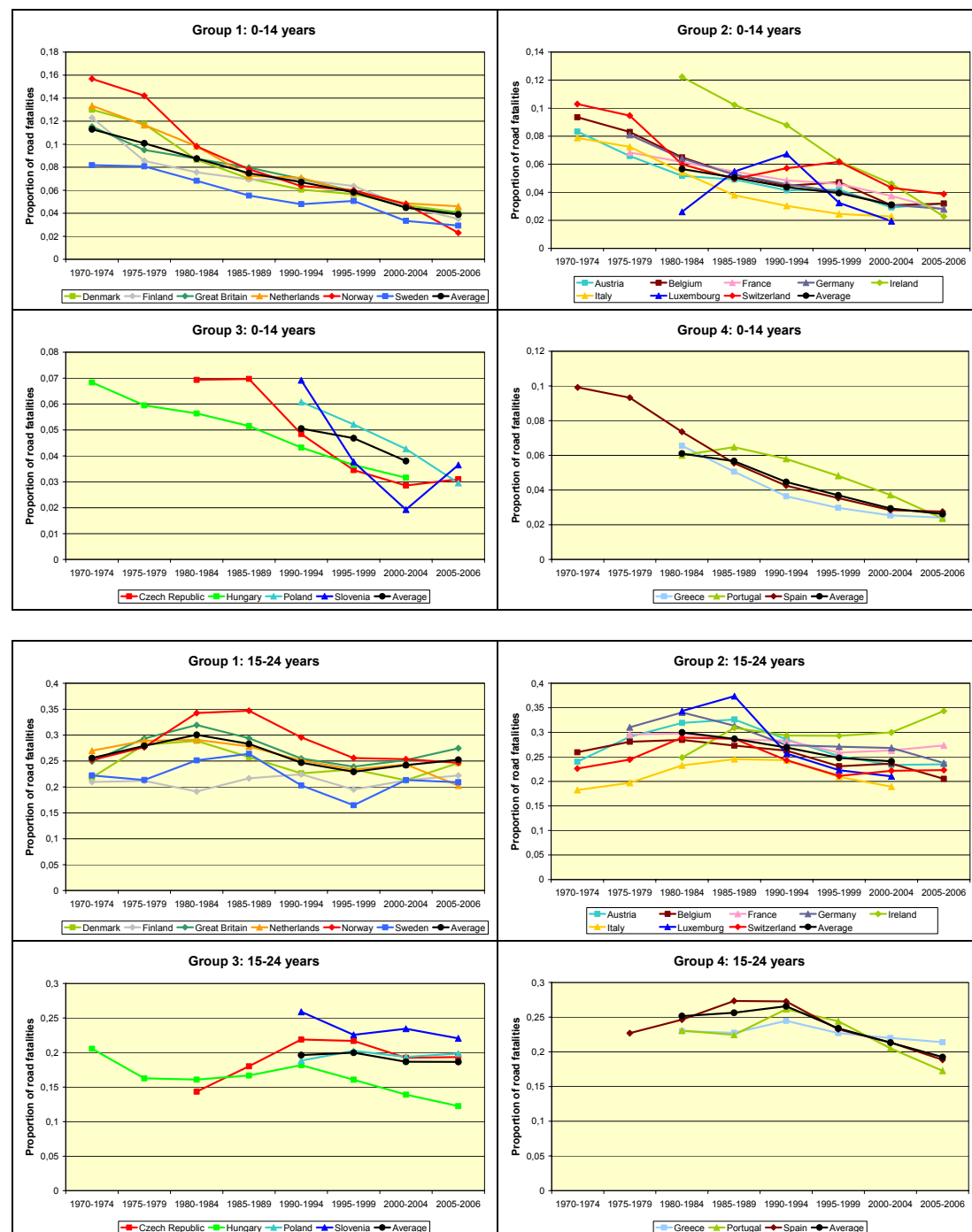Spain: with vehicle fleet as indicator for exposure.

Sweden

Switzerland

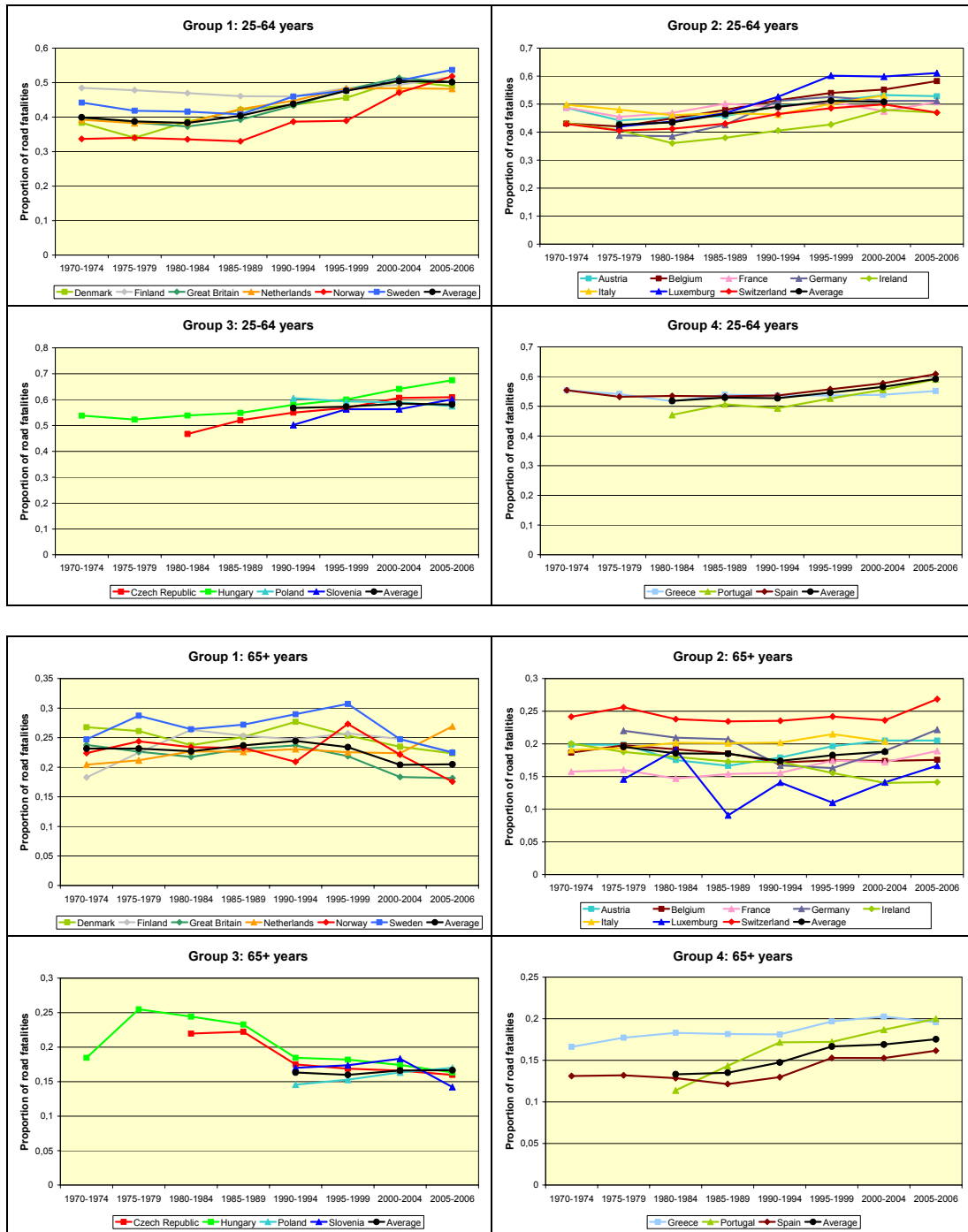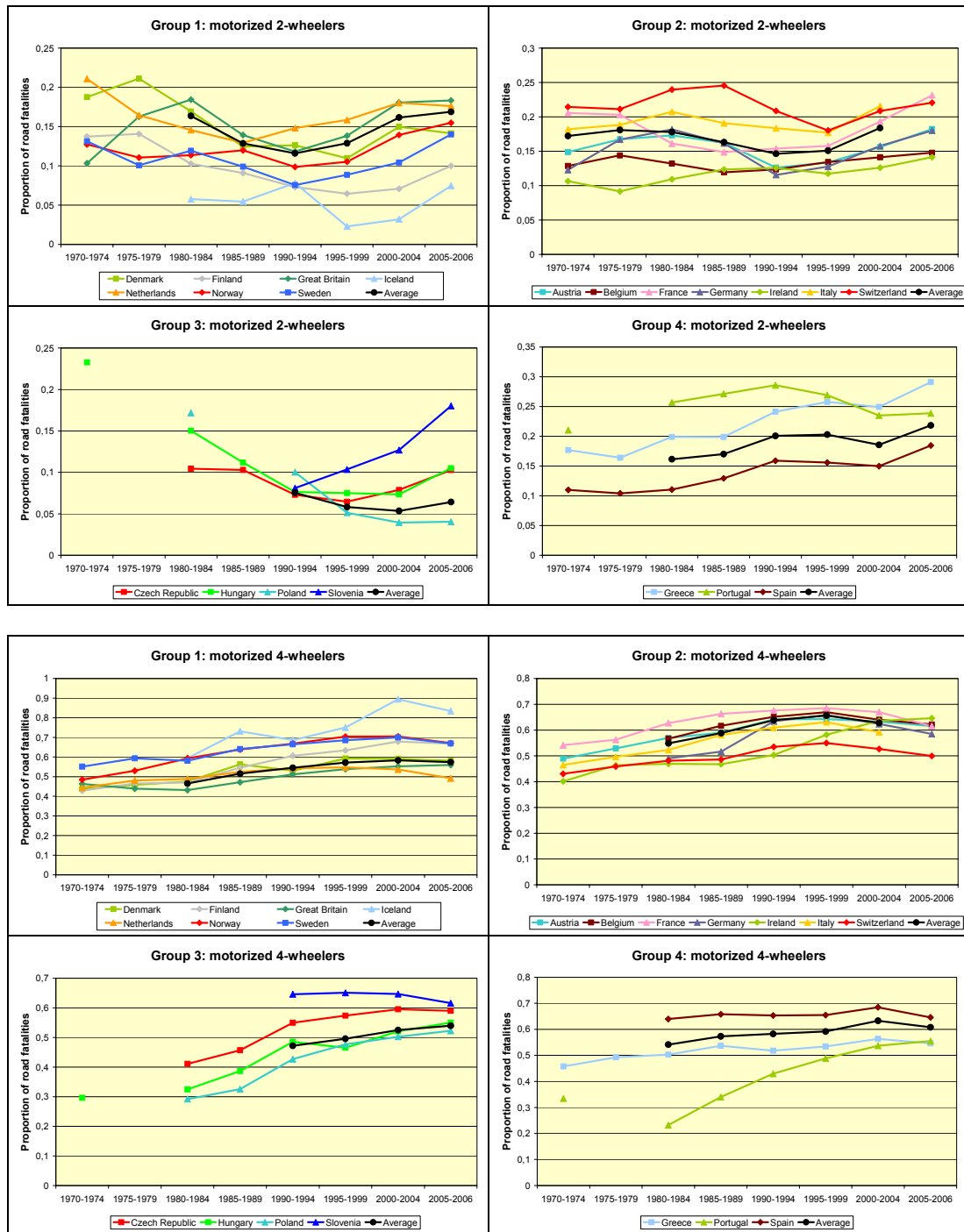166
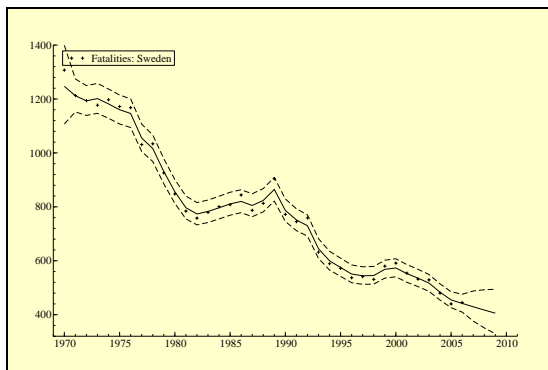
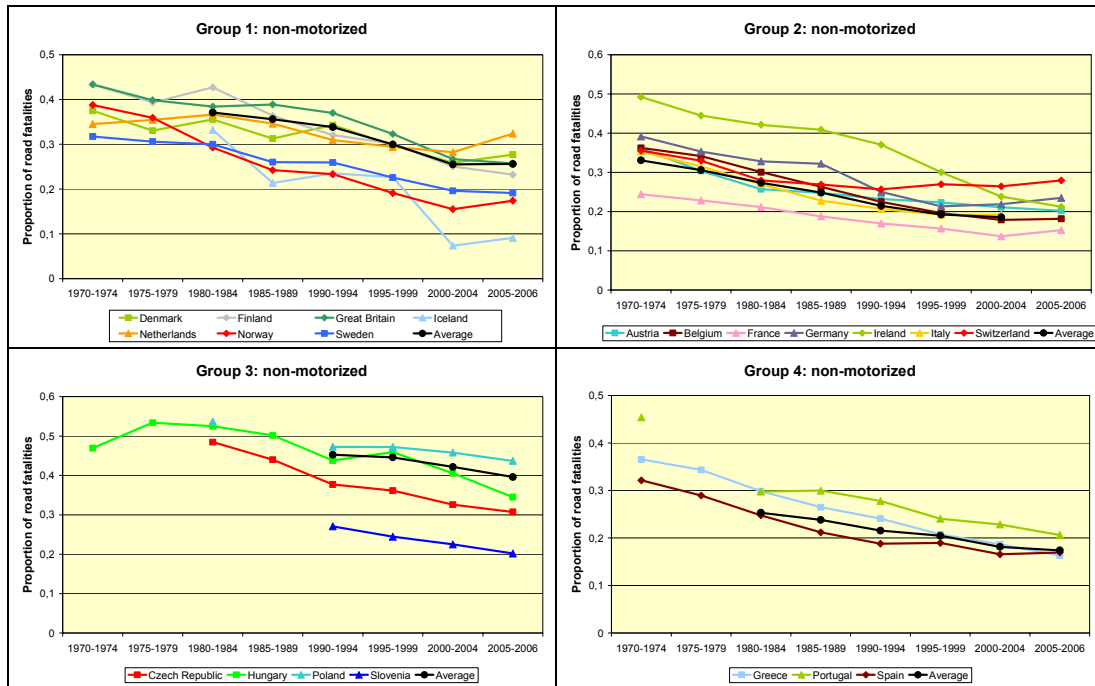# Appendix 8.   Disaggregate developments for groups of countries
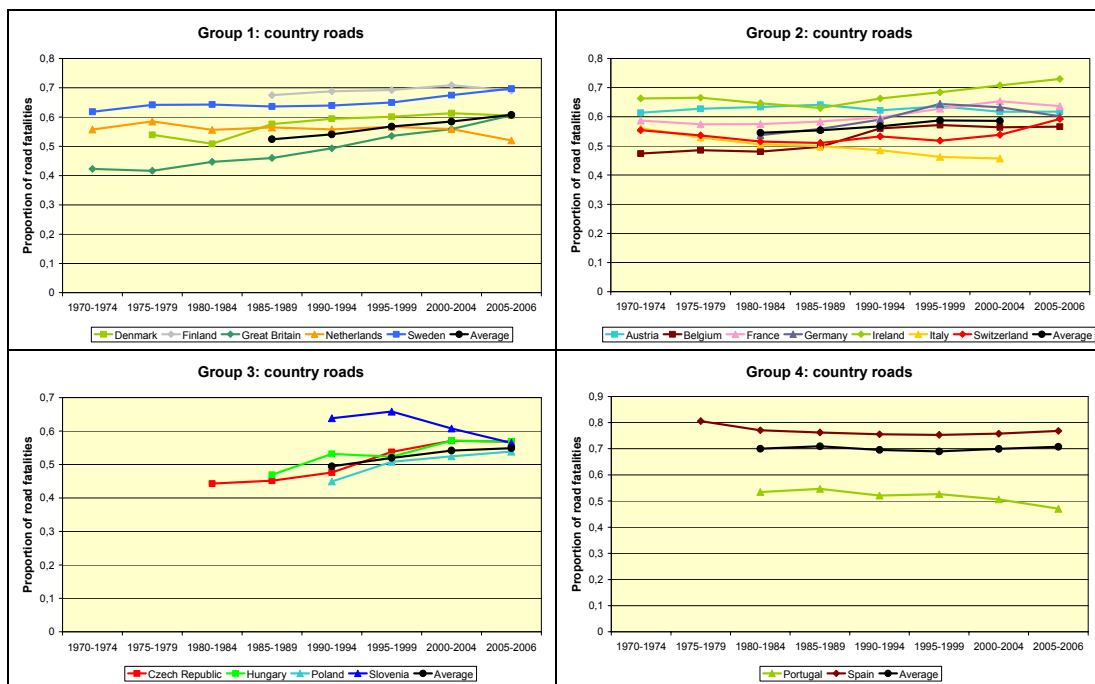
Development by age group

Group 1: 25-64 years

Group 2: 25-64 years

Group 3: 25-64 years

Group 4: 25-64 years

Group 1: 65+ years

Group 2: 65+ years

Group 3: 65+ years

Group 4: 65+ years

168

Developments by traffic mode

Group 1: non-motorized

Group 2: non-motorized

Group 3: non-motorized

Group 4: non-motorized

Developments by location

Group 1: country roads

Group 2: country roads

Group 3: country roads

Group 4: country roads
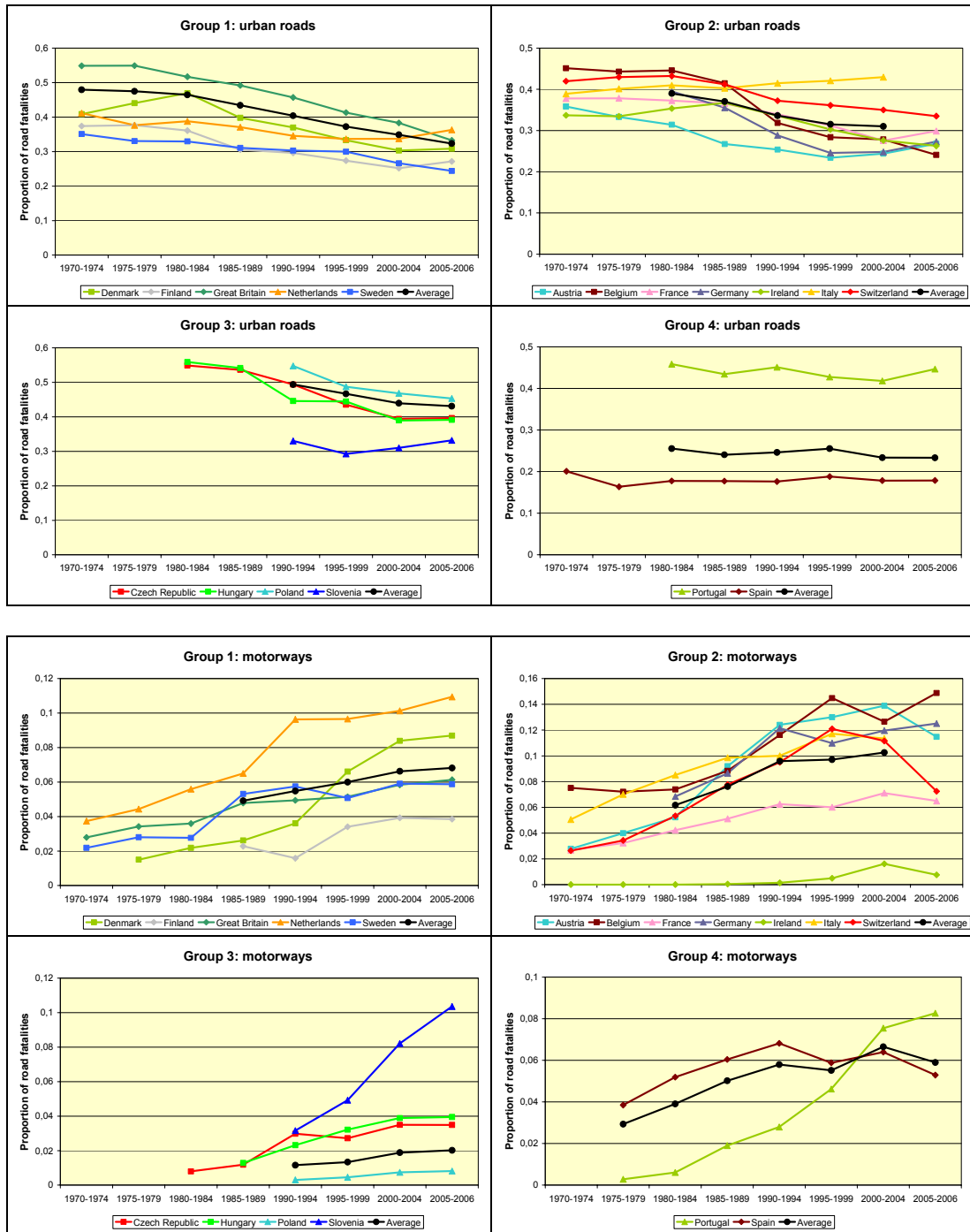
Appendix 9.   IAL - Local Accident Indicator

The Local Accident Indicator (Indicateur d'Accidentologie Locale: IAL) is computed as the ratio of the number of deaths observed in the département under study to the number of deaths that would have been recorded if the risk exposures, by road category, had been identical to those measured in France nationwide.

Five road categories are defined: (1) urban units of 5,000 + inhabitants; and outside these urban units: (2) highways (autoroutes), (3) main roads (routes nationales), (4) local roads (routes départementales), (5) 'other roadways', typically urban roads.

The risk exposure in category (1) is defined as the ratio of persons killed in an accident occurring in an urban unit of 5,000+ inhabitants to the total population of these units, expressed in tens of thousands of inhabitants (on the basis of the latest population census). For categories (2), (3), and (4), we calculate the ratio of the number of fatalities to the total mileage travelled in each of these networks, expressed in hundreds of millions of kilometres. For the last category (5), the population is used as a proxy for the traffic.

These risk levels are computed identically for all geographic areas: département, region, and all of France. The number of fatalities used is the total of the past five years, recalculated annually on a sliding basis. The choice of a structural indicator was guided by the desired objective: what we want to measure is not so much a short-term pattern as the stable notion of relative risk. For the sake of consistency, the mileage estimates are based on data (network length and mean daily flow) for the same five-year period. Therefore, the estimated values are annual averages.

To understand this properly, let us take the (fictitious) example of a département in which 500 people have been killed in the past five years, of whom 90 in an urban unit of 5,000+ inhabitants, 25 on highways, 110 on main roads, 250 on local roads, and 25 on 'other roadways.' The nationwide risk levels for these five roadway categories are respectively 1.76, 0.53, 1.99, 2.04, and 2.26. For the département observed, they stand at 3.39, 0.48, 2.66, 2.51, and 2.45. If the risk exposure in the département under study had been identical to the total French levels for each roadway category, the number of fatalities recorded in the département would have been:

90*(1.76/3.39) + 25*(0.53/0.48) + 110*(1.99/2.66) + 250*(2.04/2.51) + 25*(2.26/2.45) or 47 + 28 + 82 + 203 + 23 = 383.

The 'overall' local accident indicator for our control département is equal to 500/383, or **1.31**. For highways alone, it is equal to 25/28 = 0.89.

Appendix 10.   Literature overview of studies on regional risk analysis

Author, year[1]	Country	Level	Measure	Method	Type	Dimension
Hindle et al., 2008	England	Regions	Counts, KSI	Regression model	Descriptive	Time
Eksler et al., 2008a, b, c	EU-25, Belgium, Czech Republic, France	Regions, Municipalities	Mortality, Fatality rates, Accident rates	Full Bayes	Descriptive, Ecological	Space, time
La Torre et al., 2007	Italy	Regions	Mortality rates	Basic rates, Multiple regression	Ecological	Space
Aguero-Valverde & Jovanis, 2006	Pennsylvania	Communes	Fatal and injury accident rates	Full Bayes	Ecological	Space-time
Broughton & Buckle, 2006	England	NUTS-3	Fatalities, KSI	Basic	Descriptive	Time
Lassarre & Thomas, 2005	17 EU countries	NUTS-2	Mortality rates	Empirical Bayes	Descriptive	Space
Haynes et al., 2005	England and Wales	Districts	Fatality counts	Odds ratio, Basic rates	Descriptive	Space
Noland & Quddus, 2004	Illinois and England	Regions	Fatality and injury counts	Full Bayes		
MacNab, 2004	British Columbia	Regions	Mortality rates	Full Bayes	Ecological	Space
Amoros et al., 2003	France	Counties	Mortality and fatality rates	Basic	Descriptive	Space
Shaw et al., 2000	EU-15	NUTS-2	SMR[2]	Basic	Descriptive	Space
Williams et al., 1991	Scotland	NUTS-3	SMR[2]	Basic	Descriptive	Space
Van Beeck, 1991	Netherlands	Regions	Fatality, injury rates	Basic	Ecological	Space
Fridstrom & Ingebrigtsen, 1991	Sweden, Norway, Finland	Counties	Accident, fatality counts	GLM[3]	Ecological	Space
Baker et al., 1987	New England	Regions	Mortality rates	Basic rates, Regression analysis	Ecological	Space-time

1) For the full references: see next page.
2) SMR = Standardized mortality ratio.
3) GLM = Generalized linear model.

Full references to Appendix 10

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