Road Safety Data, Collection, Transfer and Analysis

Deliverable 4.4.

Forecasting Road Traffic Fatalities in European Countries

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1. INTRODUCTION

1.1. Background: the DaCoTA project

Traffic crashes have a major impact to European society, in 2008 over 38,000 road users died and over 1.2 million were injured. The economic cost is immense and has been estimated at over 160 billion for the EU 15 alone. The European Commission and National Governments place a high priority on reducing casualty numbers and have a series introduced targets and objectives.

The experience of the best-performing countries is that the most effective policies are based on an evidence-based, scientific approach. Information about the magnitude, nature and context of the crashes is essential while detailed analyses of the role of infrastructure, vehicles and road users enables new policies to be developed.

The EU funded SafetyNet project established the European Road Safety Observatory to bring together data and knowledge to support safety policy-making. The project developed the framework of the Observatory and the protocols for the data and knowledge, the ERSO is now a part of the DG-Move website:

http://ec.europa.eu/transport/road_safety/specialist/index_en.htm.

The DaCoTA project will add to the strength and wealth of information in the Observatory by enhancing the existing data and adding new road safety information. The main areas of work include

- *Work package 1 - Policy-making and Safety Management Processes*
  - Developing the link between the evidence base and new road safety policies
- *Work package 2 – In-depth Accident Investigations*
  - Setting up a Pan-European Accident Investigation Network
- *Work package 3 – Data Warehouse*
  - Bringing a wide variety of data together for users to manipulate
- *Work package 4 – Decision Support*
  - Presenting analysis results and data to policy makers
- *Work package 5 – Safety and eSafety*
  - Intelligent safety system evaluation
- *Work package 6 - Naturalistic driving observations*

This deliverable is a production of Work package 4.

1.2. General goals of Work Package 4 – Decision Support

The aim of WP4 is to bridge the gap between research and policy to enable knowledge-based road safety management. To support road safety decision makers, this Work Package will: (1) exploit the data available for analysis by providing forecasts of the road safety situation in the different member states and, possibly, the whole of Europe; and (2) work on the development of ready-to-use instruments. Tools that were well-appreciated in the past will be standardised and complemented by new tools. This will be done in close communication with the end-users themselves. The end-users mainly concern the policy makers, but may in some case also concern power-users from research and the industry.

The expected outcomes of WP 4 are

- National forecasts:

  To enable target setting and monitoring of the road safety progress in the different countries, forecasting models will be implemented.
- European forecasts:

  To identify common trends in different European countries, the accident outcomes will be analysed jointly.
- Web texts:

  Web texts are already provided on the ERSO website that give compact, impartial information on important road safety issues. These are updated and web texts on complementing issues will be added.
- Browser tool for data warehouse:

  A browser tool will allow easy access to information stored in the Data Warehouse that will be developed in Work Package 3.
- Country overviews:

  These will give an overview of the road safety situation in each country. The overviews will address final road safety outcomes, performance indicators, policy performance and background characteristics of the countries.
- Country indices:

  To further this information even more, possibilities are investigated to summarize the information contained in the country overviews into one or a few country road safety indices.

1.3. Objectives of present deliverable

Roads and road transport play a central role in Western societies, but the benefits they offer come at a cost. In addition to the obvious costs of building roads and vehicles and providing fuel, there are various less obvious costs: human and environmental. We focus here on road accidents and in particular on the resulting fatalities, which are the unintended consequences of the road transport system.

The frequency of accidents and the number of fatalities evolve over time. In fact the number of fatalities has decreased in most European countries in recent years. It is important to monitor these developments, focusing on a number of key questions

- Has there been a continuous, smooth development or were there abrupt changes?
- If there have been changes, are they to be attributed to changes in the actual risk of having (fatal) accidents, or rather to changes in traffic volume?
- Where does the present development get us (if continued)?

The last issue is particularly important for the setting of political road safety targets. It has been shown that in countries that have an explicit target to be reached by a particular year - for instance the reduction of the number of fatalities - more concrete actions to improve road safety have been taken (Wegman et al., 2005). Such a target has to be SMART: specific, measurable, attainable, realistic, & timely (Doran, 1981).

The European Commission has set the target to halve the number of road deaths in 2020 as compared to 2010. However, countries differ in the reductions that can realistically be expected. In some countries there is a long tradition of road safety oriented policy making and the risk is comparatively low already. In other countries, efforts to increase road safety have only recently begun and there is still a lot to achieve. In this case, a stronger reduction of the number of fatalities has been observed in past years and is also realistic to expect in the years to come.

A good way to select realistic targets for the reduction of the number of fatalities is to extrapolate the past development into the future. Such an extrapolation gives an indication where the development goes if past efforts are maintained. For some countries, this constitutes an ambitious target already. For others, past efforts might be perceived as insufficient, and the target should be chosen below the number of fatalities forecasted in continuation of the present trend. In each case, a sound forecast for the target year should form the basis for setting the target and monitoring the achievements in the coming years.

The present deliverable gives forecasts for 2020 for each European country. While the detailed methodology, including the definition of the statistical models employed was given in Deliverable D4.2 (Martensen et al., 2010), the focus of the present deliverable is on the actual forcasts.

1.4. Overview

In Chapter 2, the principles that played a role in the selection of the statistical models to forecast the fatalities up to the year 2020 are described in a relatively non-technical way. This Chapter also gives a view on problematic issues like the data quality and forecasting in times of the recession.

In Chapter 3, an overview of the resulting forecast models will be given.

In the Appendix A, the *full report* on the time series analysis of each country is given. This is a technical description of the forecasting model and the process that lead to its selection is given for each country. The use or non-use of exposure in the final model (presented in the factsheets in Appendix B) is argued on the basis of additional analyses and different forecasting models are compared according to various quality criteria. These detailed country reports are written for experts and an understanding of the statistical principals underlying latent state modeling (see Martensen & Dupont, 2010, D4.2) might be necessary to read them.

In Appendix B the *forecast factsheet* for each country is presented. These factsheets are meant to give a relatively untechnical description of the development of the fatalities (and of the exposure if available) so far. If known, the (possible) reasons for the developments are shortly described. The forecasts of the fatality numbers up to 2020 made under the assumption of continuation of past development continues are also provided. Whenever an exposure measure of the necessary quality was available (see Chapter 2), an estimation of the fatality risk is presented along with three scenarios based on different assumptions for the development of mobility in the next 20 years.

2. PRINCIPLES OF MODEL SELECTION FOR FORECASTING ROAD TRAFFIC FATALITIES

2.1. Fatalities versus Fatality Risk

In the road safety domain, the temporal evolution of the number of accidents and victims (fatalities, severely injured, injured), is a major topic of interest (COST 329, 2004). These quantities are to road safety research what stocks and flows are to economy: they are counted on a monthly or yearly basis in all European countries.

The yearly number of road traffic fatalities in the different European countries is available in the CARE database. Road safety fatalities – although by no means the only interesting measure – are the key measurement to analyse and compare the development of road safety across countries, because they are less susceptible to underreporting than other measures.

In the present work, **fatality risk** is a key concept that is assumed to underly the observed fatalities. Generally speaking, risk is defined as the occurrence of an unwanted event considered relative to the *exposure* to this risk. In the present case, the unwanted event is someone dying in a road traffic crash, and the exposure is a count (or estimation) of all situations where someone *could* have become a fatal crash victim. We assume that everyone can become a fatal crash victim whenever they take part in road traffic. Therefore, an estimation of road traffic mobility is an appropriate indicator of the exposure to the risk of becoming a road traffic fatality.

In principle, the fatality risk can be split in two components: the risk of being involved in a road crash and the risk of dying as the result of that crash. The accident risk depends mainly on factors like driving behaviour, infrastructure and enforcement. The risk of dying given an accident is determined more by the use of protective devices, the crashworthiness of the vehicle, and the efficiency of trauma care. Bijleveld et al. (2008) have consequently suggested modeling the risk of being involved in an injury accident and the risk of dying given an injury accident as separate variables in a multivariate model. To do so, one has to consider a count of road crashes that lead to an injury next to the number of road traffic fatalities.

In the present case, however, we have decided to ignore this differentiation between accident risk and fatality-given-accident risk, because the counts of injury accidents are subject to under-registration. Differences in the importance of underregistration occur between countries, but also within a given country, for example when the registration of injury accidents has gradually increased over the years or depending of the severity of the accident (less severe accidents tend to be reported less).

Consequently, in the present study the term “fatality risk” refers to the number of fatalities relative to an estimate of road mobility in the country in question.

It is defined as follows:

Fatalities = Mobility * Fatality risk.

And consequently:

Fatality risk = Fatalities / Mobility.

In the following, the term `risk´ will always be used in the sense of ´fatality risk´ as defined here, unless explicitly mentioned.

2.1.1. Fatality peaks and their interpretation

For many western European countries, fatality numbers reached a peak in the early 70s. In other words, the trend was rising before the 70s and decreased afterwards (Yannis, Antoniou, Papadimitriou, Katsochis, 2011). At first, many road safety researchers wondered what had caused this change of direction. One was almost looking for a miraculous measure, which – when applied to other countries – would cause a similar trend change.

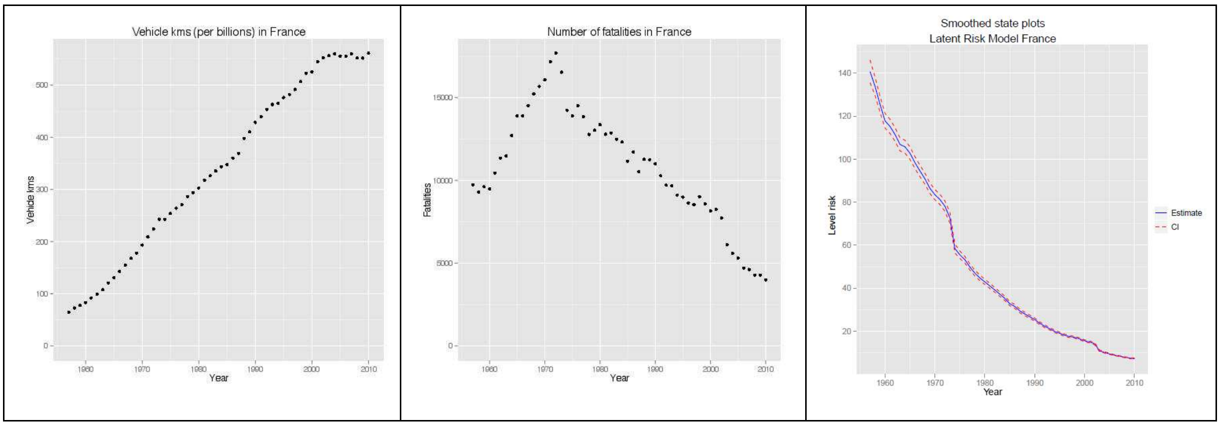

Figure 2.2: Developement of vehicle kilometres (upper left), fatalities (upper right) and fatality risk (lower left) in France, 1957 – 2010.

However, when considering the development of the fatalities jointly with that of mobility, a completely different picture arises. As an example, the number of vehicle kms, the number of fatalities, and the fatality risk for France are presented in Figure 2.2. While the number of fatalities shows a sharp peak in 1973, the fatality risk is simply a continuously decreasing line. This means that the “fatality peak” simply corresponds to the moment where the decay in risk became strong enough to compensate for the adverse effect of the increase in mobility on the number of fatalities. Fatalities started decreasing despite of an ever-increasing mobility. In 1991, Oppe described the observed fatalities as the result of an exponentially growing mobility and an exponentially decreasing fatality risk. This conception lies at the basis of the models that are employed here to analyse and forecast the fatalities.

For some countries, the “fatality peak” occurred more recently. Examples are presented in Figure 2.3. Portugal and Spain deviate somehow from the general “fatality peak” pattern. In Portugal there was a peak in 1975 but the decrease afterwards did not persist, as in the second half of the 80s the fatalities started rising again. The final turning point was only in the late 80s. For Spain, there was only one turning point -- also in the late 80s -- but the rise before and the decrease afterwards were not as smooth as predicted by the increase of the traffic volume. As a consequence, the risk trend, although not showing the large peak visible in the number of fatalities, does reflect some of the irregularities of the fatality series.

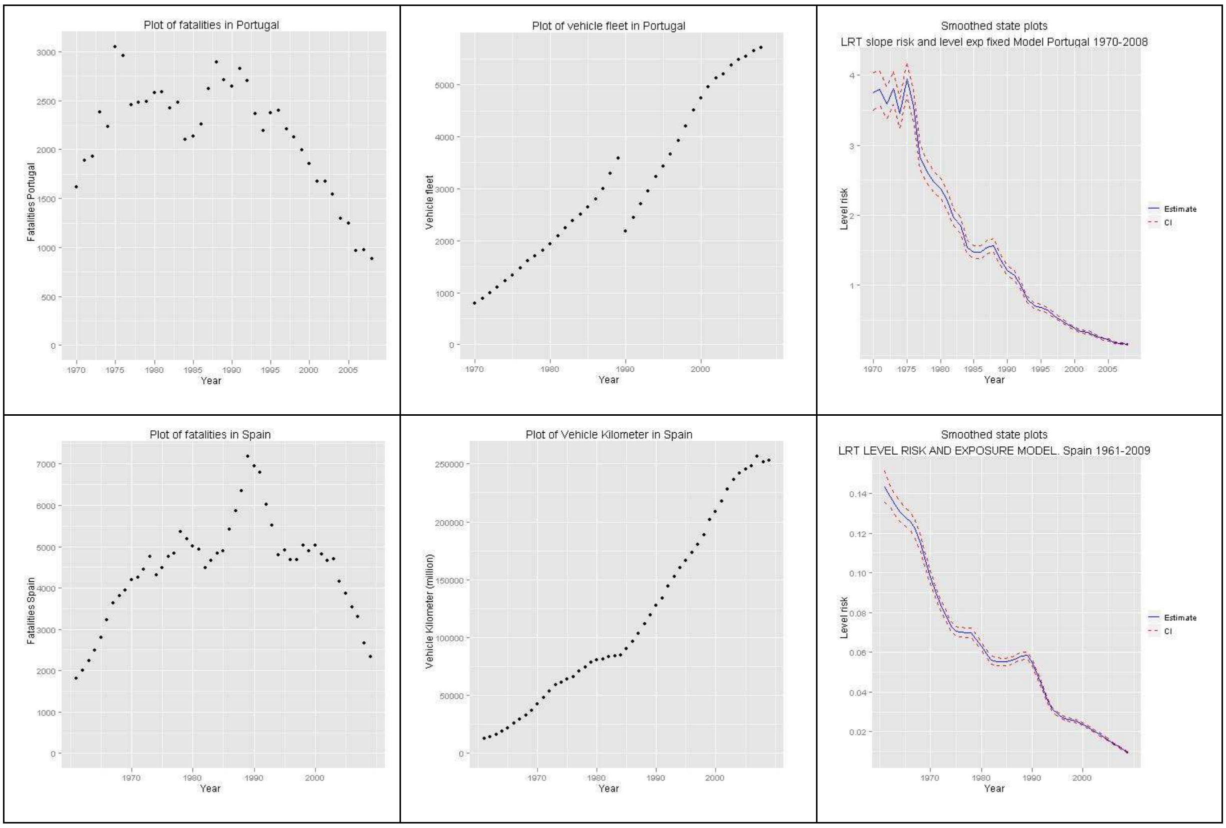

Figure 2.3: Number of fatalities (left hand panels) and fatality risk (right hand panels) for Portugal (upper panels) and Spain (lower panels).

To summarize, the risk trend shows to what extent the rises and falls in the development of road traffic fatalities are to be considered a “simple” consequence of the changes in mobility, and to what extent they have to be attributed to changes in the fatality risk.

2.2. Modelling the fatality risk: the importance of adequate mobility indicators

In order to identify the fatality risk - or the number of fatalities per unit of mobility - one needs a measure of mobility. In Yannis et al. (2005), a selection of measures for mobility is discussed. The preferred measure is the number of vehicle kilometres. If these are not available, the vehicle count (i.e. the fleet) or oil sales are alternative options.

The number of vehicle kilometres driven in a particular country is not directly measured but estimated. It can be based on sample counts that are interpolated, on odometer readings during the vehicle inspections, on toll payments, on questionnaires, or on a combination of several of these methods. This makes vehicle kilometres impossible to compare across countries. Even within a country, it is important to watch out for changes in the estimation method of vehicle kilometres or in the sample size of counts and questionnaires.

2.2.1. Consequences of using insufficient mobility indicators

The quality of the estimation of the fatality risk depends crucially on the quality of the mobility estimator. We will therefore give three examples for potential pitfalls in the registration and interpretation of the mobility estimators and discuss the consequences for the estimation of the fatality risk.

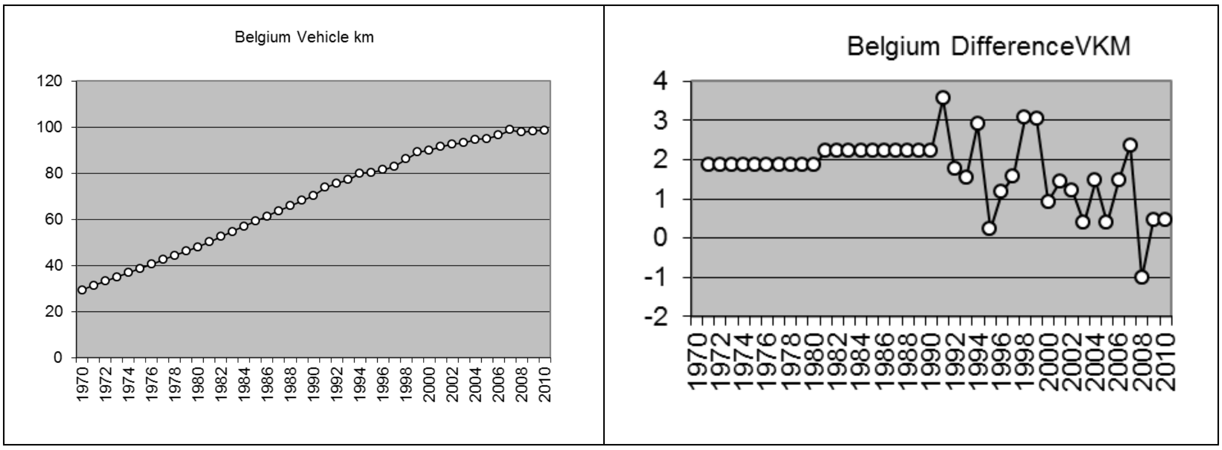

Figure 2.4: Belgian Vehicle kms from 1970 to 2010 (left-hand graph) and difference in the number of Vehicle kms from one year to the next (right-hand graph)

As a first example, the number of vehicle kilometres for Belgium is plotted below along with the differences in the same numbers from one year to the next (Figure 2.4). The difference scores. from 1970 to 1980 and those from 1980 to 1990 are systematically the same. Only from 1990 on the difference scores vary as one would expect for actual yearly measurements. This suggests that the vehicle kilometres have actually been measured in 1970, 1980, and only from 1990 on yearly. Using the interpolated data in a model would give a false sense of regularity in the development which would lead to an underestimation of the true variation (and thus too small confidence intervals in the forecasts).

The second example in Figure 2.5 shows the number of registered vehicles in Bulgaria from 2001 to 2010. Between 2005 and 2006, the number of vehicles decreased by almost a million. This is due to the obligation to acquire new plate numbers for each registered car. The million cars had not been in use anymore. So, while from 2006 on the number of vehicles is probably realistic, the big drop between 2005 and 2006 does *not* represent a reduction in mobility.

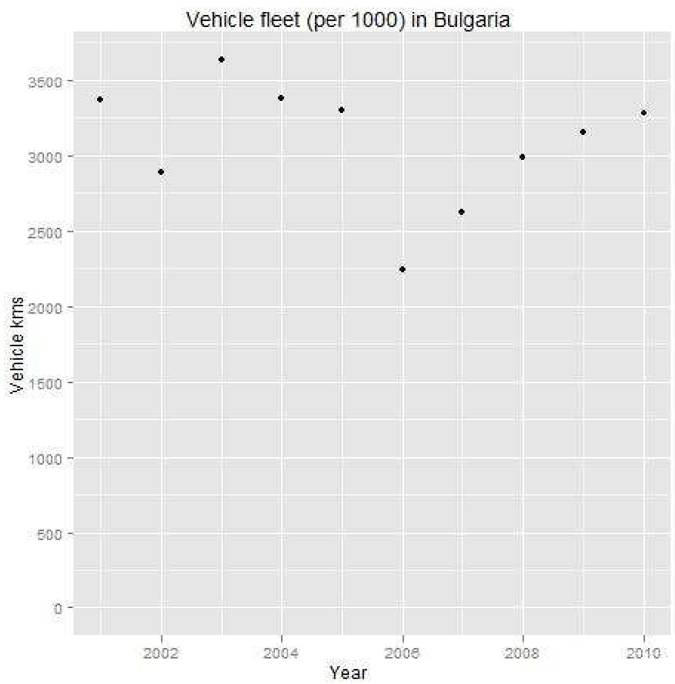

Figure 2.5: Total number of motor vehicles in Bulgaria from 2001 to 2010.

A final example of potential problems with exposure measurements concerns the number of vehicles in circulation in Greece. We see a more or less continuous rise of the number of vehicles throughout the years. Although the increase is somewhat less steep between 2008 and 2009, it is unlikely that this reflects the full extent of the reduction of mobility due to the economic recession in Greece. It is often difficult to decide whether fleet size adequately reflects short term changes in mobility, as for example due to a recession.

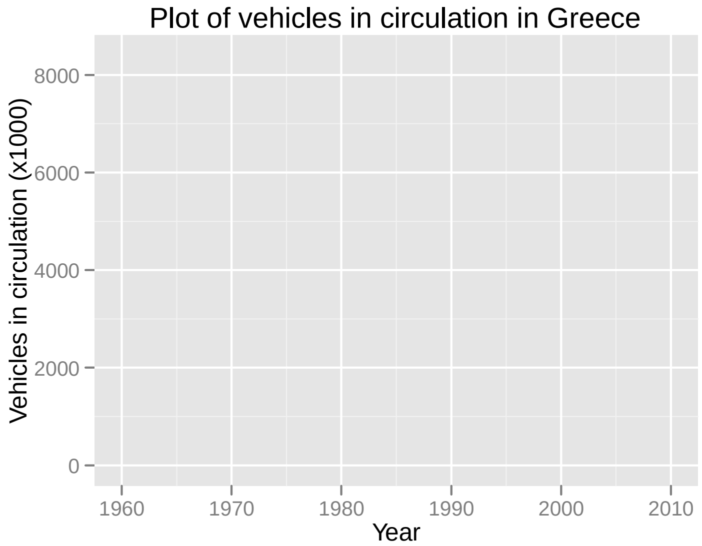

Figure 2.6: Number of registered vehicles in Greece – 1960 to 2010

If the chosen mobility indicator used does not accurately reflect mobility, as in the examples above, the estimation of the fatality *risk* becomes flawed. As an example: the number of fatalities has shown a decrease since 2008 – but many measures of mobility (especially vehicle fleet) do not. Did the risk actually decrease? Or is the reduction of mobility not appropriately represented by the data used?

The danger of using a flawed mobility measure for the calculation of the fatality risk is to confidently attribute changes in fatality developments to changes in road safety (i.e. to changes in the fatality risk), while in fact they may after all be a consequence of changes in mobility.

Other inaccuracies in the mobility measures (e.g., a drop in the vehicle fleet that is in fact due to cleaning the database), might also lead to distorted risk estimates, since they correspond to a correction of the number of fatalities for a reduction in mobility that has not actually occurred. In the case of an artifactual drop in the mobility measure, the risk would be seen as rising, while in fact it is not.

2.2.2. Relation between mobility and fatalities

As noted above, it is in principle important to take mobility into account when analyzing and forecasting the development of road traffic fatalities. However, rather than using a flawed exposure measure, it should better be acknowledged that one does not have good information about the development of mobility.

The question then is: “How to evaluate the quality of a mobility indicator?” The work presented here rests on the assumption that the observed fatalities are a product of a certain fatality risk and the exposure to that risk, namely the mobility. Based on this assumption, one should expect to see a relation between mobility and the number of fatalities. If the mobility increases, one would expect more fatalities, simply because people have been more exposed to road risk. Conversely, if mobility decreases one expects fewer fatalities. Of course mobility is not the only factor affecting the number of fatalities. The fatality risk can change as well, for many reasons (road safety policies, the weather…). But changes in mobility should nevertheless affect the observed number of fatalities.

The decision to use a given mobility indicator was therefore based on whether a relation between the indicator and the fatalities could be identified or not. It should besides be noted that a mobility indicator that does not show a relation with fatalities does not contribute to the analysis and to improving the forecasts of the fatalities. The results are the same whether this mobility indicator is included or not.

We investigated the correlation between the number of fatalities and the measure of mobility in an additional analysis called the SUTSE model. Without going into details, let us simply say that due to the fact that these measures are both *time series showing stochastic trends* it is not trivial to conclude on the presence of such a relationship .

The resulting correlation between fatalities and the mobility indicator determine the model that is used for analyzing and forecasting the fatality *risk*. We differentiate 3 cases based on whether the results of this preliminary model (the SUTSE model) indicated: (1) a strong correlation (2) a moderate correlation, or (3) no correlation.

1.) In some countries, (e.g., France), the correlation between fatalities and the mobility measures is very strong. So strong in fact, that it seems that all changes of direction in the number of fatalities can be explained by changes in the mobility.

2.) In some countries, (e.g., Spain), there is a correlation between the number of fatalities and the mobility indicator, but the correlation is weak. Although mobility affects the number of fatalities, there are also variations from the fatality trend that are not due to changes in mobility. In this case, the fatality risk is assumed to vary.

3.) In some countries, (e.g., Greece) no relation between the number of fatalities and the mobility indicator can be found. This means that the number of fatalities is either not affected by mobility or that the mobility indicator does not reflect mobility accurately enough for this relation to show up. In both cases it is not useful to disentangle the fatalities into the contribution of the fatality risk and mobility.

This preliminary analysis of mobility together with the number of fatalities therefore guided two types of decision: (1) it allowed determining whether an analysis and a forecasting in terms of fatality *risk* should be done at all, (2) whenever this was the case, it provided indication on the way the risk trend should be conceptualized and modeled. Below we further explain how the two types of decisions were made.

Generally, when a correlation failed to be identified on the basis of the SUTSE model fatalities were simply analysed by themselves (without the exposure indicator). Whenever a correlation could be identified, the exposure and fatality series were considered jointly, on the basis of the so-called Latent Risk Time series Model (or LRT model, Bijleveld et al.). In this model, the fatality risk (i.e., the number of fatalities per unit exposure) is itself considered a time series – albeit a latent one. “Latent” means that this series (i.e. the fatality risk at each year) cannot be directly observed, but is estimated on basis of the fatalities and the mobility indicator.

2.3. Modeling road safety developments

A time series is a series of measurements, e.g. the yearly number of fatalities in a country, the yearly value of a particular mobility indicator. We already explained that in the LRT model, the risk (i.e. the yearly value of fatalities devided by the mobility indicator) is also considered a time serie, but one that is not directly observed (i.e. \`latent\`).

To explain some basic principles of time series modeling, will now consider the case where only the yearly number of fatalities is considered. The description here is only meant to give an idea about the concepts used. For an exact definition we refer to D4.2 (Martensen & Dupont, 2010), or to the literature about State Space Modelling (e.g., Commandeur & Koopman 2007, Bijleveld et al., 2008).

2.3.1. Interpreting changes

As examples, we will first consider the development of the fatalities in France.

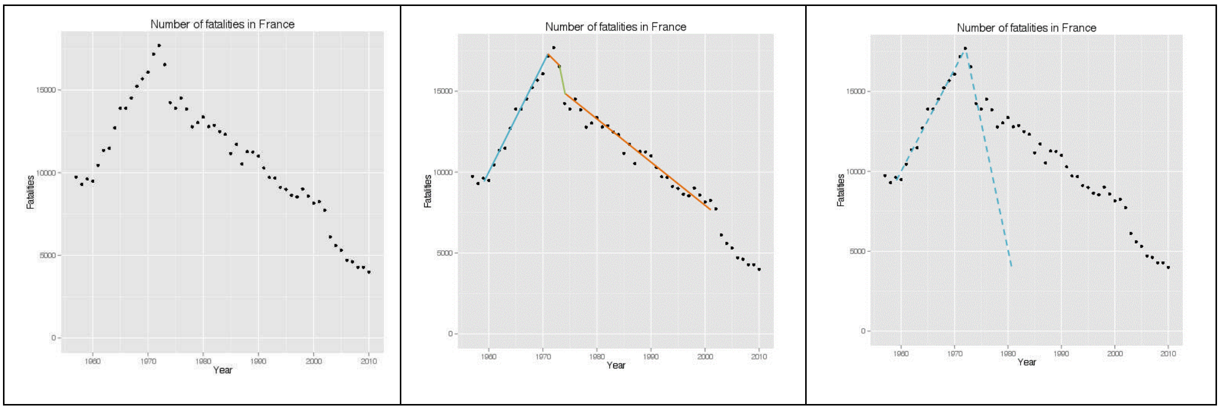

Figure 2.7: Developement of fatalities in France, 1957 – 2010. Middle panel: Post-hoc interpretation of changes in early 70´s. Right panel: Possible interpretation of changes in 1974 and forecasts derived from it.

From 1957 to 1972 the fatalities followed more or less a straight line (see blue line in middle panel). This means that each fatality number could simply be calculated by taking last year´s value and adding a fixed number to it. This number, the difference from one year to the next, is called the **slope**. The slope indicates the *direction* of the time series and can also be called the *rate of change.*

After 1972 the slope in France changed. Instead of adding a particular number to get to next year´s number of fatalities, one would have to substract a number (see red line in middle panel of Figure 2.7). This slope change is a very radical one. Slope changes can also be more subtle changes to the rate of change (e.g. from a shallow to a steeper decrease).

After 1972, the fatalities in France did not decrease in a strictly regular way. In 1974 (and later on in 2003), we see that the drop of the fatalities is clearly sharper than for the other years (green line in middle panel). Afterwards however, the fatalities continued in the same direction as they had before. In technical terms, such sharper *drops (or lifts) that have no effect on the rate of change afterwards* are called ***level* changes** (ref. D4.2).

Of course, the development of the number of fatalities usually does not lie exactly on a straight line. If the deviation from the line is not structural, this is considered an **irregularity**. The difference between a level change and an irregularity is that after the level change, the next observations would continue at the changed level, in contrast after an irregularity the next observations should continue at the old level.

For forecasting purposes, it is very important to determine whether a change is to be considered as a slope, as a level change or as an irregularity. Looking at the development of French fatalities, road safety analysts in 1974 could have some reasons to be very optimistic about the fatality development for the ten years to come. At that moment there was no information about whether the recent sharper decrease would turn out to be a change to the rate of change that was there to stay (i.e. a slope change), or whether this was a one-time drop (i.e. a level change). In 1974, one might have assumed that fatalities would keep decreasing as they had between 72 and 74 (see blue line in right hand panel), and consequently have forecasted less than 5000 fatalities before 1990 (a result that was in fact achieved only a quarter of a century later).

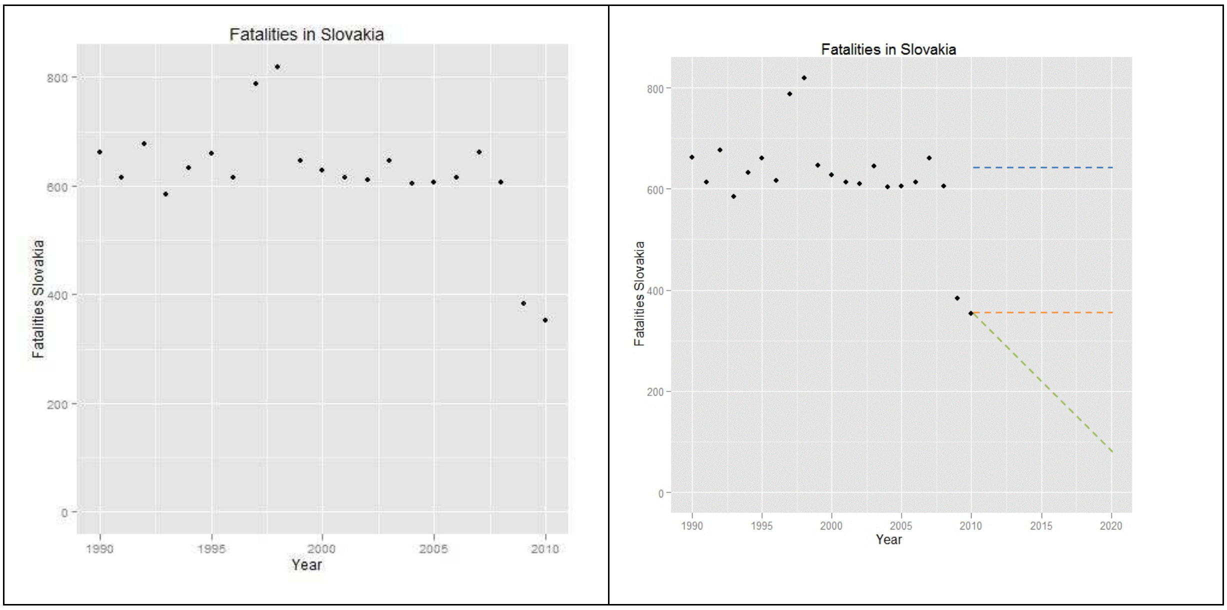

Figure 2.8: Development of road traffic fatalities in Slovakia (left) and possible forecasts on the basis of different interpretation of recent changes (right).

Another example is the much shorter series of fatalities that has been registered for Slovakia. Most of the time, the number of fatalities has been stagnating. Between 1996 and 1999 a sharp increase immediately followed a sharp decrease. This increase was consequently immediately cancelled out and is an example for a strong *irregularity*. Since 2008, a strong decrease is observable again in the number of fatalities. In this case, we have no means of determining whether this change has to be considered the result of an irregularity (similar to those in 1997 and 1998), a level change, or a slope change.

Importantly enough, the 10 year forecasts differ dramatically depending on which type of change is assumed. Under the assumption of a level change one would expect the fatality number to be higher than 600 in 2020 (blue line in left hand panel). Assuming a level change - and the return of the development to a much shallower decrease afterwards - the forecasted number for 2020 is 263 (red line). Under the assumption of a slope change however, the fatalities are expected to keep on decreasing at the rate observed between 2008 and 2010, in that case (see green line), the expected outcome for 2020 is 44 road traffic fatalities. These three numbers differ considerably. It is therefore all the more unfortunate that the interpretation of changes in the development can often be made only in hindsight.

For the present work it has obviously been tried to gain information to on the nature of the recent changes. The progress in road safety measures as well as the economic development has been taken into consideration (to the extent that it was available). However, given that the number of fatalities is a complex product of several factors, even the experts within a country often do not know what kind of change they are seing.

2.3.2. Fixing components

The aim of the models that we develop is to account for the observed developments – or trends – in the data. Depending on this, one may need to allow the slope and level to differ at each observation point or to remain constant (apart from being affected by explanatory variables). In the former case the slope and level are defined as being random (or stochastic), while they are said to be fixed or deterministic in the second case.

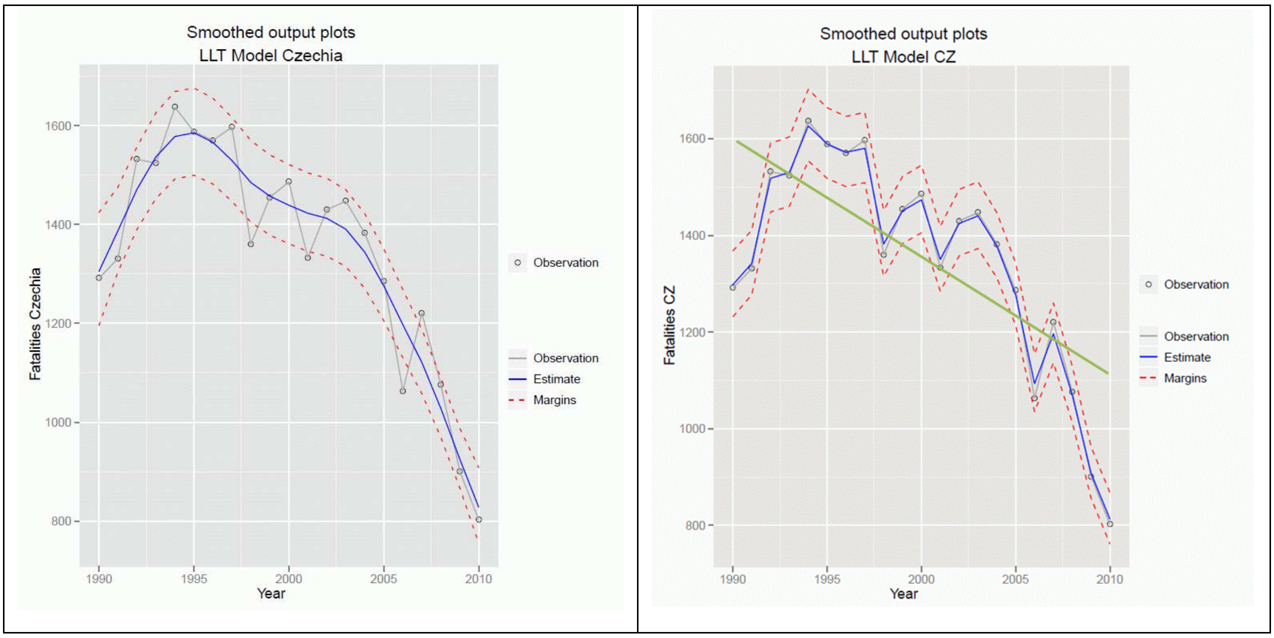

Figure 2.9: Czech Republic model of fatalities 1990 - 2010. Left: the level is fixed. Right: the slope is fixed.

In Figure 2.9, two versions of the model of the fatalities observed in the Czech Republic are presented. In the left panel the level is fixed. This means each change observed is either a change in direction or an irregular. The trend estimated by this model (the blue line) is a smooth curve, and all sharp edges are considered `irregulars´. To forecast the values for 2020, the blue line is simply continued in its final direction.

In the left panel, the slope is fixed. The green line represents the slope, i.e. the average change. For each year this average change is applied to last years' value, but we can see this alone does not come very close to the observed values (grey line and bullets). The rest of the observed changes is captured by level changes. The fixed slope and the level changes together form the trend (blue line) which is a series of lifts and drops. The trend of the fixed slope model consequently has a much more `edgie` shape than that of the smooth trend model on the left. Each lift or drop is independent of the next, changes don´t carry on to the next time points. The end of the trend is the starting point of the forecasts, but the direction is determined by the average slope value (the green line). This means the fixed slope model forecasts a much more shallow decrease than the fixed level model.

2.3.3. Interventions

Normally, the deviations from the trends, the changes in direction (slope changes) and the lifts and drops of the series (level changes) determine together the direction and the size of the confidence intervals for the forecasts. Some changes however, cannot be considered part of the process that lies at the basis of the other changes observed. If a change has to be considered a structural break, it is modeled by an intervention and is consequently not considered part of the `business as usual´ that is forecasted by the model. Such interventions can either be changes of the measurement, changes of the level or changes of the slope.

2.4. Forecasting in times of changes

Since the onset of the recession in 2008 many countries have shown a decrease in fatalities that is stronger than usual. As examples, Spain and Denmark are presented here.

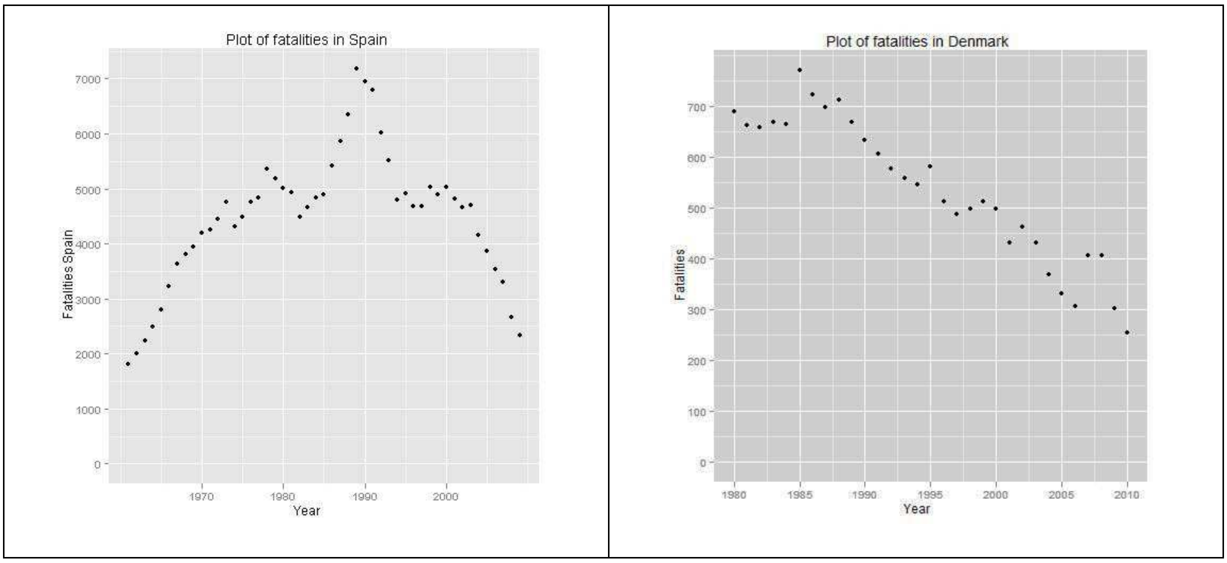

Figure 2.10: Yearly number of fatalities in Spain (left panel) and Denmark (right panel) as example for drop in fatalities after 2007.

For some countries we have good mobility indicators, and consequently we can be confident about the fact that the reduction in the number of fatalities indeed exceeds that of the number of kilometres driven. This means that, in these countries, the fatality risk has reduced with the recession. As examples, the developments of the fatality risk from the UK and from Belgium are presented in Figure 2.11.

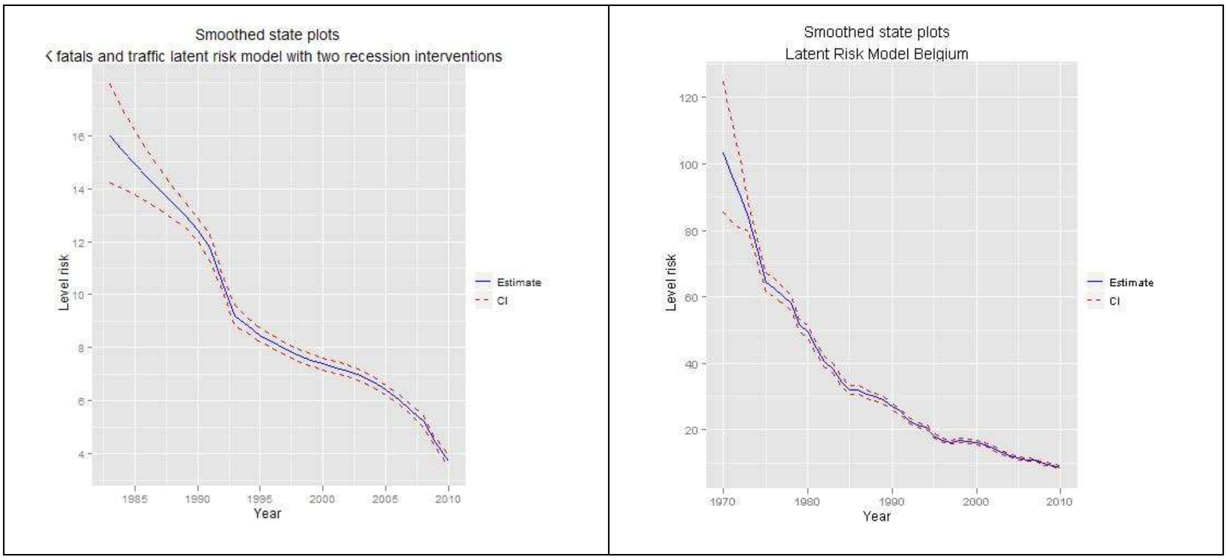

Figure 2.11: Fatality risk (fatalities/mobility) as estimated by LRT in UK (left panel) and in Belgium (right panel) to demonstrated reduction in fatality risk after 2007.

In other countries, as for example Greece, we see that the fatalities have decreased, and the risk seemingly as well, but the quality of the mobility estimator leaves some doubt as to whether the decrease of mobility due to the recession has been fully captured. In that case, it is difficult to judge whether the risk is actually reduced.

Finally, there are countries where the fatalities have been stagnating or even increasing up to 2008 and started decrease only then. The recent drop in fatalities is particularly difficult to interpret in this case because efforts to improve road safety have also considerably increased around the same time in these countries (ref. D4.6, Country overviews). This is the case for example of Romania and Bulgaria (see Figure 2.12).

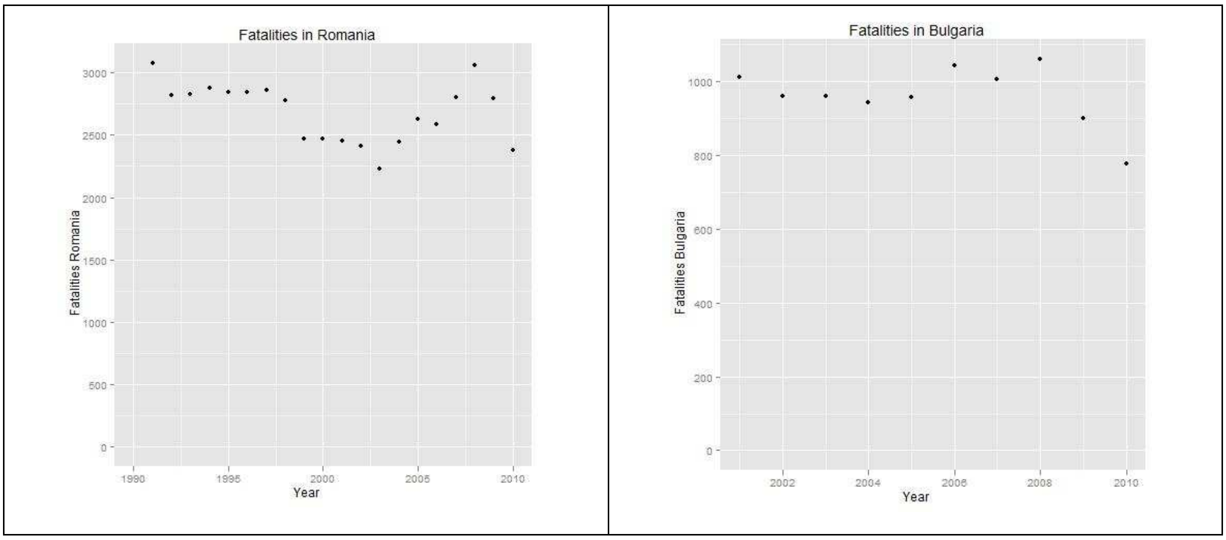

Figure 2.12: Yearly number of fatalities in Romania (left panel) and in Bulgaria (right panel).

The question is then how to deal with these decreases when forecasting the fatalities up to 2020. Below, the examples of the UK and Spain are given. In both countries, a recession took place in the early nineties during which the number of fatalities decreased strongly. Figure 2.13 shows what would have been forecasted under the assumption that the most recently observed rate of change would carry on until 2010. In both cases the fatalities for the subsequent years would have been strongly underestimated. Obviously, it would not have been wise to assume that the decreases observed in a recession time would continue afterwards.

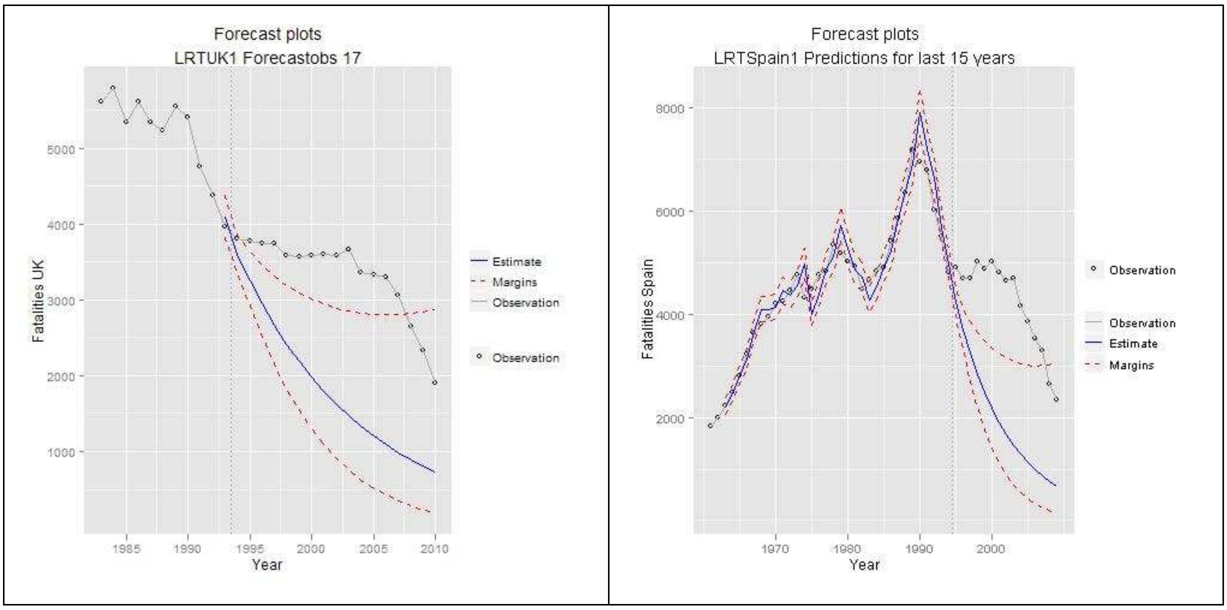

Figure 2.13: Plot comparing the model predictions (straight line) with the actual observations ("bullets") for an LRT model based on the fatalities observed up to the `mid ninety recession`. UK (left) and Spain (right). In both cases the developments during the recession form the basis for overoptimistic forecasts.

2.4.1. Possible strategies to deal with recession in forecasts

In the following, we will discuss a number of options for dealing with the recent reduction of the number of fatalities in the forecasts of fatalities up to 2020.

2.4.1.1. Doing nothing

Given that we neither know how the recession will proceed nor how it exactly affects the fatality risk, it is questionable whether specific modeling measures should be taken to compensate for the extra decrease in fatalities (and fatality risk) observed since 2008. One could simply assume that the recession is part of the `business as usual` that has led to the fatalities observed so far and that possible variations introduced by it, will contribute to the size of the confidence interval.

Pros:

1) No assumptions need to be made over the continuation of the economic situation and its effect on the number of fatalities.
2) No actual changes in the development of road safety, independent of the economic situation will be ignored (e.g. improvement in road safety management).

Cons:

1) In past recession times, this would have led to overoptimistic forecasts
2) The confidence intervals might not be taken serious enough.

2.4.1.2. Fixing the slope

A fixed slope model (see Section 2.5.3) is a conservative model. Rather than basing the direction of future developments on the most recent years, the average decrease over the whole series is used as basis to estimate the direction of the forecasted developments. This can be applied to the fatality risk in the case of a latent risk model, or to the number of fatalities in the case where the model is run without any mobility indicator.

Pros:

1) No over interpretation of short term changes at the end of the series.

Cons:

1) If there has been a real trend change (e.g. due to a reform of the road safety management system) this will have relatively little influence on the forecasts. This is especially a problem with very long series, where the influence of the last two years on the total slope of the series is negligible.
2) If the direction of the development has actually changed in the past they are inappropriately modeled by a fixed slope and the slope cannot be fixed.

2.4.1.3. Placing an intervention

The models employed in the present study allow specifying interventions (also called breaks). An intervention defines a (particularly strong) change into the model. This change is ignored for the rest. For the calculation of the confidence intervals around the forecasts, this change is considered something \`out of the ordinary\`, and not as part of the "normal variation" that is observed in the past and is also expected to occur in the future. Applying interventions to the recent drop is not a solution to the dilemma of forecasting in recession times. To the opposite, it carves the recent changes \`in stone\` while there is reasonable doubt that this would be adequate. However, such interventions can also be specified along with a "relapse", or a cancellation of the observed effect after a time to be determined.

Two questions have to be answered in this case: 1) How much of the drop in the fatalities or fatality risk should be attributed to the recession?, and 2) how long should these effects be assumed to last. For countries where earlier recession episodes with effects on the fatality risk have been observed, like in the UK, these can serve to estimate the size and length of the current recession effect. This, however, requires that the assumption is made that the current recession is similar to the previous recession episodes in terms of length and strength. Alternatively, one can work with different scenarios for different durations of the recession.

Pros:

1) Differentiating between recession effects and reductions of the fatalities due to other reasons.

Cons:

1) Only possible when data from an earlier recession episodes are available and assumed comparable.

2.5. Summary

A number of considerations that guided the analysis of the road safety developments in European countries have been described. The fatality risk, i.e. the number of fatalities per unit of mobility, plays a central role in this analysis. To investigate whether a time series model in terms of fatality *risk* is appropriate, the annual development of the fatality numbers and of the best available mobility indicator were at first analysed jointly in a preliminary analysis. Whenever a relation between fatalty numbers and the mobility indicator could be demonstrated, an analysis in terms of the fatality *risk* (the latent risk timeseries model, LRT, Bijleveld et al., 2008) was conducted. Otherwise the fatalities were analysed by themselves. Special attention was paid to the effect of recent (2008-2010) decreases in the number of fatalities and their effect on the forecasts up to 2020.

3. OVERVIEW OF FATALITY DEVELOPMENTS AND FORECASTS IN EUROPEAN COUNTRIES

This overview summarizes the main aspects of the results obtained from the analyses of road safety developments for the different countries: the relationship observed between the developments of the fatality and exposure series first, the types of models applied to capture the dynamics in the past developments of the trends modelled and, finally, the forecasted development and expected average reduction in the different countries.

3.1. Relationship between the exposure and fatality series:

In total, the results for some 30 countries are presented in this report. In 20 cases, the “most desirable” exposure indicator was available, namely vehicle kilometres. In 7 other cases, vehicle fleet was the only one available. Fuel consumption has been used as exposure indicator in the case of Cyprus. Finally, for 2 countries (Lithuania and Malta) no exposure indicator was available at all.

A relationship between the exposure and fatality series was not systematically identified, although it was more often the case when vehicle kilometres was used as exposure indicator than when other types of exposure indicators were used. Table 3.1 summarizes the different types of exposure indicators that have been used for each and every country, as well as the total number of cases where correlated series or common slopes could be observed.

It is important to mention that, in all instances where a correlation (positive) was observed between the two series, this correlation was based on the slopes (and not on the levels). The values of the slope represent the direction and strength of the change that takes place in the observations from one year to the next. The slope values for the exposure tend to be positive (i.e.: exposure is always increasing) while those for the risk are most often negative (i.e.: the risk decreases). As a consequence, the positive correlations between the two random slopes indicates that the decrease in the annual fatality numbers weakens when the increase in the annual number of vehicle kilometres becomes stronger. Often, the tests conducted revealed that the slopes of the two series were so strongly related that the random variation of their values could be considered one single, common process (“common slopes”). This was observed in 5 of the 9 cases where a relationship could be identified on the basis of vehicle kilometres (Denmark, Finland, France, the Netherlands, UK). The same observations were made in the case of Portugal and Estonia, where vehicle fleet was used as exposure indicator.

In some cases (e.g.: Hungary, Poland, Bulgaria…), the absence of a correlation between the two series can be attributed to insufficient data, short series or the quality of the exposure series, for example. In other instances however, we could not observe a relationship between the fatality and exposure series, even though the available exposure data could be considered the “best possible exposure indicator” and the series were of reasonable length (e.g: Norway, Ireland, Iceland). The length of the observation series used for each country is indicated in Table 3.2.

Exposure indicator			
Vehicle kilometres 20 countries:	Vehicle Fleet 7 countries	Fuel consumption 1 country	None available
Austria Belgium Czech Republic Denmark Finland France Germany Hungary Iceland Ireland Italy Norway Poland Romania Slovenia Spain Sweden Switzerland The Netherlands UK	Bulgaria Estonia Greece Latvia Luxembourg Portugal Slovakia	Cyprus	Lithuania Malta
5 « common slopes » 4 correlated series	2 « common slopes »	No correlation	

Table 3.1: Type of exposure indicator selected for the different countries and correlations identified between the development of the exposure and fatality series.

In all cases where a relationship between exposure and the fatality series could be evidenced, the development of the annual fatality numbers was modelled and defined as the result of the joined development of the risk and of the exposure (Latent Risk Model or LRT). Often however, we were not able to identify any significant relationship between the exposure and fatality series. In most of these cases, a univariate model (also called “Local Linear Trend” or LLT model) was applied instead of the Latent Risk model, and the development of exposure was not taken into account to forecast the fatality numbers.

3.2. Type of model applied for the different countries

The identification of a satisfactory relation between the exposure and fatality series determined the use of the latent risk model or of a univariate model to model the past developments in yearly fatality numbers. On the basis of the Latent Risk Model, two trends are actually modelled: the exposure trend, and the risk trend. When using the univariate model (also called “Local Linear Trend” or LLT model in this case), the trend for the fatality numbers is the only one to be modelled.

Various types of Latent Risk or LLT models could be selected for the different countries depending on whether the trend(s) components – the level and the slope – were defined as fixed or as varying over the years (random components). The first criterion that is used when deciding to declare the trend component as random or fixed is their variance. It is only to the extent that the variances of the components are significant that they can be defined as random.

Apart from that, other considerations also intervened in this decision. As explained in the introduction of this report, for many of the countries analysed, the last years of observations are characterised by stronger decrease in the number of fatalities (and weaker increase in the exposure). These changes seem to be related to the occurrence of the economic crisis, but we have of course no certainty with respect to this. Defining the slope as random basically amounts to acknowledging that these recent changes are part of the trend to be forecasted in the future. The stronger changes at the end of the series are thus likely to exert a particularly strong influence on the forecasted fatality numbers, wich might as a result be overly optimistic. In order to avoid this, two alternative solutions have been applied on a “case-by-case” basis to the different countries: (1) either define the changes suspected to be induced by the crisis as “exceptional” (and thus as being *no* part of the trend dynamics to be forecasted in the future), or (2) define the slope as fixed. The second solution could only be applied within reasonable limits (namely: when the variations in the past developments of the slope values were small enough to reasonably define the slope as being fixed).

Table 3.2 below provides provides an overview of the interventions that have been specified in the models selected for the different countries, along with details of the years for which these interventions have been defined and the model components that they concern (i.e.: the level or slope components of the trends and the specific trend concerned: exposure, risk, or fatality trend).

	1970-1999																													
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
AT																														
BE																														
BG																														
CY																														
CZ.																														
DK																														
EE																														
FI																														
FR																														
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IS																														
IE																														
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LT																														
LU																														
MT																														
NL					lev.																				lev.					
NO																														
PL																				lev.										
PT																					lev.									
RO																														
SK																														
SI											lev.																			
ES																														
SE																														
CH																								lev.						
UK*																						sl.	sl.	sl.						

	2000 - 2010										
	00	01	02	03	04	05	06	07	08	09	10
AT											
BE											
BG											
CY											
CZ.											
DK											
EE											
FI											
FR											
DE											
EL											
HG			lev.						lev.		
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PT											
RO									sl.		
SK											
SI				lev.							
ES											
SE											
CH											
UK*									sl.	sl.	sl.

Table 3.2 : Interventions specified in the trends modelled for the different countries (red: fatality series, green: exposure, blue: risk, orange: exposure and risk); “lev.”: level; “sl.”: slope. Grey cells indicate years that were not taken into account. Countries denoted with “*” correspond to countries for which interventions have been initroduced with the specific aim of accounting for changes presumably related to the economic crisis.

3.2.1.1. Latent Risk Models:

Below, an overview is provided of the different subtypes of LRT (Table 3.3a) that have been selected for the different countries. The most frequently selected model subtype is indicated in the yellow-coloured column.

One should be aware that the decision was made to fix the risk slope whenever common – or highly correlated – slopes were observed. On the other hand, the decision was often made to fix the risk slope because of the uncertainties related to the developments observed at the end of the series, around the occurrence of the economic crisis.

The most common subtype of LRT model is the one where the development of *exposure* is declared to be random on the basis of the *slope* (changes of direction), and that of the *risk* to be random on the basis of the *level*. For the exposure, the slope changes express the fact that the rate of change is decreasing over the years, i.e. the exposure keeps growing in most countries, but not as fast as it used to in the past. In contrast, the risk trend is characterised by drops and lifts (random variation of the level), but the general direction of the year-to-year changes in the number of fatalities per unit of exposure remains the same.

Clearly, there is no other "common" model subtype emerging for the remaining countries.

Exposure trend: level fixed, slope random **Risk trend:** Level random, *slope fixed*	**Exposure trend:** level fixed, slope random **Risk trend:** level and *slope fixed*	**Exposure trend:** level fixed, slope random **Risk trend:** level fixed, slope random	**Other models:**
Denmark France The Netherlands Spain Switzerland Norway Portugal Estonia Belgium Germany ⇒ **10/16 countries**	Cyprus	UK Italy	Austria (no component fixed) Finland (only slope risk fixed) Slovenia (only level exposure fixed)

Table 3.3: Overview of the Latent Risk Models subtypes selected for the different countries

3.2.1.2. LLT models:

Fatality trend: slope fixed	**Fatality trend:** level and slope fixed	**Fatality trend:** fixed level
Bulgaria Greece Luxembourg Lithuania Ireland Poland Sweden Latvia Slovakia **=> 9/14 countries**	Hungary Iceland Malta	Czech Republic Romania

Table 3.4: Overview of the subtypes of univariate models applied to the different countries.

Among the countries to which univariate models have been applied, the fatality trend is most often modelled wih a fixed slope and a random level (a similar trend dynamic than the one observed for the rixk trend on the basis of the LRT model thus). For three countries (Hungary, Iceland, Malta) the model selected is "fully deterministic" (all trend components are considered fixed). In other words, the development of the fatalities is defined as a straight line, with constant rate of change throughout the years. These results should be considered with particular caution. The number of observations for all three countries was small (either because the country itself is small, as in the case of Iceland and Malta, or because the number of years for which data were available was limited, as in the case of Hungary). One should bear in mind that the forecasts in such cases might well be *overly* conservative and pessimistic.

3.3. Overview of the forecasted developments:

Tables 3.5 and 3.6 offer an overview of the expected development of the fatality numbers predicted on the LRT and LLT models respectively. In each table, the countries have been sorted on the basis of the most recently observed annual fatality number, those with the largest numbers (hence, the largest countries) being presented first.

For each country, the type of slope (i.e.: either stochastic or fixed) selected for the final model is specified, along with its value. One will note that the slope value is the one estimated for the last years of observation when the slope is stochastic (and that there is consequently no single slope value for the whole series).

The forecasted annual fatality number for 2020 is also provided, along with a calculation of the average reduction (in percent) between the last number of fatalities observed and the 2020 forecast. This calculation is based on the following formula: $1 - Exp\left(\frac{Ln(2020) - Ln(LastObs)}{nyears}\right)$.

Note that this information is not provided for countries with very small number of fatalities, which do not allow sound conclusions on the developments of the fatality series (all countries that had between 199 and 8 fatalities in 2010). UK is also not included in this overview, given the uncertainty surrounding the forecasted value for 2020 related to the occurrence of unusually strong decreases in fatality numbers that took place around 2008 (see Appendix A, p. 412).

Country	***Last observation***	***Slope type***	***Slope value****	***Forecast 2020***	***Expected average reduction:***
			4000 – 3000 fatalities		
Italy	4090	Stochastic	-9	1836	7.7%
France	3994	Fixed	-4.3	2576	4.3%
Germany	3648	Fixed	-6	1973	6.0%
			2500 – 1000 fatalities		
Spain	2336	Stochastic	-7.5	438	14.1%
			999 – 500 fatalities		
Portugal	885	Fixed	-8	375	6.9%
Belgium	875	Fixed	-5.3	521	5.6%
The Netherlands	640	Fixed	-6	301	7.3%
Austria	523	Stochastic	-7	304	5.9%
			499-200 fatalities		
Switzerland	327	Fixed	-5.2	216	4.10%
Finland	272	Fixed	-5.3	180	4.04%
Norway	210	Fixed	-5	132	4.28%
Denmark	255	Fixed	-5	154	4.9%

Table 3.5: Latent Risk models – Overview of the last number of fatalities registered, slope types and values, forecasted number of fatalities for 2020 and expected average annual reduction up to 2020

Caution should be taken when comparing the results presented in Tables 3.5 and 3.6 with each other. Indeed, while of the slope values derived from LRT models represent yearly changes in the fatality *risk*, i.e., changes in the number of fatalities “purified” from the increase in exposure (billion vehicle kilometres or thousand vehicles), those obtained on the basis of the univariate models represent the annual changes in annual fatality numbers and include the influence of exposure. As a consequence, the decrease expected on the basis of the calculation of the average reduction is somewhat less important than the decrease in the fatality *risk* (see for example Austria and Portugal).

Country	Last observation	Slope type	Slope value	Forecast 2020	Expected average reduction
4000 – 3000 fatalities					
Poland	3907	Fixed	-2	3207	2.0%
2500 – 1000 fatalities					
Romania	2377	Stochastic	-15	546	13.7%
Greece	1281	Fixed	-4	898	3.5%
999 – 500 fatalities					
Czech Rep	802	Stochastic	-10.5	271	10.3%
Bulgaria	776	Fixed	-2.8	607	2.4%
Hungary	739	Fixed	-4	555	2.8%
499-200 fatalities					
Sweden	358	Fixed	-3.5	206	4.9
Slovakia	353	Fixed	-3	263	11.3%
Lithuania	300	Fixed	-9	119	8.8
Latvia	218	Stochastic	-12.5	66	11.3%
Ireland	212	Fixed	-2	180	1.6%

Table 3.6: Univariate models – Overview of the last number of fatalities registered, slope types and values, forecasted number of fatalities for 2020 and expected average annual reduction up to 2020

For both LRT and univariate models, one will notice that the fact that the slope for the risk or fatality trend is declared to be fixed or stochastic is also important. First, the predicted average reduction is more similar to the slope value when the latter is defined as fixed rather than as reandom. This is logical given that the change that is estimated to have taken place from one year to the other in the past is assumed to be fixed and thus to stay constant over the years. When past developments involve a stochastic slope however, the change taking place from one year to the other is varying, and the value presented in the table is the one estimated for the last year of the series. There is consequently less convergence with the average percent reduction calculated for the future developments. The difference should nevertheless not be too important, as can be seen on the basis of Figure 3.1.

Figure 3.1 shows that the expected average reduction is much larger when the forecasted number (2020) is based on a stochastic rather than on a fixed slope. One should bear in mind that for many countries, the series were characterised by sudden drops in the fatality numbers in the recent years, and that these recent years exert a stronger influence on the forecasts (and, hence on the calculated average reduction) when the trend modelled is based on a stochastic rather than on a fixed slope. As explained earlier, these recent changes are difficult to account for. Given the absence of information allowing a reliable interpretation of these sudden changes (economic crisis…), we have no guarantee that the decrease in fatality numbers will go on with such a strength in the future.

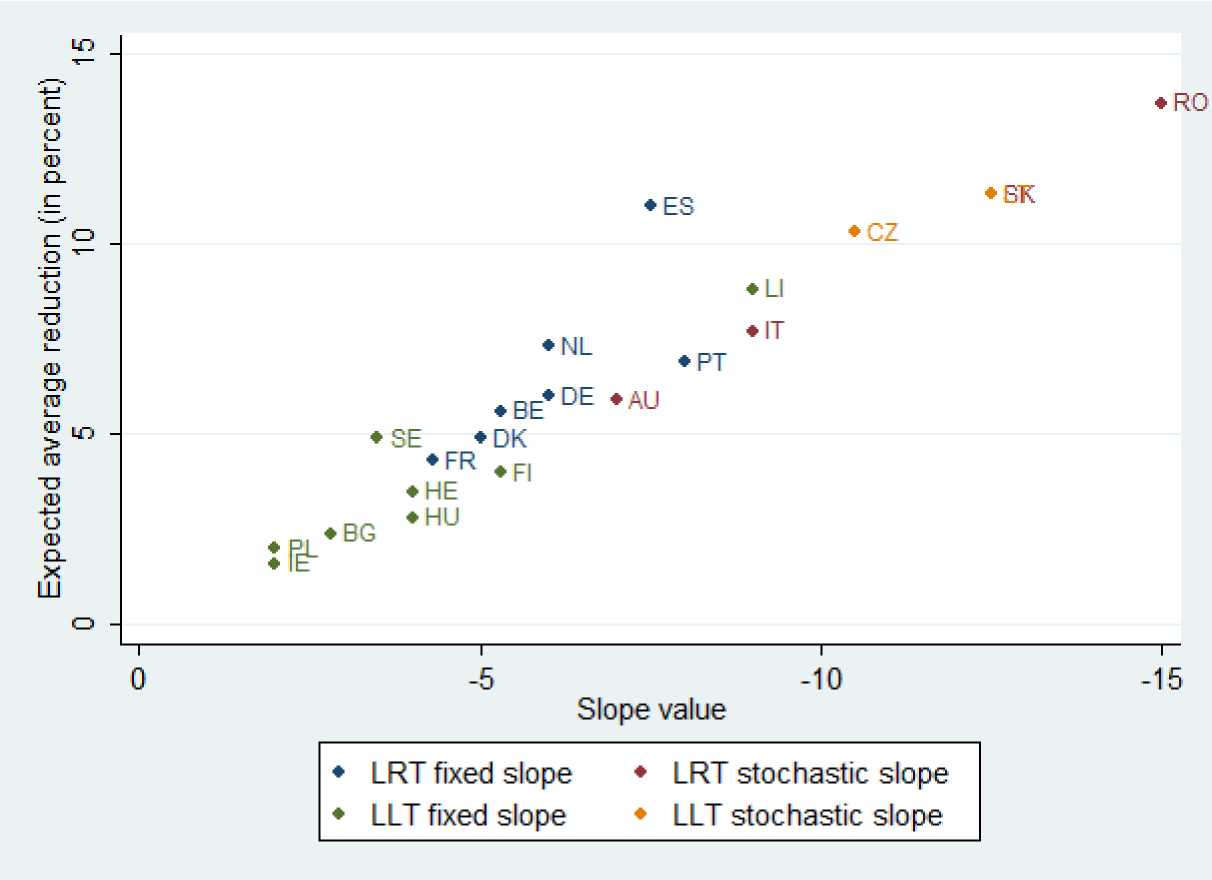

Figure 3.1: Plot of the expected average reduction against the slope values for the various countries.

3.4. Country-comparisons based on the expected average reduction

It is sensible to compare the average reduction in the number of fatalities expected for the different countries, but only to the extent that this is done separately for different modelling techniques (i.e.: Latent Risk vs. Univariate models) and separately for fixed and random slopes models. Hence, the presentation adopted in Figure 3.2 where the expected annual average change is presented apart for the LRT and univariate models based on fixed and random slopes.

Figure 3.2 also illustrates the fact that average reductions calculated from random slopes models are generally higher than those calculated on the basis of fixed slopes models. The expected average reduction calculated from univariate models with fixed slopes varies from 1.6 to 4.9%, with the exception of Lithuania for which a very large decrease (8.8%) is expected. Univariate models with random slopes have been applied to the Czech Republic and Latvia, where 10.3 and 11.3% annual reductions in fatality numbers are expected.

For the Latent Risk models with fixed slope, the average reductions expected vary from 4.3 (France) to 7.3 (the Netherlands). The average reduction expected for Spain is exceptionally high: 11%. Two subgroups are immediately visible among countries to which Latent Risk models with random slopes have been applied: the first one having clearly lower average expected reductions (5.9 and 7.7% for Austria and Italy respectively) than the other (11.3 and 13.7% for Slovakia and Romania respectively).

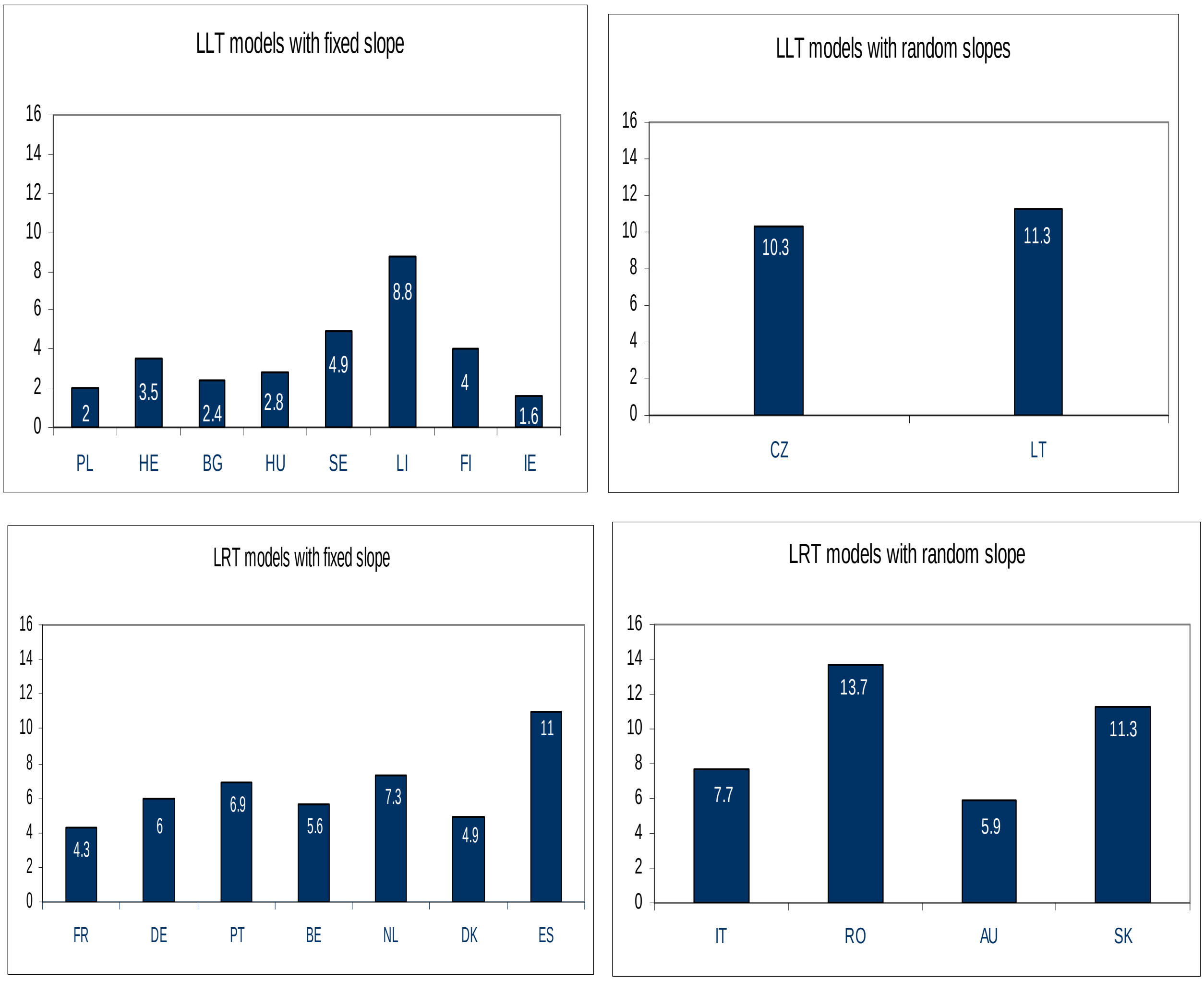

Figure 3.2: Expected average annual reduction (in percent) calculated from univariate models with fixed slope (upper, left-hand graph), from univariate models with fixed slope (upper, right-hand graph), from Latent Risk models with fixed slope (lower, left-hand graph), and from LRT models with random slopes (lower, left-hand graph)

4. CONCLUSION

The Latent Risk Time Series Model is a recent and very promising framework to model road safety fatalities. So far, it had only been applied to single countries (Stipdonk et al, 2008, Bijleveld et al., 2008). The present work is the first large scale field trial to modelling road safety fatalities in terms of fatality risk and exposure to that risk.

A comprehensive analytical framework has been developed and systematically applied to all European countries. For each of them, the fatality and exposure data were carefully screened and the assumptions on which the fatality risk concept lies (relation between exposure and fatality series, quality of the exposure data…) have been tested. The LRT was then applied to those countries for which these assumptions hold.

In a number of countries, the main assumption of the risk conception – a relation between fatalities and mobility could not be observed. For countries in which the exposure measure gives an appropriate reflection of the mobility, the use of the LRT model is not generally a problem but it does not add any information to modelling the road safety fatalities in a more traditional approach, e.g., the Latent Linear Trend model (LLT, Commandeur & Koopman). I some countries, however, the exposure measure might not show a relation with the number of fatalities because it gives a distorted reflection of the country´s mobility. In those latter cases, the use of the LRT model would be misleading. In the present work, in both cases, the fatalities were modelled by the LLT model.

For each country the road safety development of the last 10 to 50 years (depending on the available data and the continuity of the general political situation) has been described, the best exposure measure was identified and the development of the mobility described. The most appropriate model to capture both evolutions was identified. Finally, forecasts to 2020 were derived from that model.

The results are presented in two versions: the full report and the factsheet.

The full report is a comprehensive description of the analytical process. It provides the details of different possible time series models, the criteria for the selection of the most appropriate model and the forecasts derived from it. This is a rather technical report meant to support the future evaluation and up-date of the forecasts, even when conducted by a different party.

The forecast fact sheet gives a quick overview of the most important features of the development of fatalities and mobility. Whenever applicable, it also describes where the development of the fatality risk (i.e. fatalities per unit of mobility) differs from that of the pure fatalities. The forecasts for 2020 are provided and, if appropriate, three scenarios based on three different assumptions concerning the future mobility development are used as a basis to produce alternative forecasts.

This dual presentation allows the experts to understand the background of the forecasts, reproduce the analyses, adjust them to account for changing conditions and/or additional information while at the same time making the core results available to decision makers and the larger public to serve for the interpretation and evaluation of the developments in the future years.

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APPENDIX A: COUNTRY FORECASTS 2020 – FULL REPORTS

Analysis framework

For each country the road safety development of the last 10 to 50 years (depending on the available data and the continuity of the general political situation) was analysed. A description of the fatalities and - whenever available - of the mobility indicator formed the starting point for the analysis. Each country was analysed according to the following framework, based on the considerations described in Chapter 2.

The SUTSE model

In the SUTSE model, the yearly numbers of fatalities and the best available mobility indicator are analysed jointly to determine whether there is a relation between the two variables. The correlation between the two levels and between the two slopes was tested. Moreover a version of the model was run where the relation between both variables was estimated by a coefficient (beta). If one of the correlations or the estimated coefficient was significant, it was assumed that fatalities and mobility were related and a Latent Risk Analysis (LRT model) was the next step.

Apart from the usual test whether the correlations differed significantly from zero, it was also tested whether they differed significantly from 1. If they did not, fatalities and exposure are assumed to be highly related and in the latent risk analysis the slope of the risk was fixed.

If none of the correlations or the estimated coefficient differed significantly from zero, it was assumed that fatalities and the mobility measure are unrelated. The mobility measure was consequently not used to forecast the number of fatalities. The fatalities were forecasted in latent linear trend model (LLT model).

The results of the SUTSE analysis also indicated how the trend for the latent risk should be modeled in subsequent analyses. As noted above, a very strong correlation between fatalities and mobility suggests that the slope of the fatality risk is a constant. This means that the fatality risk decreases at a *fixed, continuous rate* throughout the series. Consequently, deviations of the observed fatality risk (i.e. fatalities / mobility) from that trend for a particular year should be interpreted as a level change, but not as a change in direction (slope changes). Thus, whenever the “strong correlation” case of figure was indicated on the basis of the SUTSE analysis, the slope for the fatality risk was defined as “fixed” for all subsequent latent risk analysis. In technical terms, we call this a *fixed slope model* (see Section 2.5.3).

Interventions

Normally, the deviations from the trends, the changes in direction (slope changes) and the lifts and drops of the series (level changes) determine together the direction and the size of the confidence intervals for the forecasts. Some changes however, cannot be considered part of the process that lies at the basis of the other changes observed. If a change has to be considered a structural break, it is modeled by an intervention and is consequently not considered part of the `business as usual´ that is forecasted by the model. Such interventions can either be changes of the measurement, changes of the level or changes of the slope.

1) Changes of the measurement cause a change in the registered number of fatalities or in the registered mobility without an actual change to fatalities or mobility respectively. Examples are a change in the registration procedure or cleaning of the vehicle database. This is modeled by an intervention in the measurement equation.

2) Changes in the level of either the fatality risk or the mobility can be modeled by a level intervention. The classic example for a level intervention on road risk was the seat-belt law in 1981 in Great Britain, that lead to a sharp drop in the number of fatalities and consequently in fatality risk.

3) Changes in the direction of change for either the fatality (risk) or mobility can be modeled by an intervention on the slope. It should be considered carefully though, whether a change of direction should really be interpreted as a structural break that is not part of the dynamics that have to be forecasted. In practice slope interventions are rare.

Fixing components

In the latent risk model (LRT) the development of the fatalities and the mobility is analysed in terms of four types of changes: level changes and slope changes to the fatality risk, and level changes and slope changes to mobility. However, not all types of changes actually occur in each series. Moreover, especially for short series, changes can often be considered as either level or slope changes.

When the variations for a particular type of change are not significant this type of change can be excluded from the model. In technical terms, this is called *fixing a component*. By fixing a particular component (e.g. fixing the risk slope), one forces the model to attribute all changes to the other type of change. For example, in a model with a fixed risk slope, the general direction of the risk trend cannot change. It is determined on the basis of all years in the analysis. All deviations from this trend are considered lifts or drops in the level rather than permanent changes in direction. The forecasts are consequently based on the average direction across all years.

When the level is fixed all changes are interpreted as changes in direction. In practice this means that abrupt changes are smoothed, because the change of one year is supposed to carry on in the next year. The forecasts of such a smooth trend model is mostly based on the last observed direction.

For the forecast it can make a big difference which component is fixed. The risk slope was fixed when the fatalities were highly related in the SUTSE model (see Section 2.5.1). In all other cases the decision for fixing components were based on

1) Significance of the components (fixing only non-significant components)

2) Model quality. When fixing a component lead to the violation of one of the model assumption (see Martensen & Dupont, 2010 for more details) this was reversed.

3) Prediction quality. If none of the components was significant, usually either the level or the slope could be fixed. In this case the prediction quality of the model in the past was considered. The data up to 2000 (or 2003, or 2007) were used to predict the remaining years up to 2010. The model with the smallest prediction errors was selected.

When the data gave no clear indications as to what kind of changes have occurred, the slope of the fatality risk was fixed, because fixed slope models are more conservative and were preferred in these times of (sometimes dramatic) change.

The latent linear trend model (LLT) for fatalities, which was run when there was no mobility measure that was related to the fatalities, has just two components: level (fatalities) and risk (fatalities). Fixing either of these two components proceeded according to the same principles as described above.

Reporting structure

Each country report follows the outline below:

- Raw data
  - *Exposure*
  - *Fatalities*
- SUTSE model
  - *SUTSE model: development of the state components*
  - *Relation between the exposure and fatality series*
- The LRT Model / LLT Model
  - *Model selection*
  - *Development of the state components*
  - *Quality of the predictions*
- Forecasts 2011 - 2020
- Scenarios (only for LRT)

AUSTRIA

1. Raw data

1.1 Exposure

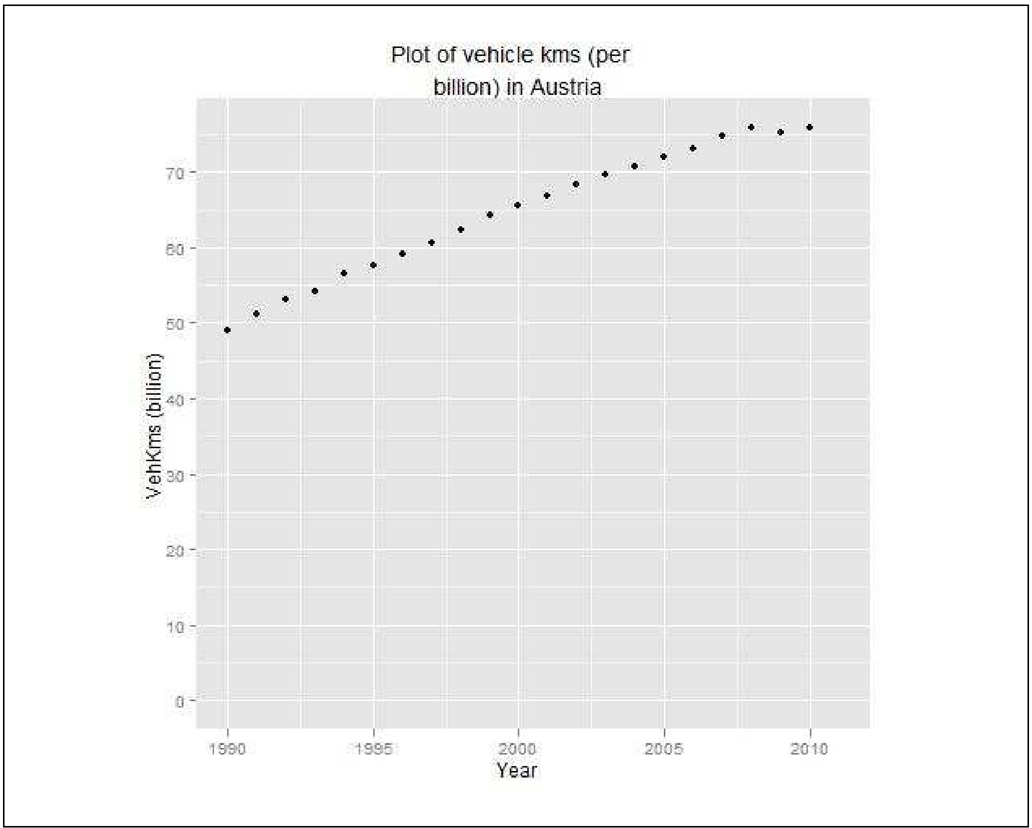

Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for Austria from 1990 to 2010

The vehicle kilometres are estimated on the basis of various sources, notably fuel consumption calibrated with data from different traffic counts (census or microcensus) and vehicle fleet[1]. From 1990 up to 2008 the increase has been almost linear. The number of vehicle kilometres has been stagnating in 2009 and 2010.

1.2 Fatalities:

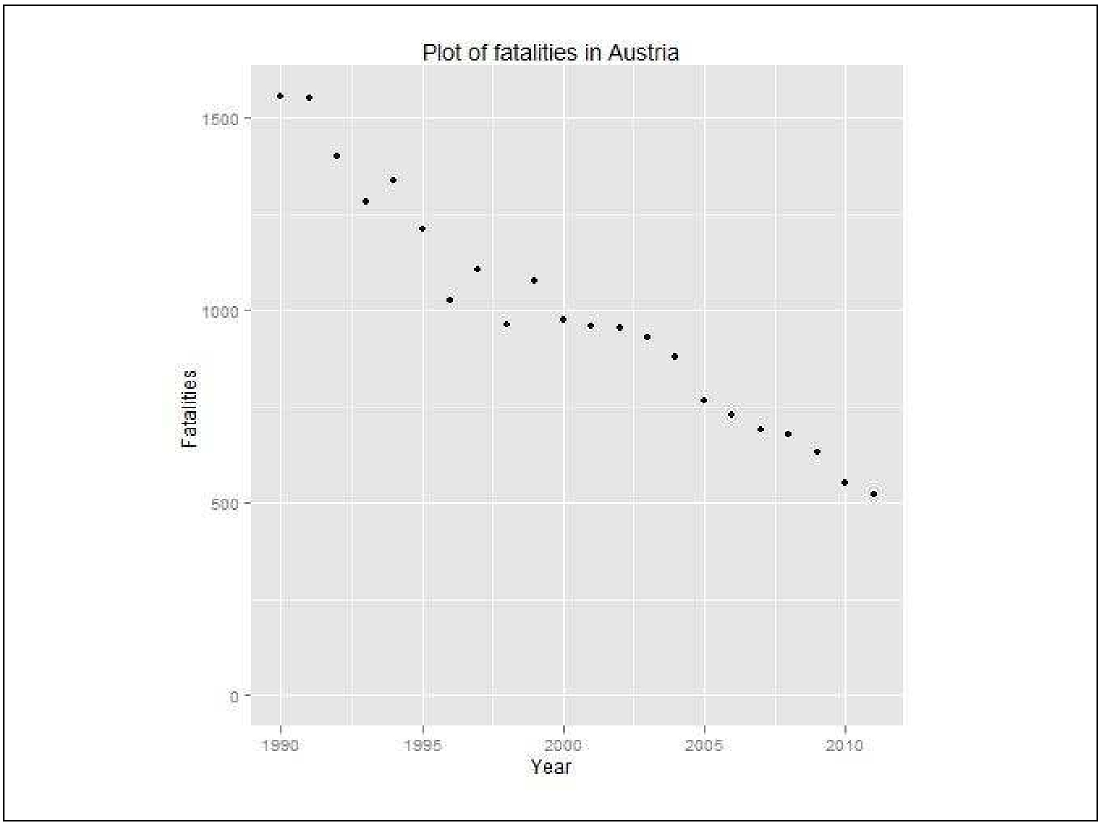

Figure 2 : Plot of the annual fatality counts for Austria from 1990 to 2011

The raw series for the fatalities has continuously decreased between 1990 and 2011. The number of fatalities observed at the end of the series (679) is 3.79 times lower than the starting value (2574). One can note that the variation of the fatality counts over the year is much larger than that of the vehicle kilometres.

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[1] Anderl M., Köther T., Pazdernik K., et al:AUSTRIA´S ANNUAL AIR EMISSION INVENTORY 1990-2010. Submission under National Emission Ceilings Directive 2001/81/EC. Wien, 2011.

2. The SUTSE Model:

2.1 Development of the state components[2]:

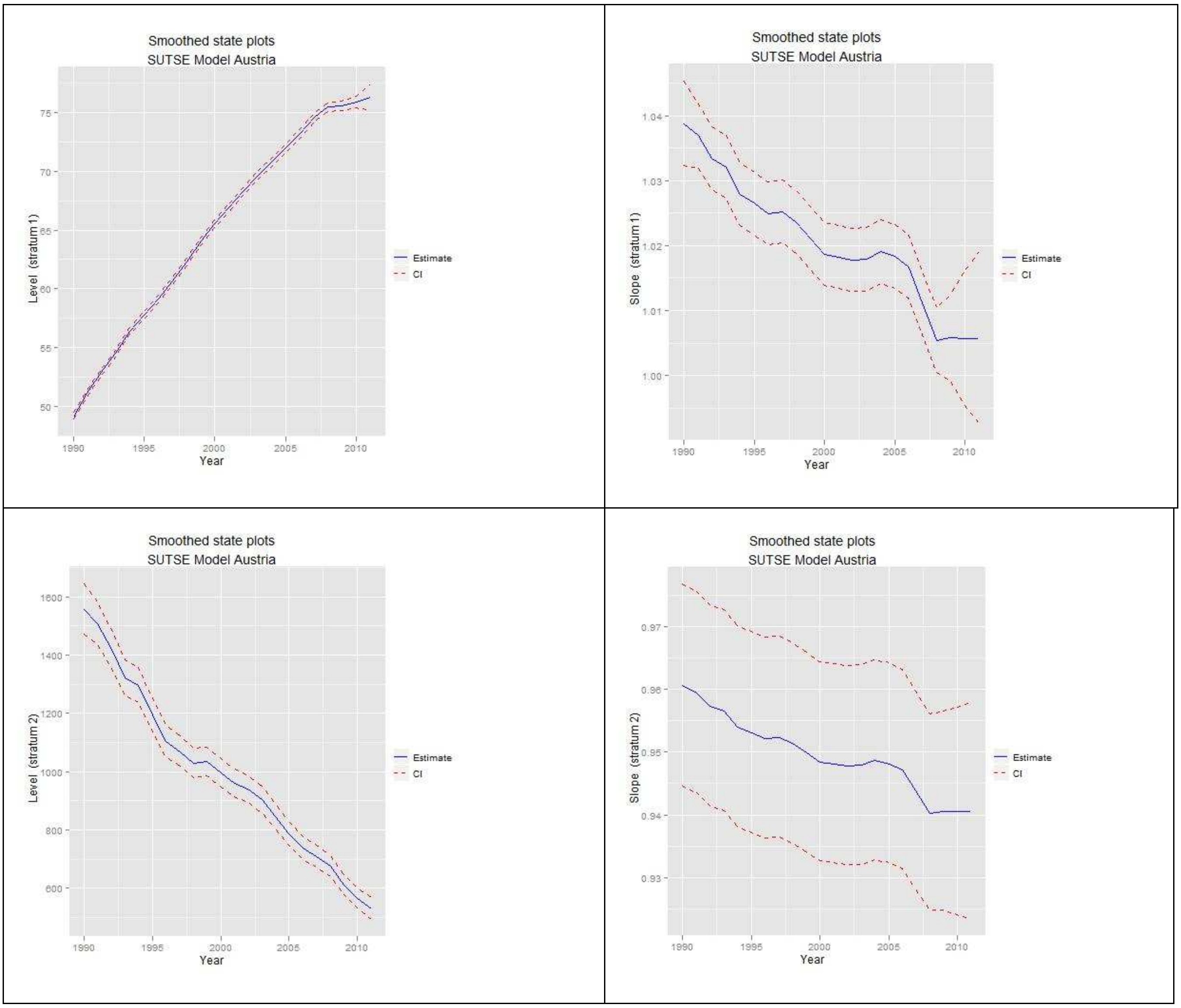


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the right-hand graphs, the slope developments in the left-hand graphs.

[2] Given that annual fatality numbers are available up to 2011 but vehicle kilometres are available until 2010 only, the vehicle kilometre value for 2011 has been defined as “not available” and estimated from the model.

2.1.1 Exposure

The trend for exposure is estimated around 49 billion kilometres at the start of the series and around 76 billion kilometres at the end. The trend increases smoothly, in a seemingly linear way.

The various values taken by the slope over the series are plotted in the upper right part of Figure 3. Each slope value indicates the percent change in the vehicle kilometres that took place from one year to the other. All these values exceed 1, which means that the number of vehicle kilometres has systematically increased from one year to the other. The “size” of these annual increases, however, varies over the years: While at the start of the series the increase was around 4 %, it became less strong with the years to eventually oscillate between 0 and 1% in the last years.

For exposure, the slope component is the only one to vary significantly over time.

2.1.2 Fatalities

Around 1500 fatalities have been registered in Austria in 1990. In 2011, there were around 500, so one third less. The trend has been declining steadily and rapidly.

All slope values are smaller than 1, which indicates a decrease of the annual fatality numbers over the whole series. The size of the slope values have also been decreasing throughout the series, which means that the decrease in the annual fatality numbers accelerated with the years (from a 4% annual change in 1990 to around 5 and 6% in 2011). This variation in the values of the slope of the fatalities is not significant, however. Actually, no state component is varies significantly as far as the fatality series is concerned..

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components:

The disturbances of the exposure slope are the only that can be considered stochastic. The other components do not vary significantly over time. The two series can therefore not be considered to be related on the basis of their stochastic components. Hence, none of the covariance tests for the levels and the slope are significant.

2.2.2 Correlation between the irregulars:

The correlation between the irregulars is also non significant.

2.2.3 Estimation of the relationship by means of a coefficient:

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). The beta coefficient for the relationship between the latent developments of the two series is equal to 0.85 and is not significant (p=0.35). As a consequence, the two series cannot be considered to be related

Model title	***SUTSEAustria***	***SUTSEbetaAustria***
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	97.41	97.10
AIC	-193.99	-193.48
Hyperparameters		
Level exposure	1.26E-05 nsc	8.82E-21 ns
Level risk	1.37E-03 nsc	9.74E-04 ns
Slope exposure	1.68E-05 *c	1.73E-05 *
Slope risk	7.13E-06 nsc	5.63E-24 ns
Correlations		
level-level	-1	
slope-slope	1	
Observation variances		
Observation variance exposure	1.23E-05 ns	1.78E-05 ns
Observation variance risk	6.51E-04 ns	8.90E-04 ns
Beta	/	1.04 ns

Table 1: Model criteria and results for SUTSE models- Austria

3. The LRT Model:

3.1 Model selection:

No relationship could be identified between exposure and fatalities on the basis of the data at hand. Yet, the series used here is rather short (starts in 1990 only), so that it is difficult to decide with certainty whether the two series are actually unrelated. As a consequence, both LLT and LRT models have been fit to these data. The two types of model could thus be compared on the ground of their ability to correctly predict past observations for the fatalities. In addition to the LLT model, 3 versions of the LRT model were run: one where all hyperparmeters are estimated, one with fixed slope for risk, and finally one with both the exposure level and the slope for risk fixed.

The LLT and LRT models cannot be compared on the basis of the log-likelihood values or Akaike criterion. The two types of models satisfy the residual assumption (independence, homoscedasticity and normality) equally well. The full LRT model seems better able than the LLT to predict past observations for the annual fatality numbers. Further inspection (see section 3.3) reveals that each type of model “misses” part of the observations in a different way: the LLT tend to underestimate fatality numbers from 1999 to 2004, while the LRT model adequately predicts this part of the series but tends to underestimate the fatality numbers from 2004 up to 2011. The two other versions of the LRT model (with a fixed slope for risk or with a fixed slope for risk and fixed exposure level) are clearly less able to adequately predict the fatality numbers than either the LLT or full LRT models. As a consequence, the full LRT model will be selected as a basis to calculate the forecasts presented below.

Model title	**LLTAustria**	**LRT Austria1**	**LRT Austria2**	**LRT Austria3**
Model description	LLT model for fatalities in Austria	LRT model for Austria - Full model	LRT model for Austria - Risk slope fixed	LRT model for Austria – Level exposure and risk slope fixed
Model Criteria				
ME10 Exposure		-3.12	-2.99	-3.20
MSE10 Exposure		15.76	14.52	16.46
ME10 Fatalities	14.20	0.70	50.47	56.42
MSE10 Fatalities	2715.47	2733.77	3939.78	4591.77
Log-likelihood	28.96	97.41	97.34	97.09
AIC	-57.65	-193.99	-194.05	-193.73

Model Quality

Box-Ljung test 1 Exposure		0.21	0.20	0.00
Box-Ljung test 2 Exposure		0.21	0.21	0.12
Box-Ljung test 3 Exposure		0.65	0.65	0.21
Box-Ljung test 1 Fatalities	0.64	0.40	0.47	0.34
Box-Ljung test 2 Fatalities	0.70	0.41	0.47	0.34
Box-Ljung test 3 Fatalities	0.72	1.35	1.47	1.17
Heteroscedasticity Test Exposure		1.31	1.29	1.28
Heteroscedasticity Test Fatalities	0.98	0.33	0.27	0.36
Normality Test standard Residuals Exposure		4.78	4.54	3.67
Normality Test standard Residuals Fatalities	0.13	1.37	1.27	0.91
Normality Test output Aux Res Exposure		0.33	0.32	0.39
Normality Test output Aux Res Fatalities	1.26	1.50	1.71	2.69
Normality Test State Aux Res Level exposure		6.04*	5.82	4.42
Normality Test State Aux Res Slope exposure		0.18	0.16	0.14
Normality Test State Aux Res Level risk	0.26	0.88	0.83	0.82
Normality Test State Aux Res Slope risk	0.06	0.38	0.27	0.39

Variance of state components

Level exposure		1.26E-05 nsc	1.03E-05 nsc	-
Level risk	3.76E-03 *	1.12E-03 nsc	1.18E-03 *c	9.92E-04 *
Slope exposure		1.68E-05 *c	1.76E-05 *	1.75E-05 *
Slope risk	8.68E-19 ns	2.03E-06 nsc	-	-

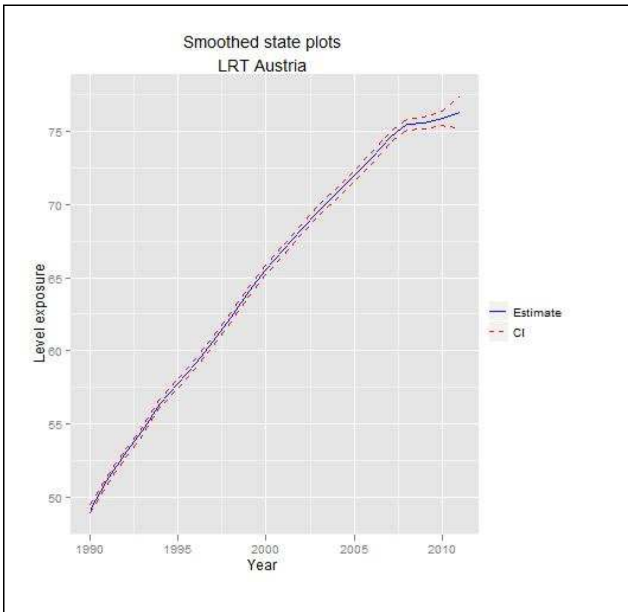
Correlations between state components

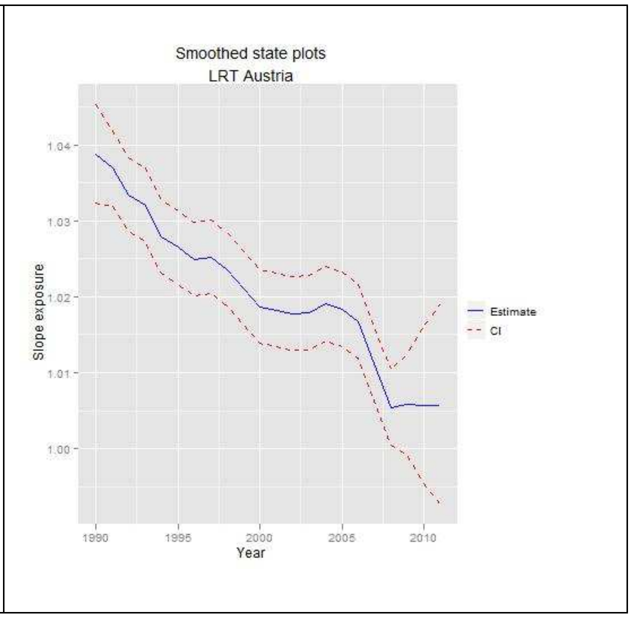
level-level		1.00	1.00	

slope-slope		-1.00		
Observation variance				
Observation variance exposure		1.23E-05 ns	1.30E-05 ns	1.77E-05 *
Observation variance risk	1.00E-09 ns	6.51E-04 ns	6.45E-04 ns	8.78E-04 ns
Interventions				

Table 2: Overview of the results for the LLT and LRT models - Austria.

3.2 Development of the state components:





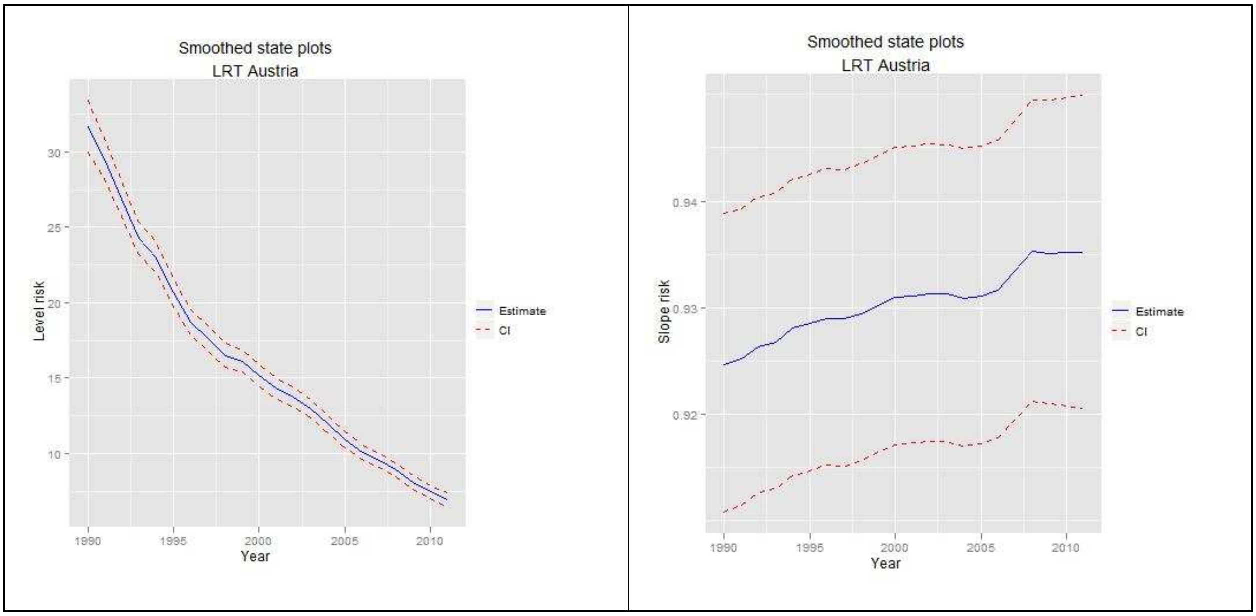


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure:

Only the slope component varies significantly over time for the exposure series.

The various values taken by the slope over the series are plotted in the upper right part of Figure 4. Each slope value indicates the percent change in the vehicle kilometres that has taken place from one year to the other.

All these values exceed 1, which means that the number of vehicle kilometres has systematically increased from one year to the other. The “size” of these annual increases, however, obviously decreases over the years. This means that the annual increase in the number of vehicle kilometres has weakened over the years (from 4% to 0.5% annual increase).

The trend (level) for exposure is estimated around 49 billion kilometres at the start of the series and around 76 billion kilometres at the end. The trend increases smoothly, in a linear way.

3.2.2 Risk:

Contrary to the exposure series, none of the state component for the risk can be considered to vary significantly over time.

The trend starts around 32 fatalities per billion vehicle kilometres to end at around 3 fatalities per billion vehicle kilometres in 2011. In other words, the risk estimated for 2011 is about 10 times less as it was in 1990. The plot of the development of the slope values over the years is almost flat. The slope values correspond to a general annual decrease of the risk of about 7%.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2011. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series.

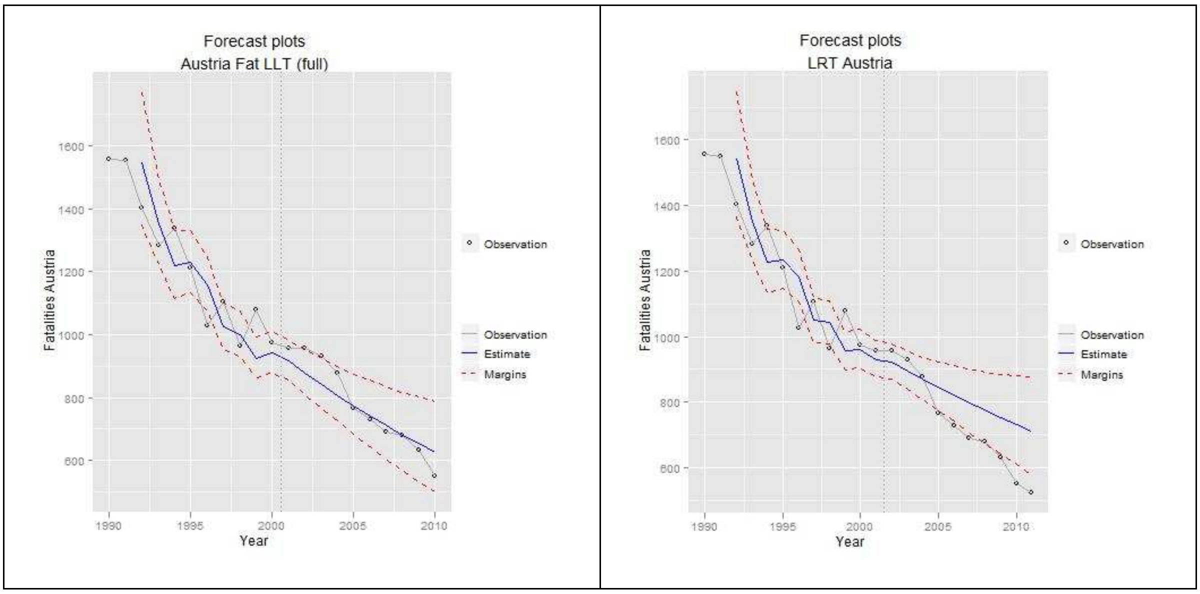


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Austria for the LLT model (left-hand graph) and for the full LRT model (right-hand graph).

As noted above, neither the LLT nor the LRT model are able to perfectly predict past observations: While the LLT underestimate them in the period 1999-2004, the LRT overestimate them for the subsequent 2004 – 2011 period.

4. Forecasts 2010 – 2020:

The forecasts obtained from the model provide an indication of the vehicle kilometres and fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.* Under this assumption, the annual number of vehicle kilometres should increase up to 80 billion in 2020.

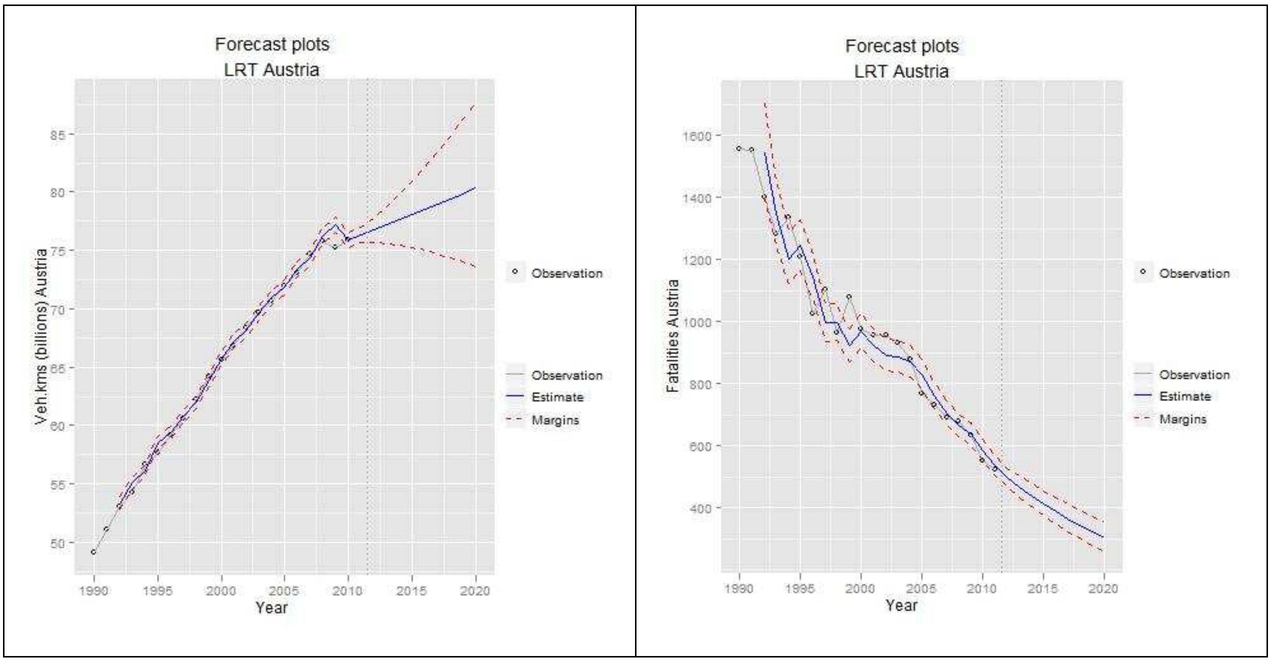


Figure 6: Plot of the vehicle kilometres (left-hand graph) and annual fatality numbers (right-hand graph) for Austria forecasted between 2011 and 2020 (LRT Austria1).

Still assuming that past developments will extend into the future, the fatality numbers for Austria should keep on decreasing after 2011 (although at a lower rate than between 1970 and 1990). The predicted value for 2020 is 304 fatalities. Table 3 provides the details of the values forecasted for exposure and fatalities for all years from 2011 up to 2020.

	Vehicle kilometres (billion)				Fatalities		
Year	Predicted	Confidence Interval		Year	Predicted	Confidence Interval	
2012	**77**	75	79	2012	**497**	442	559
2013	**77**	74	80	2013	**468**	405	540
2014	**78**	73	82	2014	**440**	372	520
2015	**78**	73	84	2015	**414**	342	501
2016	**79**	72	86	2016	**389**	314	482
2017	**79**	71	88	2017	**366**	289	463
2018	**79**	70	90	2018	**344**	266	446
2019	**80**	69	93	2019	**324**	244	429
2020	**80**	68	96	2020	**304**	225	412

Table 3: Forecasts of the Latent Risk Model (LRT Austria1)

5 Mobility Scenarios

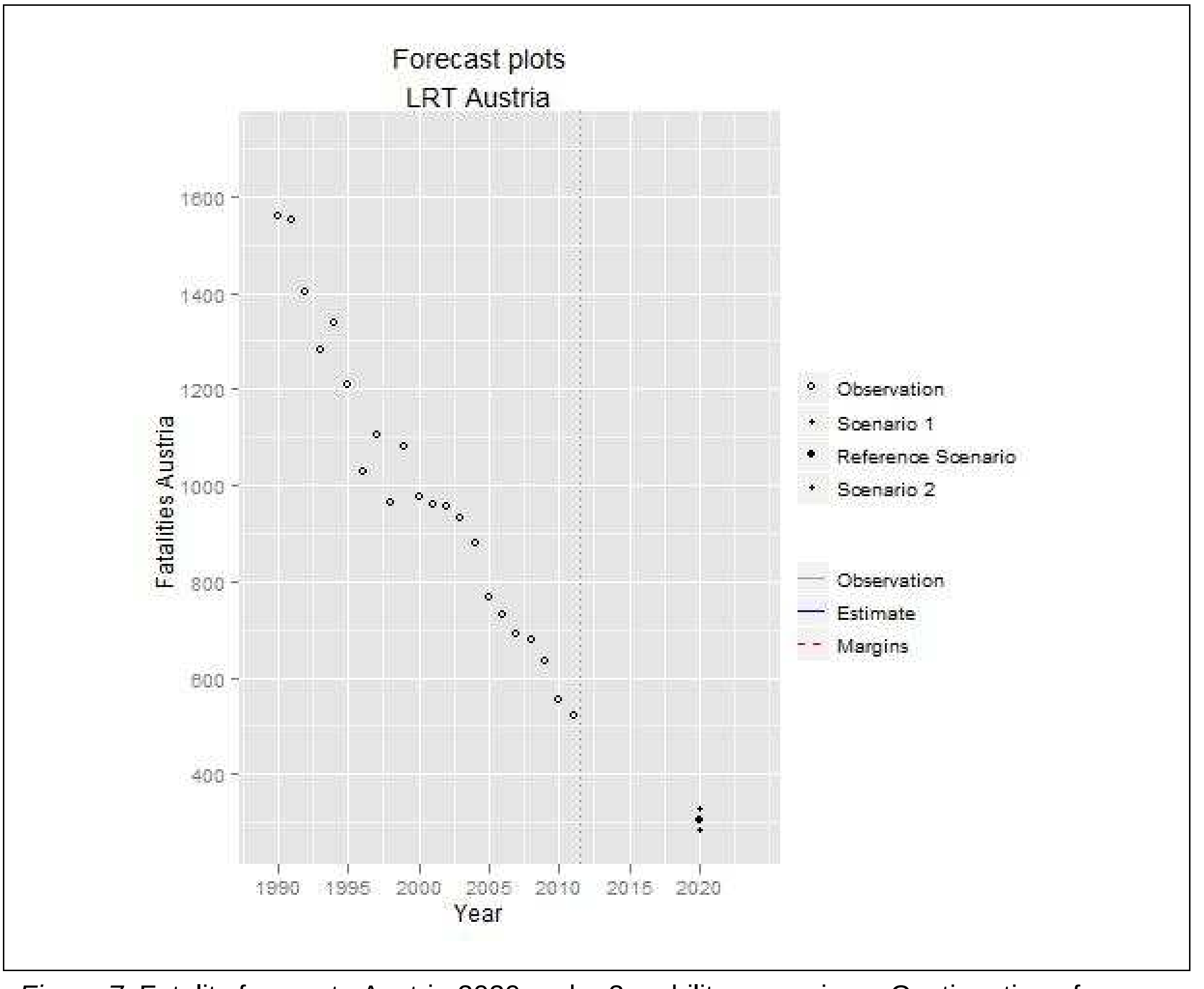


Figure 7: Fatality forecasts Austria 2020 under 3 mobility scenarios. ●Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

Given the large uncertainty around the development of the vehicle kilometres, it is informative to look at predictions for the fatalities *assuming that we now for certain the vehicle kilometres values in 2020.* To do that, we calculate three scenarios for the development of exposure, which correspond to the number of vehicle kilometres predicted by the model for that year, plus/minus one standard deviation[3]. The values for the exposure scenarios and the estimated number of fatalities under each of them are provided in Table 4, and plotted in Figure 7.

The predicted number of vehicle kilometres for 2020 is 81 billion, a scenario under which one would expect 286 fatalities, and which is represented by a full dot in Figure 7. The smaller dots in this figure represent the estimated fatality numbers assuming an increase (forecast plus one standard deviation: 89 billion), or a decrease (forecast minus one standard deviation: 73 billion) in the number of vehicle kilometres. The fatality numbers estimated for each scenario are detailed in Table 4.

	Vehicle kilometres (billions)	Fatalities
Situation 2011:	76	523
Prediction for 2020 according to mobility scenarios:		
- Continuation of development	80	304
- Stronger growth	88	327
- Lower growth	74	283

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRTAustria1). Mobility scenarios are based on predicted value +/- one standard deviation.

[3] The upper and lower scenarios now include 68% of the cases, assuming a normal distribution.

BELGIUM

1. Raw data

1.1 Exposure

The selected exposure measure are the vehicle kilometres (in billions) per annum (see Figure 1), which are considered from 1975 onwards.

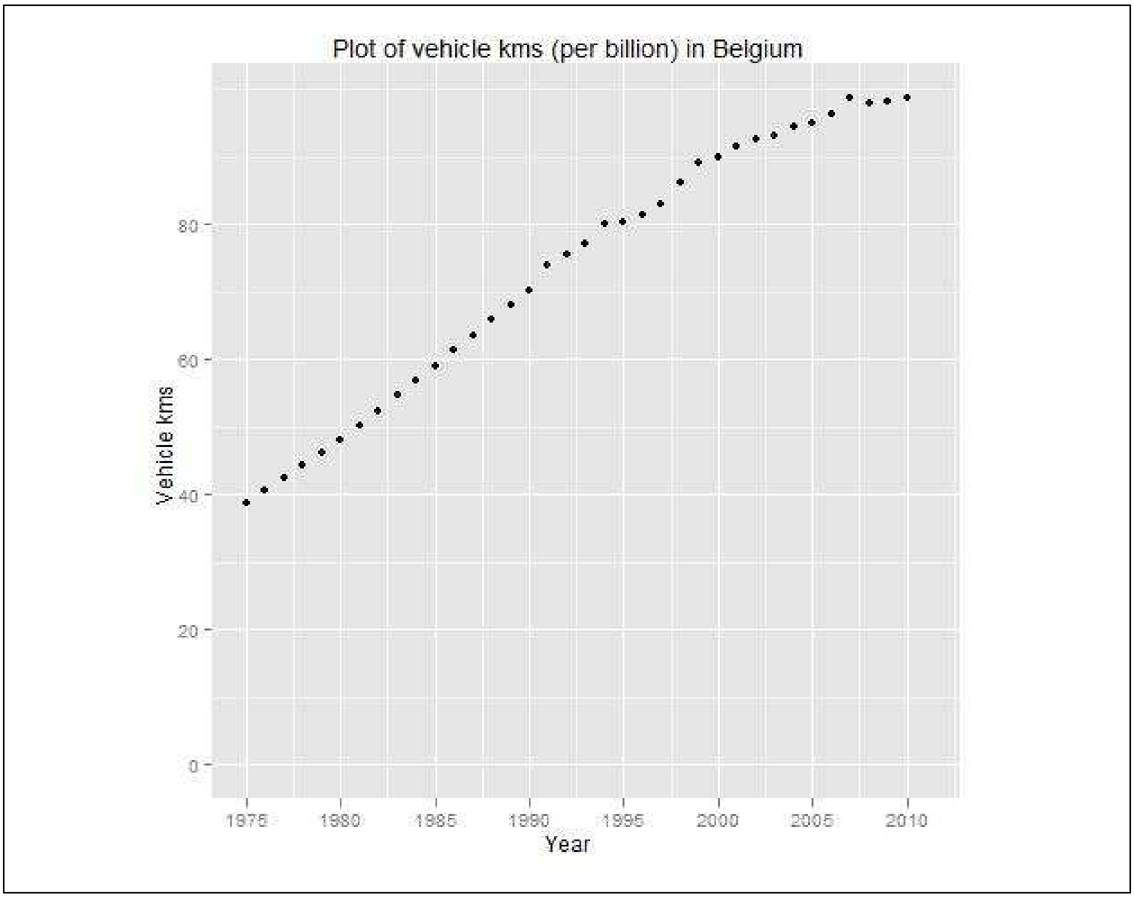


Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for Belgium from 1975 to 2010

Between 1970 and 1980 (here plotted from 1970 on) the vehicle kilometers show a constant increase of 18.6 billion per year and between 1980 and 1990 a constant increase of 22.3 billion per year. From 1990 on the increase varies from one year to the next. This pattern suggests that the vehicle kilometers were actually measured in 1970, 1980 and from 1990 on each year. The missing years in the first half of the series have probably been interpolated. To model these data, it is decided to discard the interpolated values from the series. The time series model interpolates these values by itself taking into account the uncertainty, as these do not result from truly observed values.[4] The actual values used in this analysis are therefore 1980, 1990, 1991 (and from then on each year), until 2010.

1.2 Fatalities

In Figure 2, the Belgian road accident fatalities from 1975 are plotted. The latest official number of victims killed on the spot in an accident or within 30 days after the accident concerns the year 2010. Value for 2011 is an estimation based on the number of fatalities on the spot.

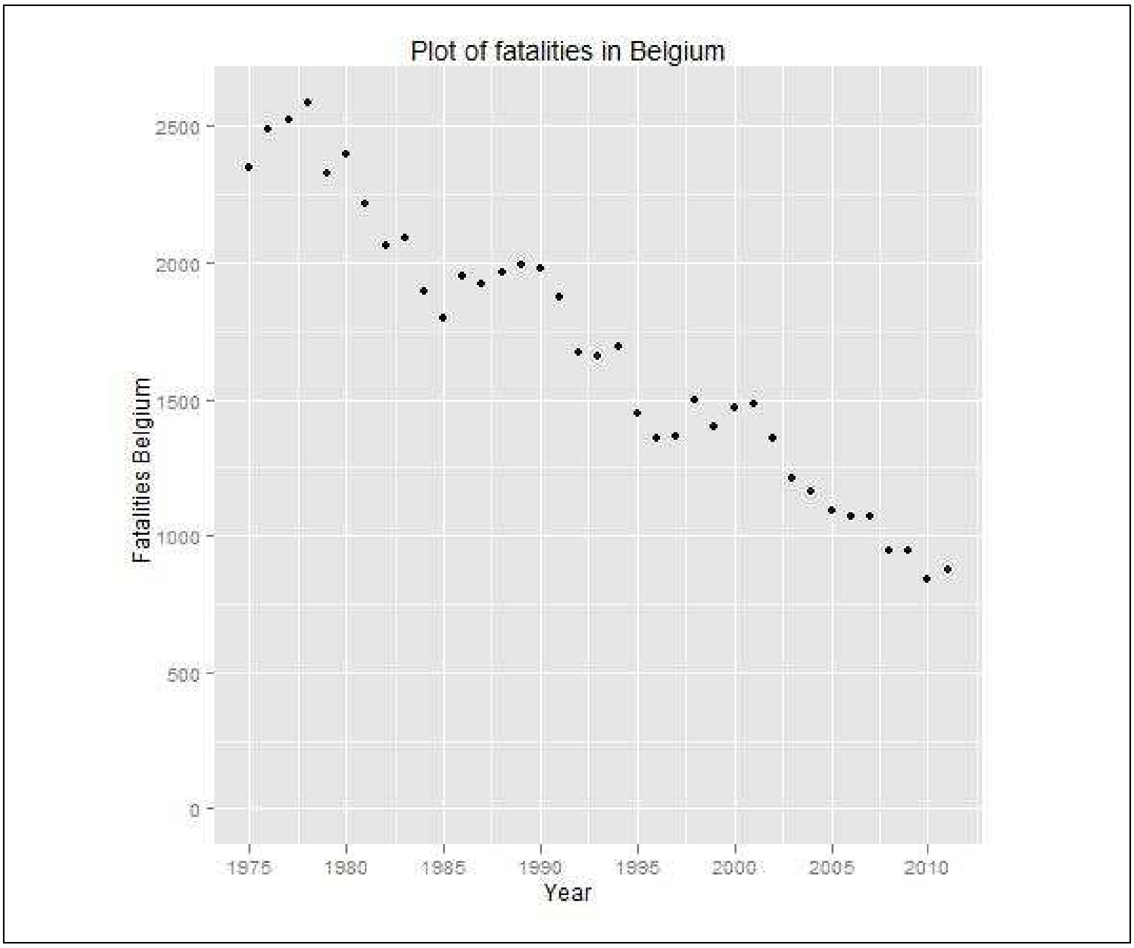


Figure 2: Plot of the annual fatality counts for Belgium from 1975 to 2011

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[4] Running the model with the complete vehicle kilometre series lead to heteroscedasticity problems. Several approaches were tried to deal with this. Shortening the series helped, but that meant ignoring all information before 85. Including two separate exposure variables (one for the pre-91 interpolated values, and one for the post 91 truly measured values) lead to other problems (most notably highly significant auto-regression tests. Eventually it was decided to include only those values that have been actually observed and to declare the ones in between as missing so as to let the model interpolate them itself. This seems to work; all residual tests are non-significant now.

In 1991, 2001, and 2002 there were changes in the registration procedure for fatal accidents. In ***1991*** the registration form was adapted, while the procedure remained the same. In ***2001*** a number of changes were implemented. *First*, a computerized version of the registration form is used since then (probably making a difference in terms of “lost forms”). *Second*, the whole Belgian police system was reformed at that time, and this may temporarily have given accident registration a lower priority. *Thirdly,* however, the statistical office paid more attention to the issue of missing accident forms for fatal victims (as registered by the hospitals), resulting in a strong decrease in the number of non-registered fatal victims. From ***2002*** on, these fatal victims for whom there was no accident form were included in the fatality counts.

It is difficult to judge the overall impact of the different measures in 2001 and 2002 on the number of registered fatalities. It is suspected that in the years 2001 to 2003 a lot has been going wrong with the newly reformed police teams and the newly implemented computerized forms (which might have led to under registration). At the same time the collection of the information from the police by the statistical office was improved. Therefore it is not quite clear when exactly the improvements began showing its effect. It can safely be assumed that the registration from 2004 on is much better than that in 2000 and before.

Usually improvements in the registration lead to an (artefactual) increase in the number of observed fatalities, which would be accounted for in a time series model by placing an intervention. However, instead from 2001 on, we observe a strong *decrease* continuing beyond 2004, suggesting that the improvements in road-safety more than compensated for the improved registration of fatal accidents.

It was therefore decided *not* to place an intervention to mark the change in measurement, because it co-occurred with an increase in traffic safety. Such an intervention cannot differentiate between the effects of an improved measurement on the one hand and an actual decrease in risk on the other hand.

2. The SUTSE Model

2.1 Development of the state components

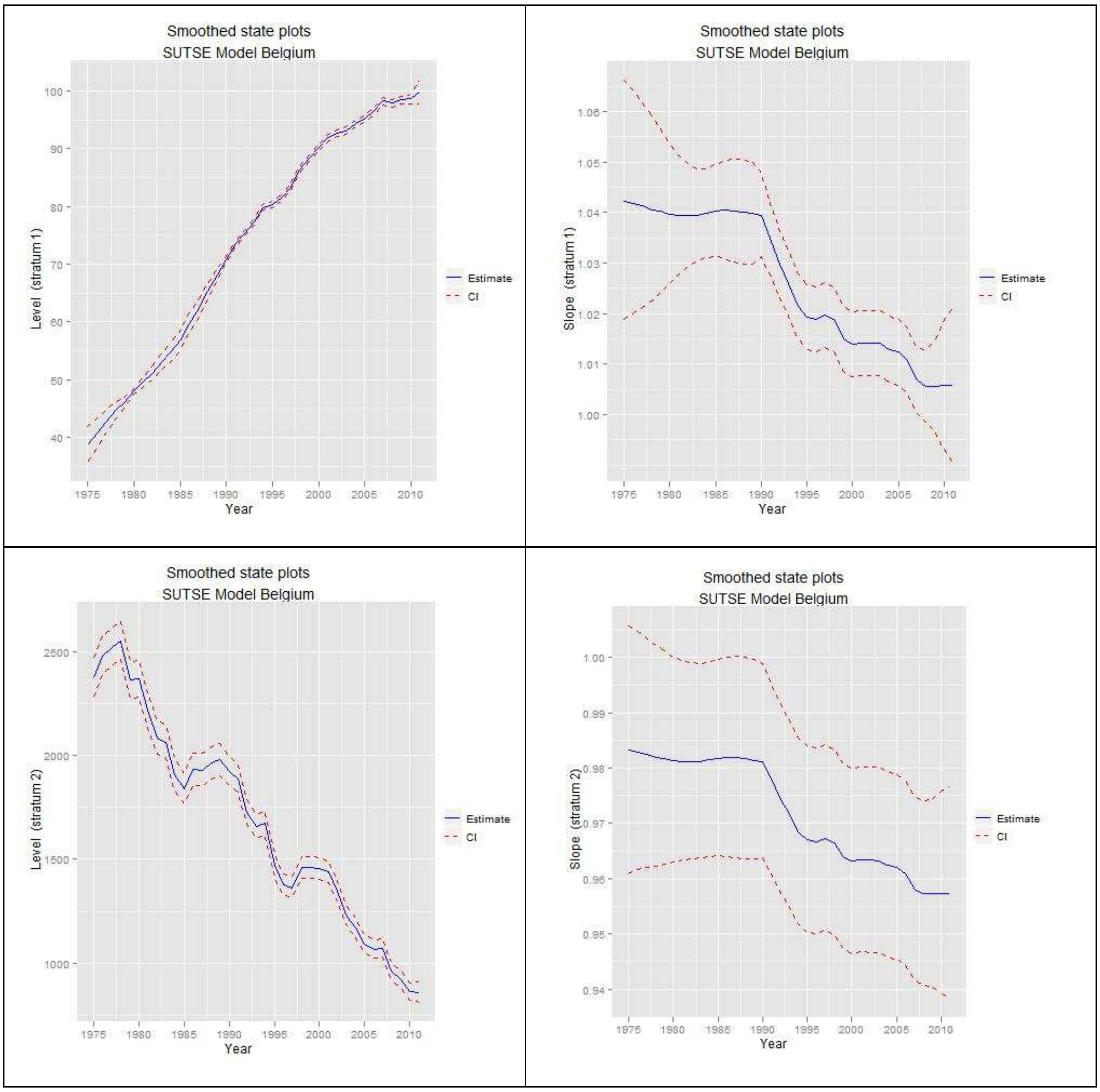


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs) for Belgium, as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The slope component varies significantly, while the level does not. The Belgian vehicle kilometers increased from almost 50 billion in 1980 to almost 100 billion in 2010. As the slope varies significantly, the increase did not take place at the same rate throughout this period. In the early seventies there was an increase of 4%, but since then the yearly increase became less and less and in the most recent years it has been only half a percent annually.

2.1.2 Fatalities

The level component varies significantly, whereas the slope does not. The fatalities have dropped from almost 2500 in 1975 to 875 in 2011. Although this decrease got stronger over the years (from -2% only in the seventies to -4% more recently), this change of rate is not significant. From 2010 to 2011 the fatalities showed a substantial increase by 35, … the first increase in a decade (not counting an increase by 2 fatalities in 2007).

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

Two state components, the level of exposure and the slope of the fatalities, cannot be considered stochastic. The two levels show a marginally significant correlation (p=0.062) and the correlation between the two slopes is not significant (p=0.269). The value of both correlations is 1. This does however not necessarily suggest the presence of common components, as each correlation involves a non-significant component.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -.35 which is not significant (p=0.7).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 1.092 and is marginally significant (p=0.068)

The results of the restricted SUTSE/LRT model are further the same as those for the full SUTSE model, indicating that the relation between fatalities and exposure does not vary over time.

Model title	*SUTSEBelgium1*	*SUTSEbetaBelgium1*
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	127.566	126.274
AIC	-254.646	-252.115
Variance of the state components		
Level exposure	6.85E-05 nsc	7.84E-05 ns
Level risk	2.60E-03 *c	1.88E-03 *
Slope exposure	1.97E-05 *c	2.02E-05 *
Slope risk	1.10E-05 nsc	1.90E-20 ns
Correlations between the state components		
level-level	1(*)	1.85E-05 ns
slope-slope	1 ns	3.54E-04 ns
Observation variance		
Observation variance exposure	2.30E-05 ns	2.6521E-05 ns
Observation variance risk	4.63E-05 ns	4.91112E-05 ns
Beta		1.092(*)

Table 1: Overview of the results for SUTSE models - Belgium

3. The LRT Model

The investigation of the SUTSE model did not clearly indicate the presence of a relation between exposure and fatalities in Belgium. However, the level correlation and the beta coefficient were both so close to significance (both p´s<.07) that there is reasonable doubt that these two time series are unrelated.

It was therefore decided to base the forecasting procedure on the latent risk timeseries (LRT) model.

3.1 Model selection

Four versions of the LRT model were run: the full model, the model with a fixed slope for risk, one where the risk slope and the level of exposure were fixed, and one where the risk slope and the exposure *slope* were fixed. The residual test for all three model variants don not indicate a violation of the assumptions underlying the Latent Risk model.

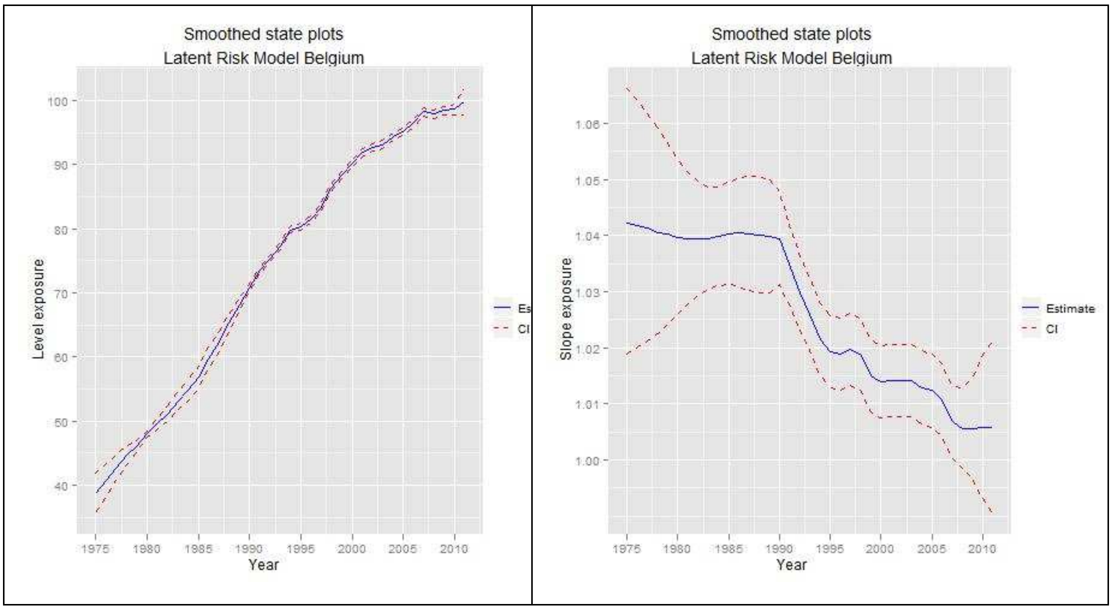
Model title	***LRT 1***	***LRT 2***	***LRT 3***	***LRT 4***
Model description	LRT for Belgium – full model	LRT for Belgium – fixed slope risk	LRT for Belgium – fixed level exposure, fixed slope risk	LRT for Belgium – fixed slope exposure, fixed slope risk
Model Criteria				
ME10 Fatalities	-313	-180	-180	-278
MSE10 Fatalities	109645	34769	34727	84714
log likelihood	127.566	127.466	125.768	119.017
AIC	-254.646	-254.554	-251.266	-237.709
Model Quality				
Box-Ljung test 1 Exposure	0.8	0.6	1.1	14.7***
Box-Ljung test 2 Exposure	1.4	1.4	1.1	21.3***
Box-Ljung test 3 Exposure	1.5	1.5	1.6	25.8***
Box-Ljung test 1 Fatalities	0.4	0.4	0.7	0.3
Box-Ljung test 2 Fatalities	0.5	0.4	1.1	0.4
Box-Ljung test 3 Fatalities	3.8	3.7	5.9	0.4
Heteroscedasticity Test Exposure	0.5	0.5	0.5	1.2
Heteroscedasticity Test Fatalities	0.7	0.6	0.6	0.8
Normality Test standard Residuals Exposure	0.3	0.3	0.9	0.5
Normality Test standard Residuals Fatalities	0.6	0.5	0.8	0.9
Normality Test output Aux Res Exposure	2.6	2.1	2.7	30.4***
Normality Test output Aux Res Fatalities	1.3	1.3	1.4	1.8
Normality Test State Aux Res Level exposure	1.2	1.2	1.8	0.9
Normality Test State Aux Res Slope exposure	0.2	0.2	0.3	0.0
Normality Test State Aux Res Level risk	0.7	0.6	1.4	0.8
Normality Test State Aux Res Slope risk	2.5	1.9	4.8	6.1*
	0.8	0.6	1.1	14.7***
Variance of state components	1.4	1.4	1.1	21.3***
Level exposure	6.85E-05 nsc	6.35E-05 nsc	-	3.45E-04 *
Level risk	1.83E-03 *c	1.87E-03 *c	1.91E-03 *	2.14E-03 *
Slope exposure	1.97E-05 *c	2.15E-05 *	3.77E-05 *	-
Slope risk	1.27E-06 nsc	-	-	-
Correlations between state components				
level-level	1.000	1	4.78E-05 *	0.15
slope-slope	-1.000		3.87E-04 ns	
Observation variance				

Observation variance exposure	2.30E-05 ns	2.45E-05 ns	1.52E-03 *	1.00E-09 ns
Observation variance risk	4.63E-05 ns	3.39E-05 ns	1.37E-04 ns	1.00E-09 ns

Table 2: Overview of the results for LRT models for Belgium

The comparison of different model versions indicates that fixing the risk slope and the exposure level did not lead to a substancial decrease in fit. A model with a fixed exposure slope instead of the level, however, clearly did not capture the dynamics of the development well, as apparent from the significant model quality tests. The model chosen for the predictions is consequently LRTBelgium3 with a fixed level for exposure and a fixed slope for risk.

3.2 Development of the state components



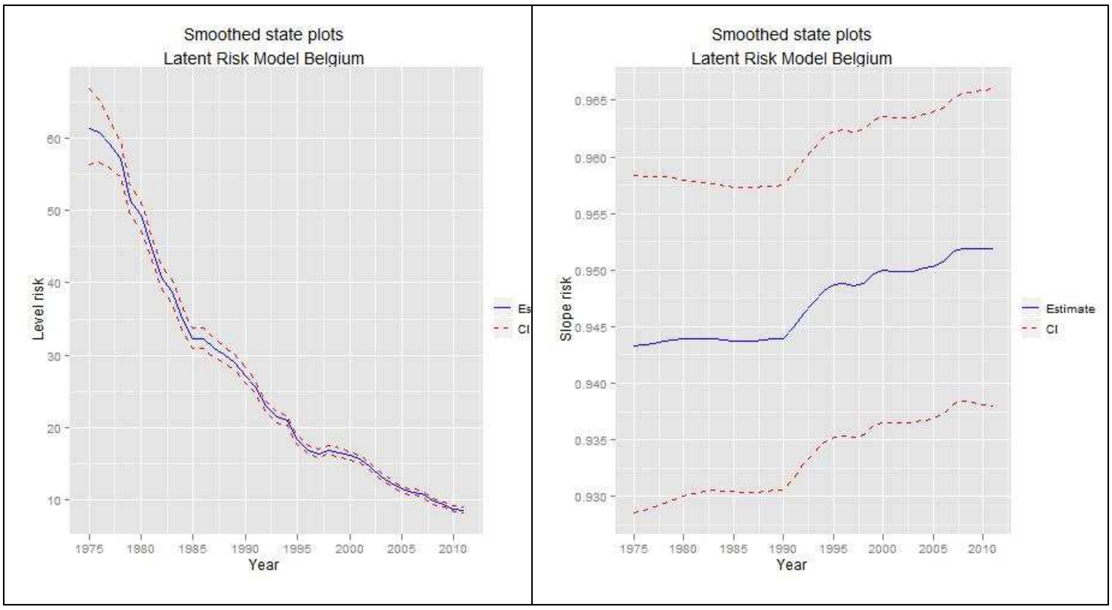


Figure 4: Developments of the state components for the exposure (above) and the risk (below) for Belgium, as estimated on the basis of the full LRT model (LRT1). The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The Belgian vehicle kilometers increased from almost 50 billion in 1980 to almost 100 billion in 2009. This increase not take place at the same rate throughout this period however. In the early seventies there was an increase of 4%, but since than the yearly increase became less and less and in the most recent years it has been only half a percent annually.

3.2.2 Risk

The risk for fatalities has been reduced in Belgium from more than 60 per billion vehicle kilometers in the mid 70s to less than 10 per billion vehicle kilometers in the most recent years. This decrease of +/- 5% yearly is expressed in the negative slope of the risk in the lower left panel of Figure 4.

Although the slope of the risk is slightly increasing (i.e. getting less negative) over the years, this reduction in the rate of decrease is not significant. In the model overview table it can be seen that a model for which the rate of decrease is fixed at 5.3% per year fits the data almost as well.

3.3 Quality of the predictions

To evaluate how well models implemented here have done in the past, the data up to 2001 are used to forecast the fatalities between 2002 and 2010. Figure 5 below shows a comparison between the predicted and actually observed values.

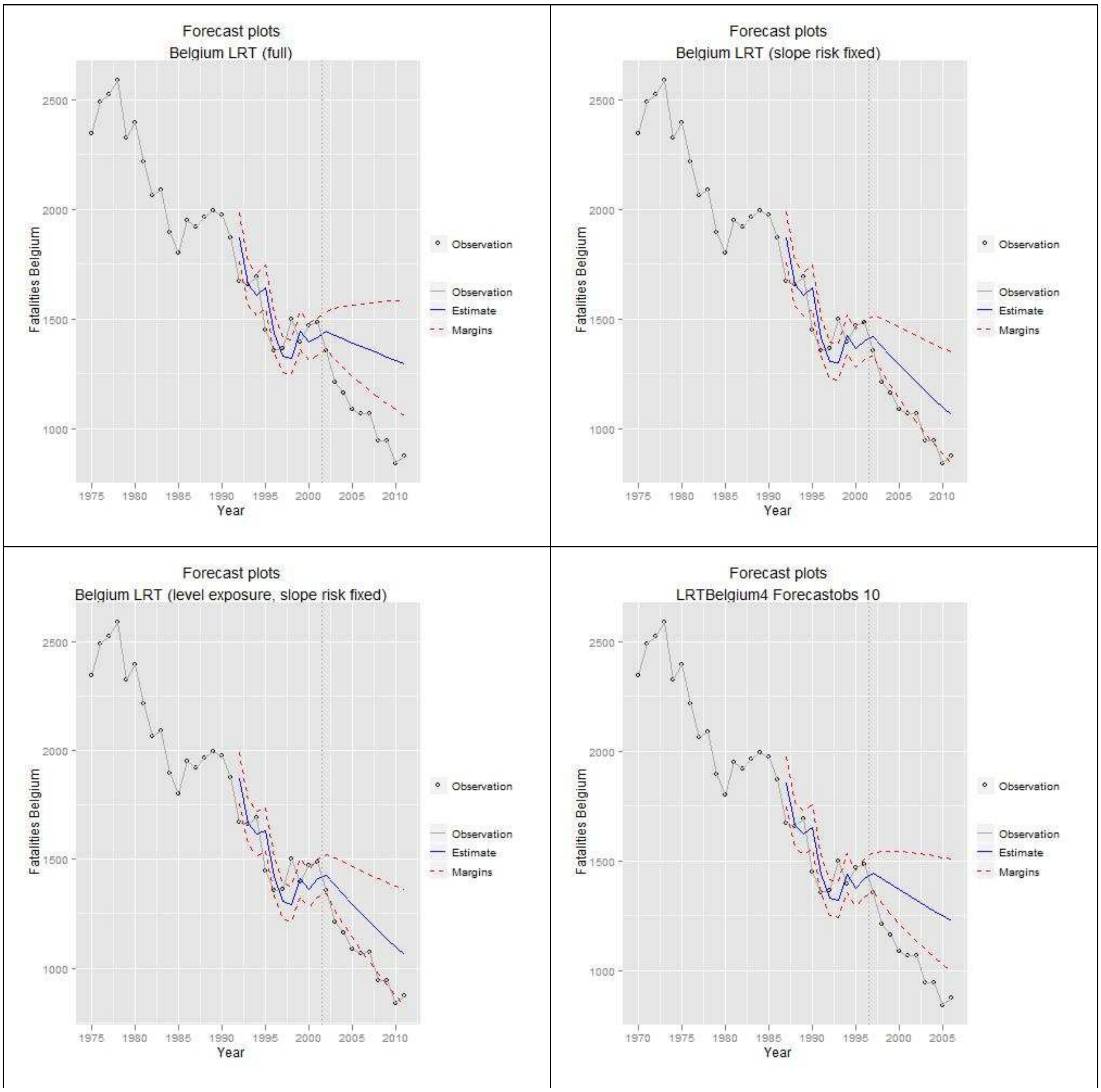


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the fatality numbers in Belgium according to 4 different LRT models: Full model (LRT1 upper left), fixed slope risk model (LRT2, upper right), *fixed slope risk, fixed level exposure (LRT3, lower left)*, fixed slope exposure, fixed slope risk (LRT4, lower right).

In Figure 5, the Belgian fatalities are forecasted up to 2011 with different variants of the Latent Risk model using data up to the year 2001. It can be seen that in the past models with a fixed slope (LRT 2 upper right and LRT 3 lower left) fared much better than the full model (LRT 1 upper left) or the model and also better than the model with a fixed slope for exposure (LRT4, lower right). This means that *in the past it has proven inefficient to derive the forecasting direction from the most recent changes in direction (which is done when the* *slope remains unfixed) and better to estimate the future rate of decrease based on the long-term development (i.e. a fixed risk slope)*. Interestingly, this is not the same for the exposure. Here the rate of increase has consistently become smaller throughout the years, and it has proven more efficient to base the forecasts of the most recent (i.e. smallest) rate of increase observed for the exposure.

4. Forecasts 2011 - 2020

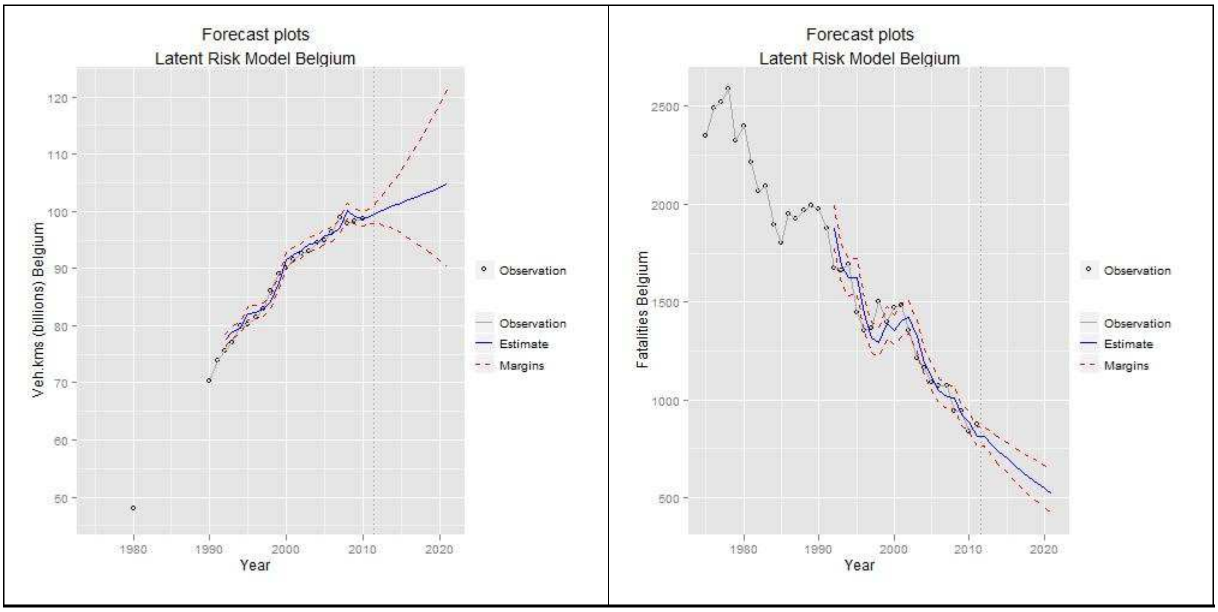


Figure 7: Plot of annual vehicle kms (left hand graph) and fatality numbers (right-hand graph) for Belgium forecasted (LRT3) between 2012 and 2020.

The forecasts in Figure 7 and Table 3 provide an indication of the vehicle kilometres and the fatality numbers to be expected between 2012 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Vehicle kilometers (billion)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2012	**100**	95	107	**774**	664	902
2013	**101**	93	110	**737**	611	888
2014	**101**	91	113	**701**	563	873
2015	**102**	89	116	**667**	519	858
2016	**103**	87	120	**635**	478	845

2017	**103**	85	125	**605**	439	832
2018	**104**	83	129	**575**	404	820
2019	**104**	81	135	**548**	371	809
2020	**105**	78	140	**521**	340	799

Table 3: Forecasts of Latent Risk Model fixed level exposure fixed slope risk (LRTBelgium3)

1.1. Scenarios

In Table 3 it can be seen that there is strong uncertainty about the development of the exposure in Belgium. As the exposure influences the prediction of the fatalities it is interesting to demonstrate how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 8 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

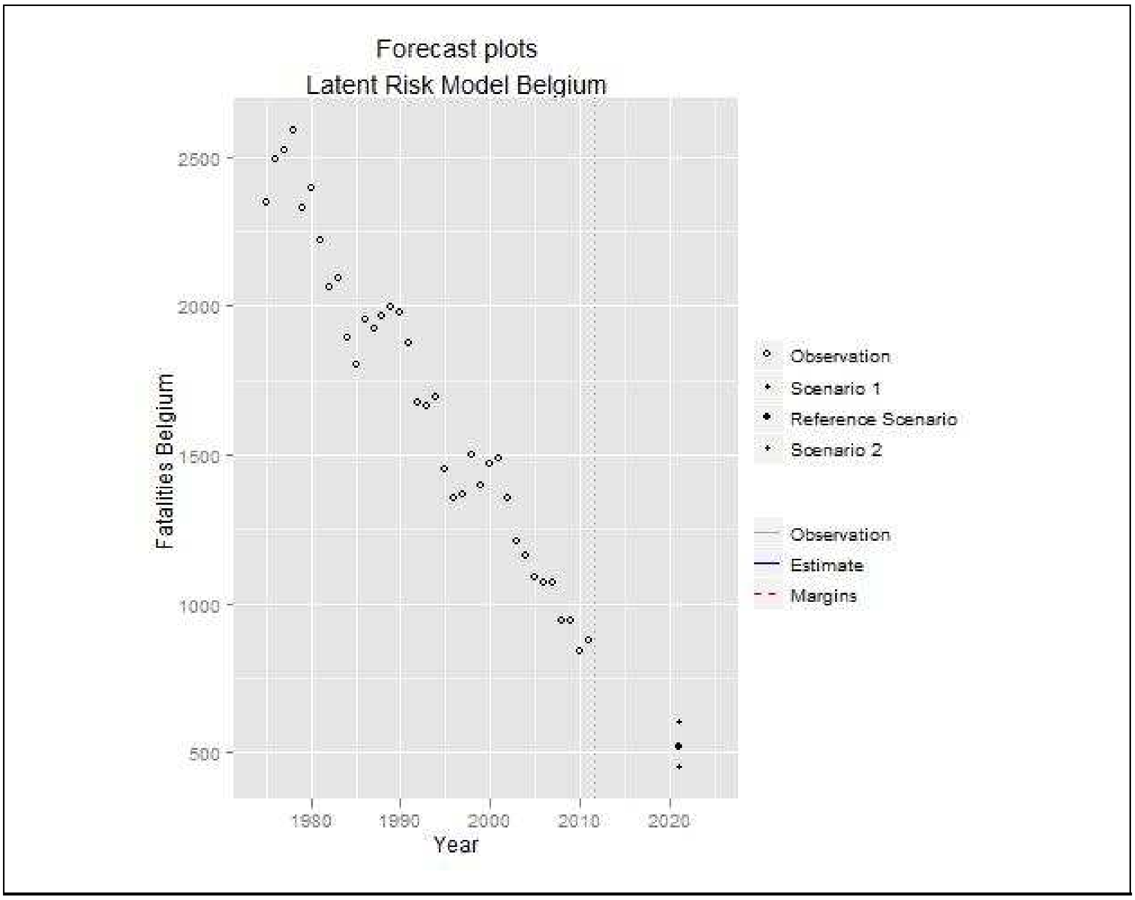


Figure 8: Fatality forecasts Belgium 2020 under 3 mobility scenarios. ●Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the vehicle kilometres as predicted from the LRT model plus/minus one standard deviation. Assuming that these predictions are correct, and thus ignoring the uncertainty surrounding the forecasts for the exposure, what would be the consequences for the number of fatalities to be expected in 2020?

The full dot in Figure 8 is the expected number of fatalities given that mobility keeps developing as it has before (prediction 105 billion veh.km per year). The circles indicate the estimated number of fatalities for an stronger growth scenario for exposure (forecast plus one standard deviation: 121 billion veh.km) and for a scenario without growth (forecasted value minus one standard deviation[5]: 90 billion veh.km). The prediction that we achieve under these three scenarios are summarized in Table 4.

	Vehicle kilometers (billions)	***Road traffic Fatalities***
Situation 2010:	98.7	840
Prediction for 2020 according to mobility scenarios:		
Continuation of development	105	521
Stronger growth	121	602
Decrease	90	451

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRT 3). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation.

The Belgian federal planning agency (Federaal Plan Bureau) predicts 112.8 billion vehicle km in 2020. Based on this the latent risk model would predict 573 fatalities.

[5] Note that 68% of all cases are between the estimated value +/- one standard deviation (under the assumption of a normal distribution).

BULGARIA

1 Raw data

1.1 Exposure

For Bulgaria the vehicle fleet (per thousand) is available from 2001 on.

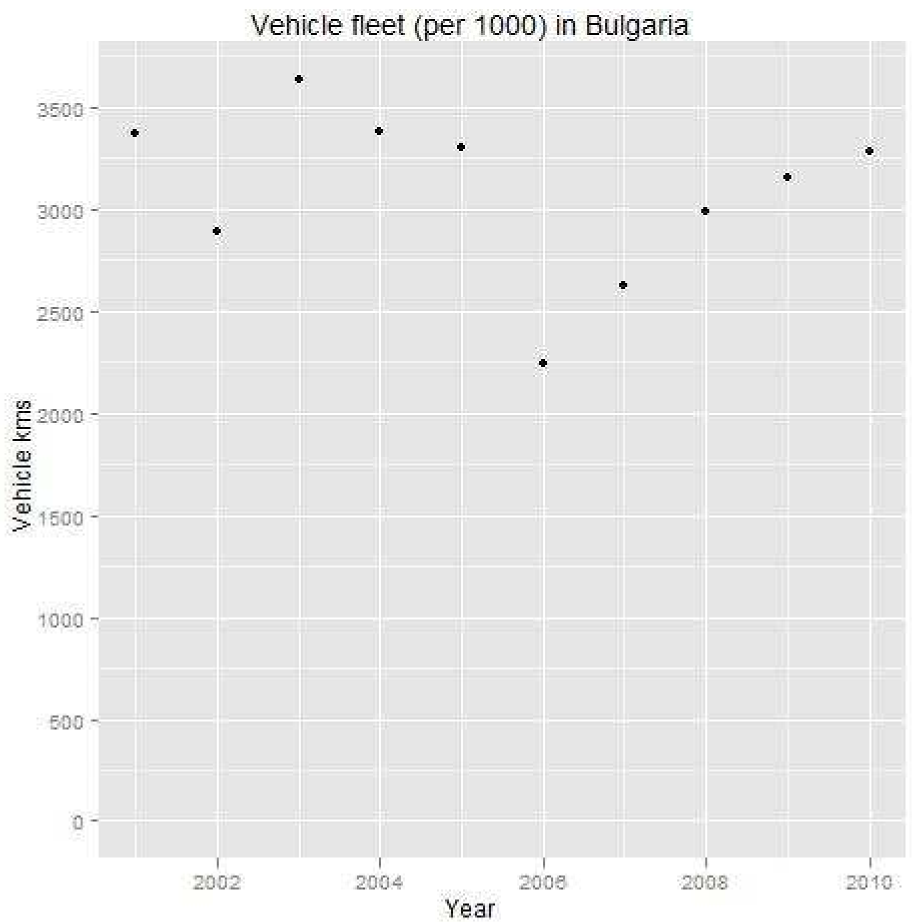


Figure 1: Total number of motor vehicles in Bulgaria from 2001 to 2010.

The vehicles are counted by the traffic police and driving an unregistered vehicle can be punished by temporary withdrawal of the licence or by fines. In 2006, the number plates were changed obliging every vehicle to be re-registered. Approximately 1 million vehicles were not re-registered indicating that these had not been in use anymore.

The vehicle count seems to behave rather erratic between 2001 and 2005. Between 2005 and 2006 there is a big drop in the number of vehicles due to the removal of cars not in use anymore. From 2006 to 2010 we see a rising trend, which slowed down a bit after 2008, which is likely to be a consequence of the recession.

1.2 Fatalities:

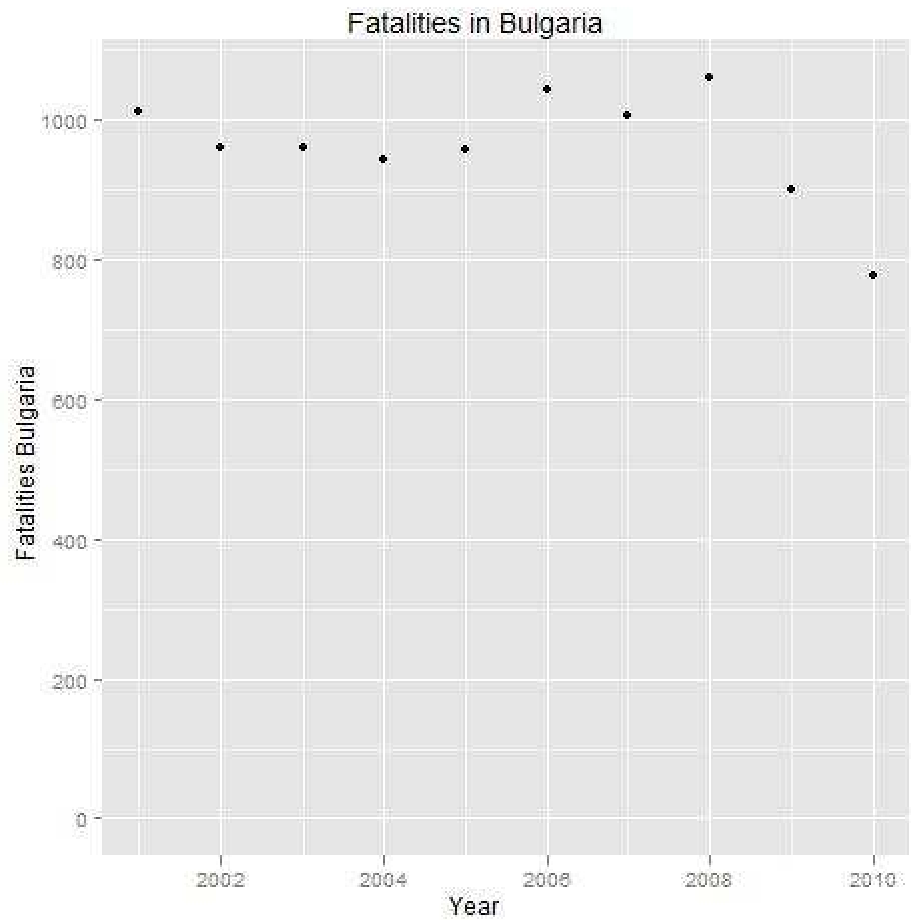


Figure 2.: Plot of the annual fatality counts for Bulgaria 2001 to 2010.

Fatality data is available in Bulgaria since 2001. The number of fatalities has been more or less stagnating between 2001 and 2005, then it was rising, and eventually it has been decreasing since 2008.

The development of the fatalities mirrors some aspects of the economic development. In the years up to 2008 there was a stable growth of 6% per year in GDP and growing oil sales, all indicating a rising mobility [1]. After 2008 the recession started which might have reduced the mobility more than the vehicle fleet data indicate and thus have caused the reduction in fatalities.

At the same time the fatalities also mirror the efforts in road safety management. In 2008 Bulgaria had a road safety management review executed by the world bank [2]. In this review a lack of funding and of a coherent strategy was diagnosed at different levels of the road-safety pyramid: target setting; data collection and analysis; selection, monitoring and evaluation of measures; road design; police work; education and awareness raising activities; trauma care. Moreover it was asserted that the know-how and equipment applied was often not up to date with common security standards and that the execution of existing rules was challenged due to the payment of `alternative fines`.

Since then, big efforts are undertaken to improve road safety in the sense that a strategic plan has been worked out concerting actions of public institutions, regional and municipal authorities, nongovernmental organizations, the private sector and civil society [1].

With exposure data that show no clear relation to the development of the fatalities it is difficult to judge whether the falling trend since 2008 is rather a consequence of the recession or of the efforts to improve road safety.

2. The SUTSE Model:

To account for the cleaing of the vehicle database in 2006, a second SUTSE model was run with a level intervention on the exposure in 2006 (SUTSE2). The intervention is significant.

2.1 Development of the state components:

For neither model (SUTSE1 or SUTSE 2) the level or the slope component is significant. Below the resulting states from SUTSE1 are presented.

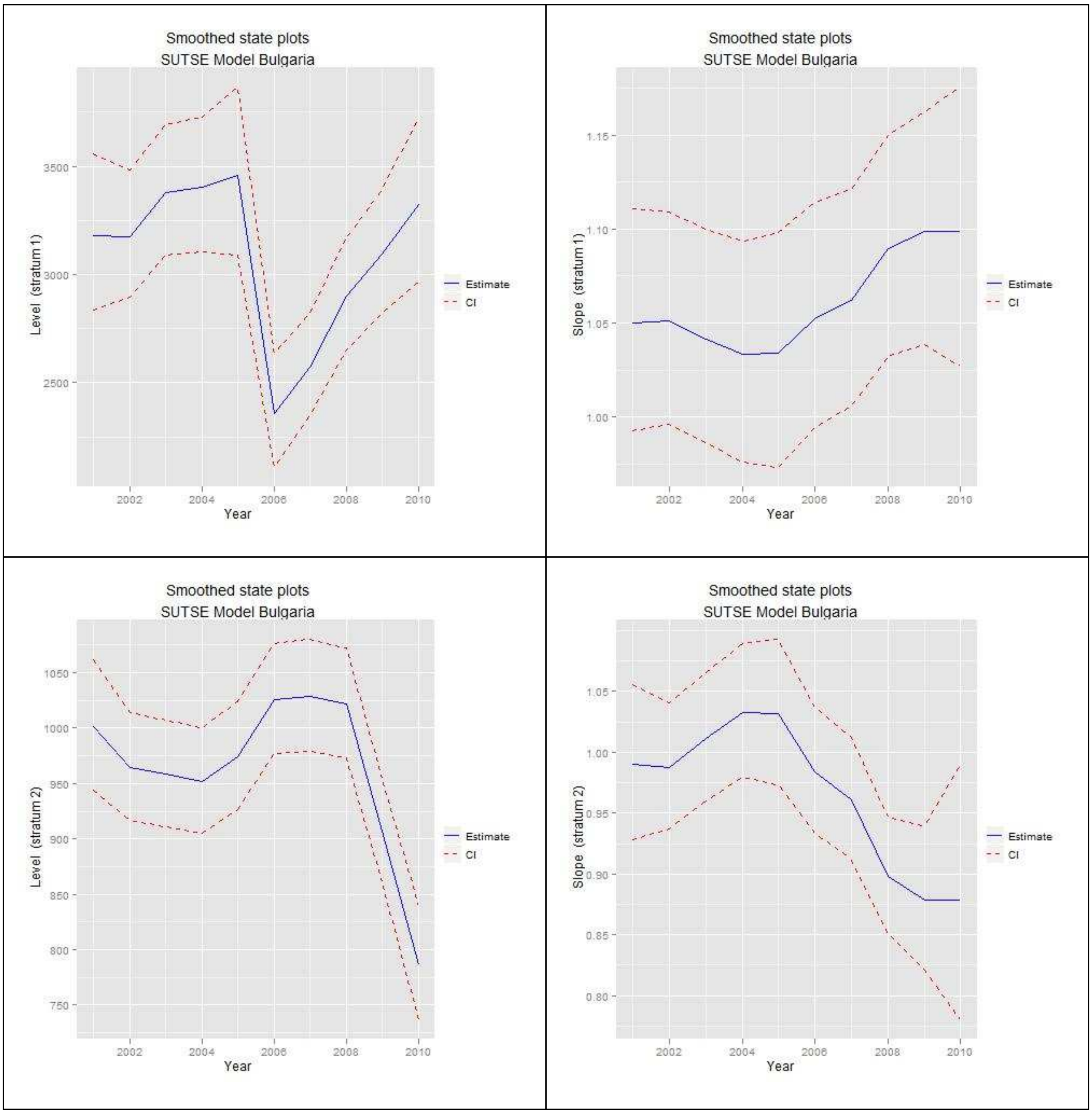


Figure 3: Developments of the state components for the *vehicle fleet* (per 1000 vehicles) (upper graphs), and the *fatalities* (lower graphs) The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Vehicle fleet

The development of the vehicle looks erratic. However, when extracting the sudden drop in 2005-2006 which is due to the change in registration, there is a continuously increasing trend, which is indicated by the slope that stays positive and does not vary significantly.

2.1.2 Fatalities

The development of the fatalities does not have a clear tendency throughout the 10 years observed here. They have been decreasing in the beginning of the millenium, then increasing, and in the end decreasing again. Neither the level nor the slope component is significant.

Model Title		***SUTSE1***	***SUTSE2***
	Model description	full model	level intervention exposure 2006
Model Criteria			
	log likelihood	-2.44	-8.6
	AIC	6.68	19.0
Variance of state components			
	Level exposure	5.92E-17 nsc	3.73E-03 nsc
	Level risk	2.23E-17 nsc	1.12E-03 nsc
	Slope exposure	5.07E-03 nsc	3.61E-04 nsc
	Slope risk	3.56E-03 nsc	2.50E-03 nsc
Correlations between state components			
	level-level	-0.47	1.0
	slope-slope	-1	-1.0
Observation variance			
	Observation variance exposure	1.28E-02 ns	5.03E-03 ns
	Observation variance risk	7.30E-07 ns	5.66E-05 ns
Interventions			
	2006 exposure level		-0.45 *
Beta		-0.84	-0.24
p (Beta)		0.11	0.17

Table 1: Model criteria and results for SUTSE models Bulgaria.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

For SUTSE 1, the correlation between the levels is .47 and the correlation between the slopes is -1. Neither correlation differs significantly from 0 (p´s = 1 and 0.183 respectively) or from 1 (p´s = 1 and .5 respectively).

Including an intervention in 2006 (SUTSE 2) changes the level correlation to 1, while the slope correlation remains -1. Both correlations remain non-significant.

2.2.2 Correlation between the measurement errors

The measurement errors of fatalities and exposure were not related (correlations <.3, p´s >.7).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities, estimated by the beta coefficient in a restricted SUTSE/LRT model, is not significant for either SUTSE model.

3. The LLT Model:

As the SUTSE did not indicate a significant relation between fatalities and the vehicle fleet, in the following we will model the fatalities by means of an LLT model.

3.1 Model selection:

Model title	***LLTFat1***	***LLTFat2***	***LLTFat3***	***LLTFat 4***	***LLTFat5***
Model description	Full LLT fatalities	Fixed level	Fixed slope	Fixed slope, level intervention 2008	Fixed slope, slope intervention 2008
Model Criteria					
ME7	97	97	97		
MSE7	15872	15872	15872		
ME4	-224	-224	-97		
MSE4	78035	78035	22331		
log likelihood	1.53	1.53	0.57	-8.37	-4.38
AIC	-2.45	-2.65	-0.75	17.14	9.17
Model Quality					
Box-Ljung test 1	0.84	0.78	0.63	1.73	2.40
Box-Ljung test 2	1.91	0.84	0.73	1.93	3.65
Box-Ljung test 3	1.92	1.91	2.40	3.87	3.66

Heteroscedasticity Test	45.78*	45.78*	23.03	21.59	1.71
Normality Test standard Residuals	0.89	0.89	0.95	0.66	1.01
Normality Test output Aux Res	2.01	2.01	0.30	0.20	1.04
Normality Test State Aux Res Level	0.46	0.46	1.00	0.68	0.26
Normality Test State Aux Res Slope	0.86	0.86	0.02	0.01	0.00
Variance of state components					
Level	3.17E-20 ns	-	6.15E-03 *	6.86E-03 *	7.77E-04 ns
Slope	3.75E-03 ns	3.75E-03 *	-	-	-
Observation variance					
Observation variance	1.00E-09 ns	1.00E-09 ns	1.00E-09 ns	1.00E-09 ns	1.00E-09 ns
Interventions					
level 2008				0.08 ns	
slope 2008					-0.16 *

Table 2: Model criteria and results for LLT models for RS fatalities in Bulgaria.

In the full LLT model, neither state component is significant (Table 2). This means that neither fixing the level nor fixing the slope by themselves leads to a significant reduction in model fit (i.e. the likelihood).

When the level is fixed (LLT2) the slope becomes significant and when the slope is fixed (LLT3) the level is significant. The fixed level model has a better fit then the fixed slope model. However, the better fitting fixed level model (and the full model as well) have a problem with the heteroscedasticity of the residuals, which is not present in the fixed slope model. In Figure 4 it can be seen why.

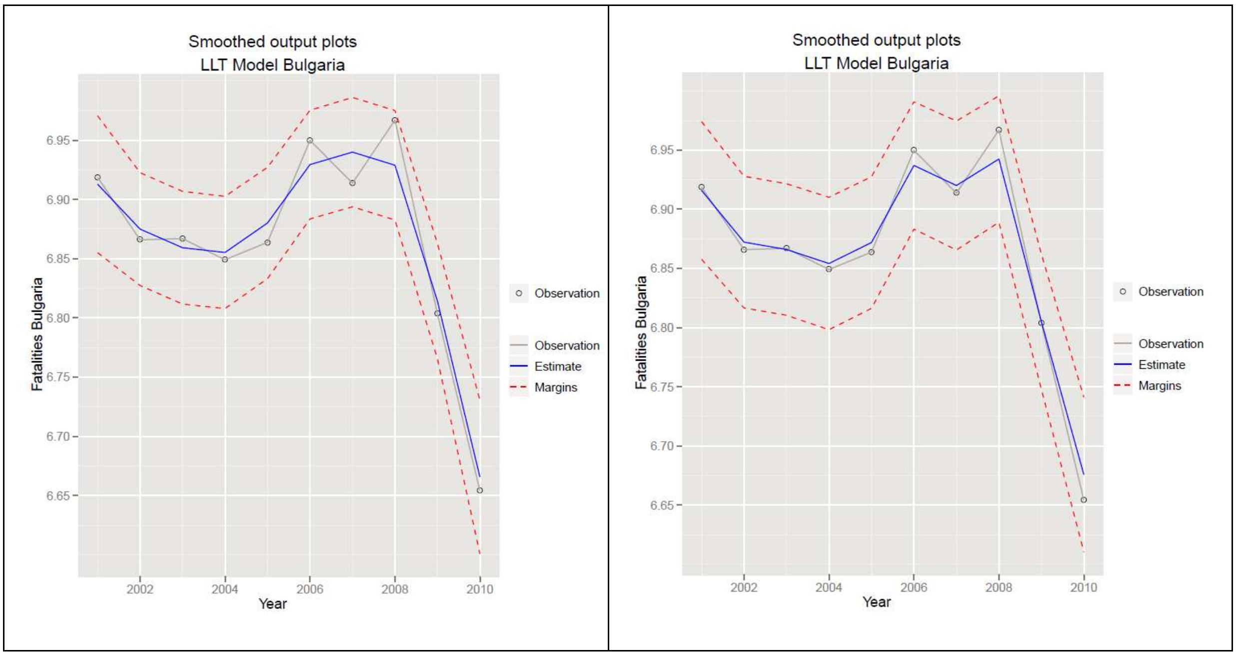


Figure 4: Model estimates and observed data for LLT2 (fixed level model, left hand side) and LLT3 (fixed slope model, right hand side).

In the fixed level model (LLT2 left hand graph), the development of the fatalities is seen as a smooth trend that slowly changes over time. We can see that especially in the years before 2008 the observed data are in contradiction to such a smooth trend. In the fixed slope model (LLT3, right hand graph), changes are assumed to follow a random pattern, where the direction of one step does not influence the direction of the next one. This model is in better agreement with the erratic development of the fatalities in the recent years and is consequently selected as forecasting model.

3.2 Development of the state components:

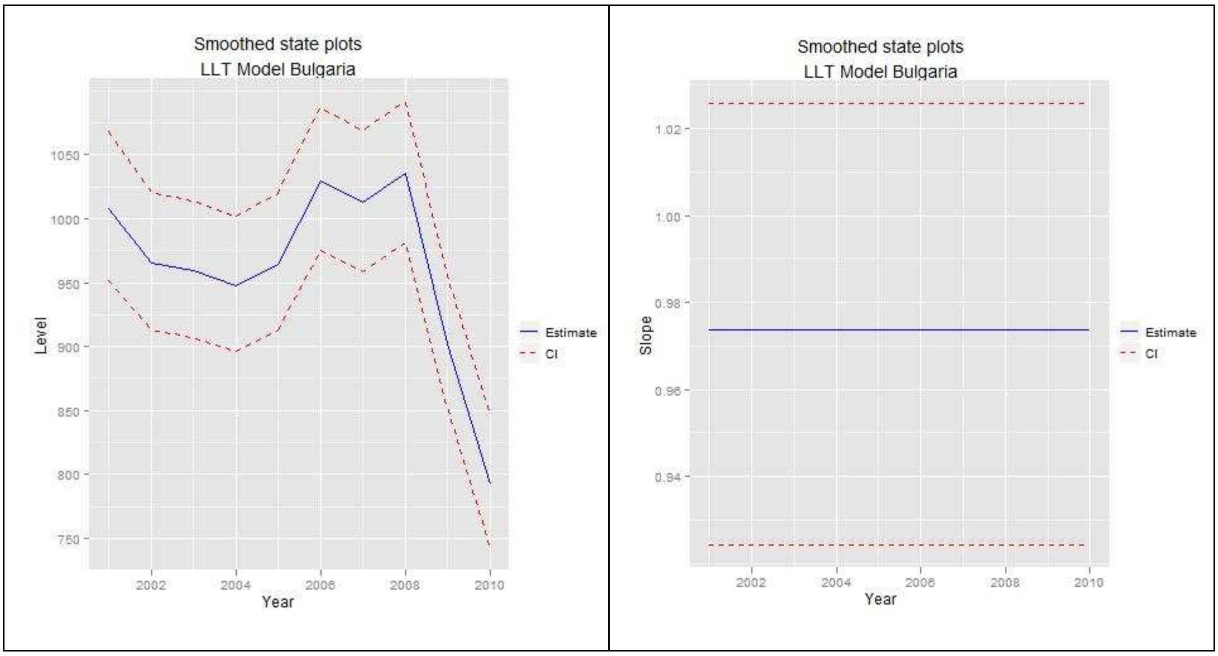


Figure 5.: Developments of the state components for the fatalities in Bulgaria, as estimated on the basis of fixed slope model LLT3.

The most appropriate model is the fixed slope model. This means that the dynamics are of the fatalities are best explained with a fixed slope, indicating a continuous decrease of 2% yearly, and random level changes added to this.

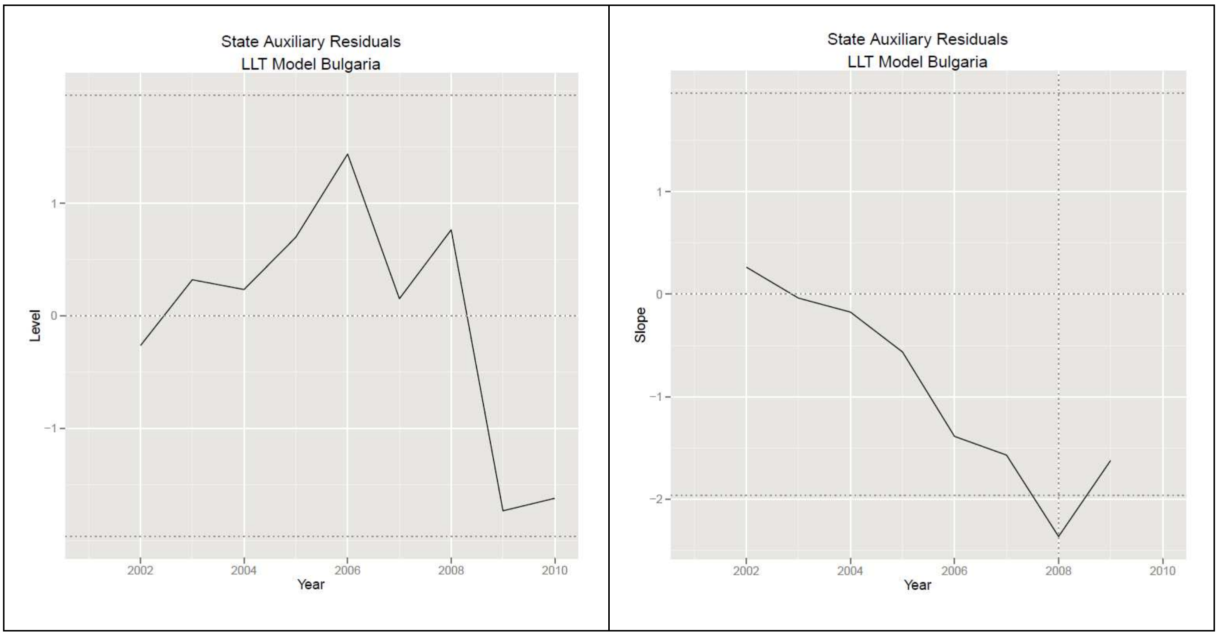


Figure 6.: Auxilliary residuals for level (left panel) and slope (right panel) of fixed slope model LLT2.

The analysis of the auxiliary residuals presented in Figure 5.5 indicates that in 2008 there was a break in the trend observed until then. A slope break (meaning a change of direction) seems to be more appropriate than a level break (a drop and then a continuation in the old direction). This break is however, not included into the forecasting model, because this would mean that the last two years (2009, 2010) form the sole basis for forecasting the development until 2020. Given that in these two years the economic crisis had its effect together with possible road safety measures, they cannot be considered reliable indicators for the development in the next 10 years.

3.3 Quality of the predictions:

To evaluate the models performance in the past, the data from 2001 to 2006 have been used to forecast these numbers for the years 2007 to 2010. For those last years, it is then possible to compare the actual values with the forecasted ones. Figure 5.6 below shows a plot of the predicted and observed values where the predictions of the years after 2006 are based on the observed values up to 2006.

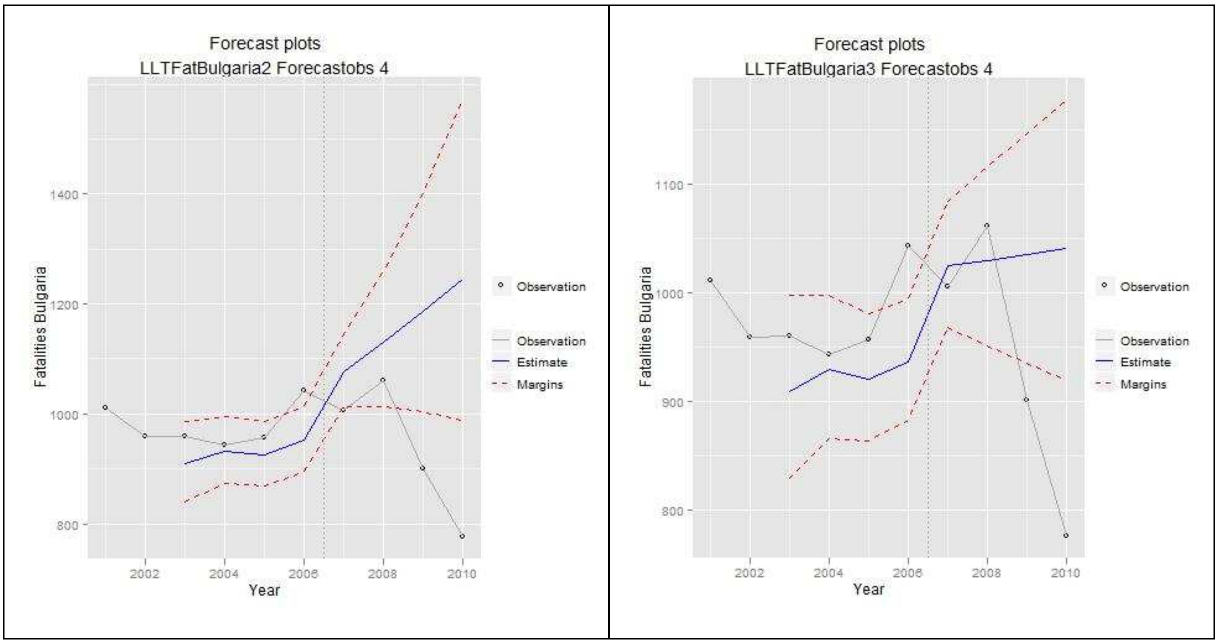


Figure 7: Plot of forecasts based on data until 2006. Left panel LLT2 fixed level model. Right panel: LLT3 fixed slope model (the model selected for forecasts).

Neither of the models based on data up the year 2006 predicts the dramatic drop of the fatalities in 2008. This illustrates that the forecasts on the basis of past developments are not necessarily predictions of what is actually going to happen.

A fixed slope model (LLT3, right hand graph) is a conservative model. Recent changes affect the forecasts only to a limited extent. The forecast of the less conservative fixed level model (LLT2, left hand graph) demonstrate that in a moment of dramatic changes a conservative model might be the wiser choice.

4. Forecasts 2011 – 2020:

The model selected is the linear latent trend model with a fixed slope (LLT3). The forecasts up to the year 2020 based on this model are presented in Figure 7 and Table 3

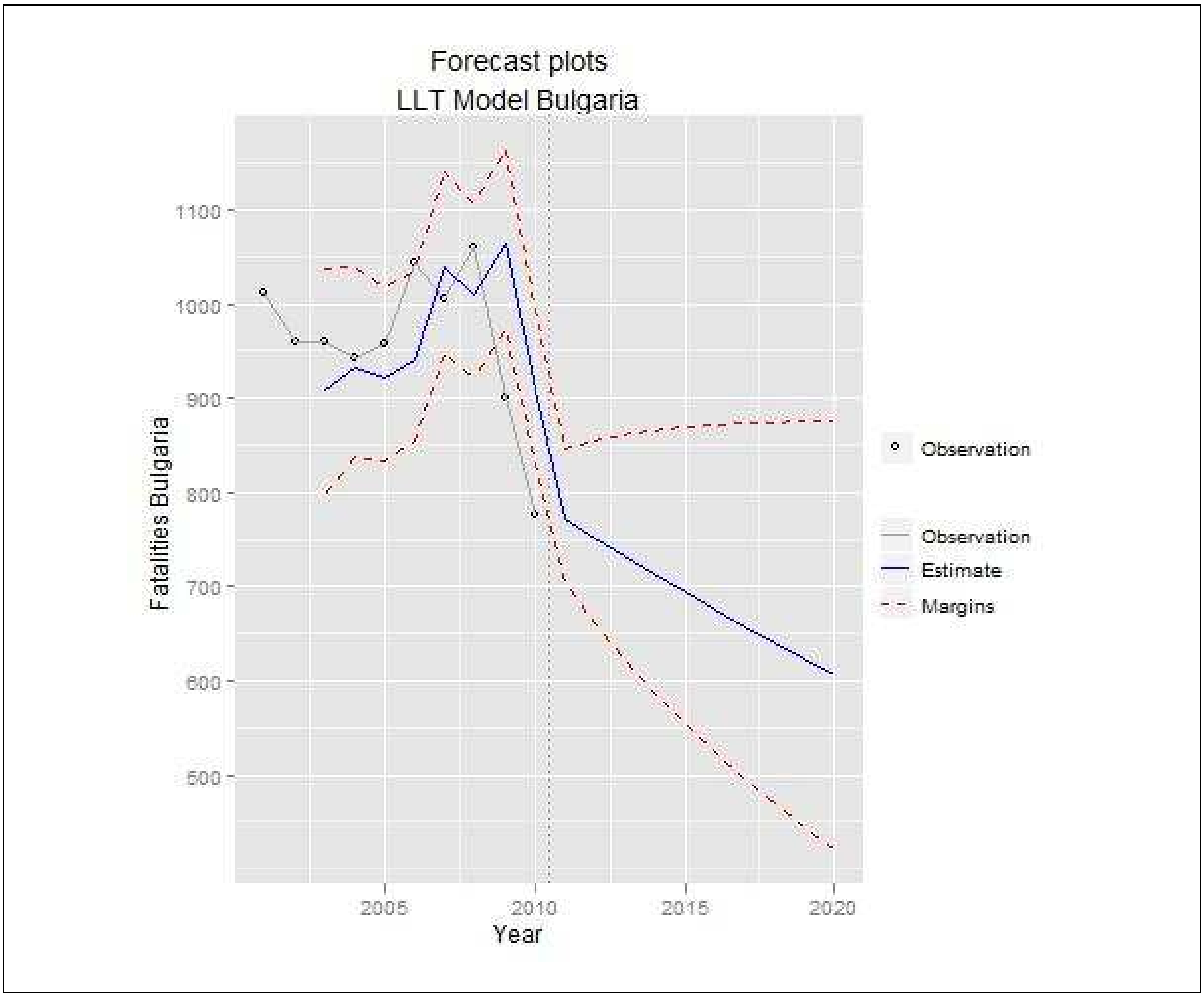


Figure 8.: Plot of the annual fatality numbers for Bulgaria and the forecasts for 2020. Based on a linear latent trend model with a fixed slope (LLT3).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**772**	646	922
2012	**752**	583	969
2013	**732**	531	1008
2014	**713**	486	1044
2015	**694**	446	1079
2016	**675**	410	1113
2017	**658**	377	1147
2018	**640**	347	1182
2019	**624**	320	1216
2020	**607**	295	1251

Table 3: Forecasts of the Latent Risk Model (LRT1 – full model).

CYPRUS

1. Raw data

1.1 Exposure

The selected exposure measure is the fuel consumption (x1000 tn.eq. of oil) per annum (see Figure 1), which are considered from 1991 until 2010. A fairly consistent increasing trend can be noticed until 2008, at which point –possibly due to the recession- fuel consumption started declining.

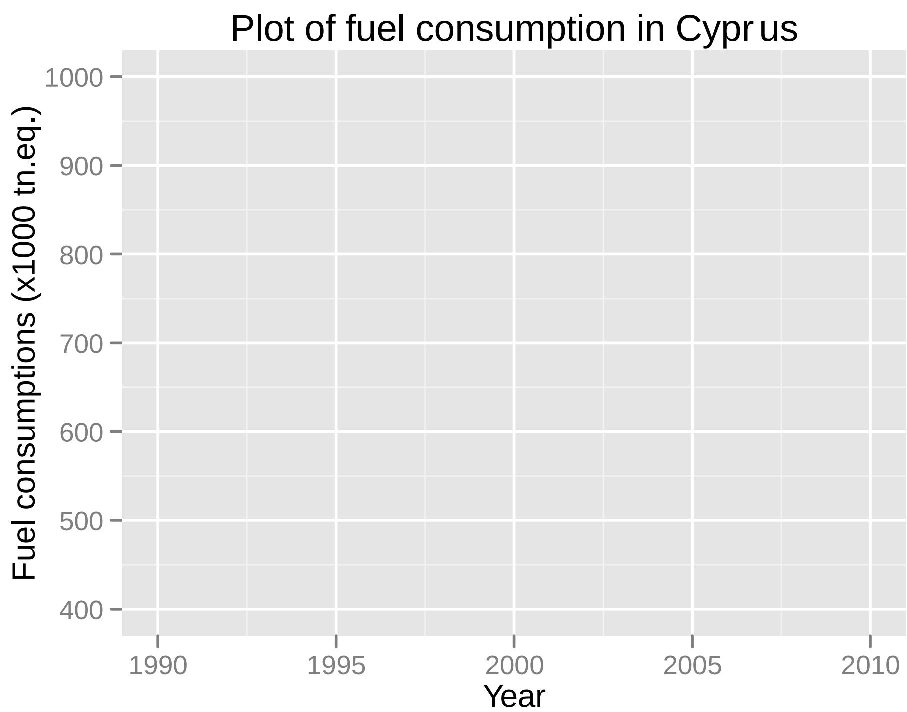


Figure 1: Plot of the annual numbers of fuel consumption (x1000 tn.eq.) for Cyprus from 1991 to 2010.

1.2 Fatalities

In Figure 2, the Cypriot road accident fatalities from 1991 to 2010 are plotted. During the first years (1990s) there is some variability and no clear trend can be observed. There is a dip in the first half of the 2000s and a consistent drop after 2004. This could possibly be attributed to the accession of Cyprus to the EU (which took place that year), and to the implementation of the first Strategic Road Safety Plan 2005 _ 2010.

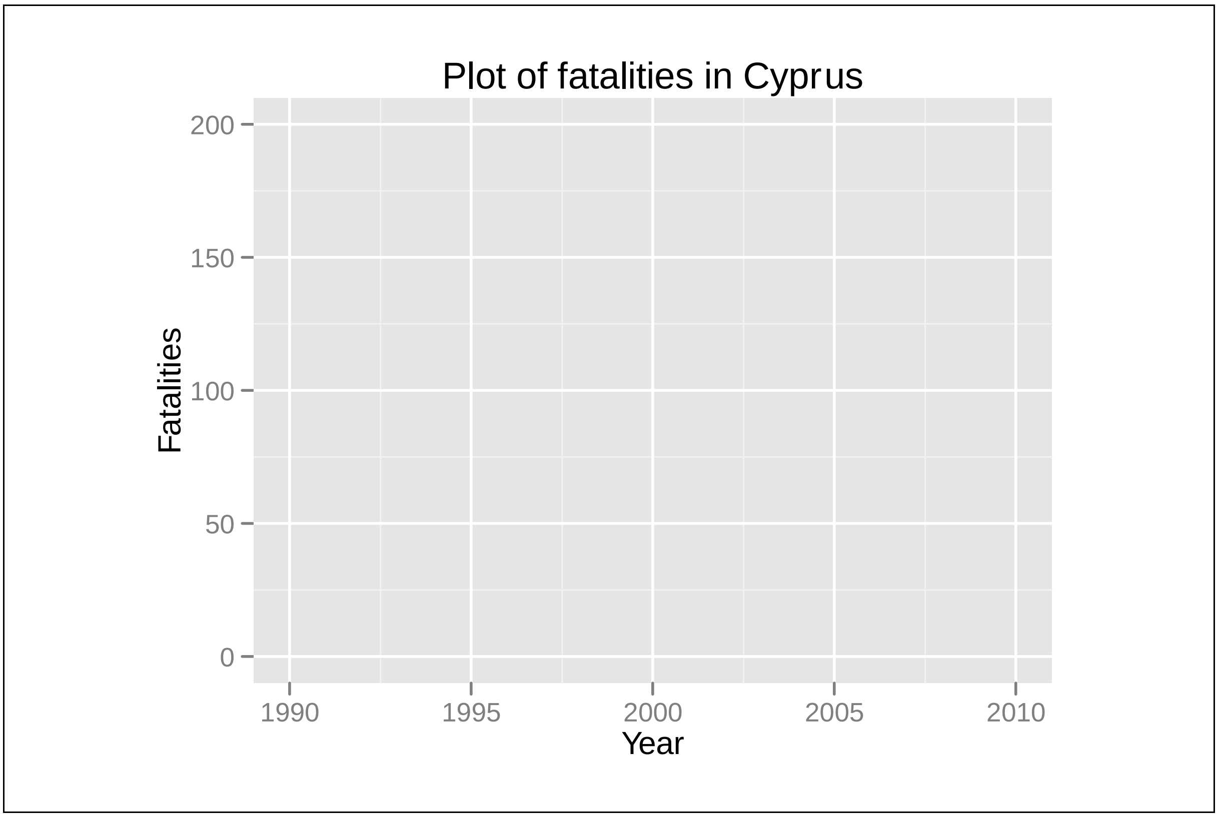


Figure 2: Plot of the annual fatality counts for Cyprus from 1991 to 2010.

2 The SUTSE Model

2.1 Development of the state components

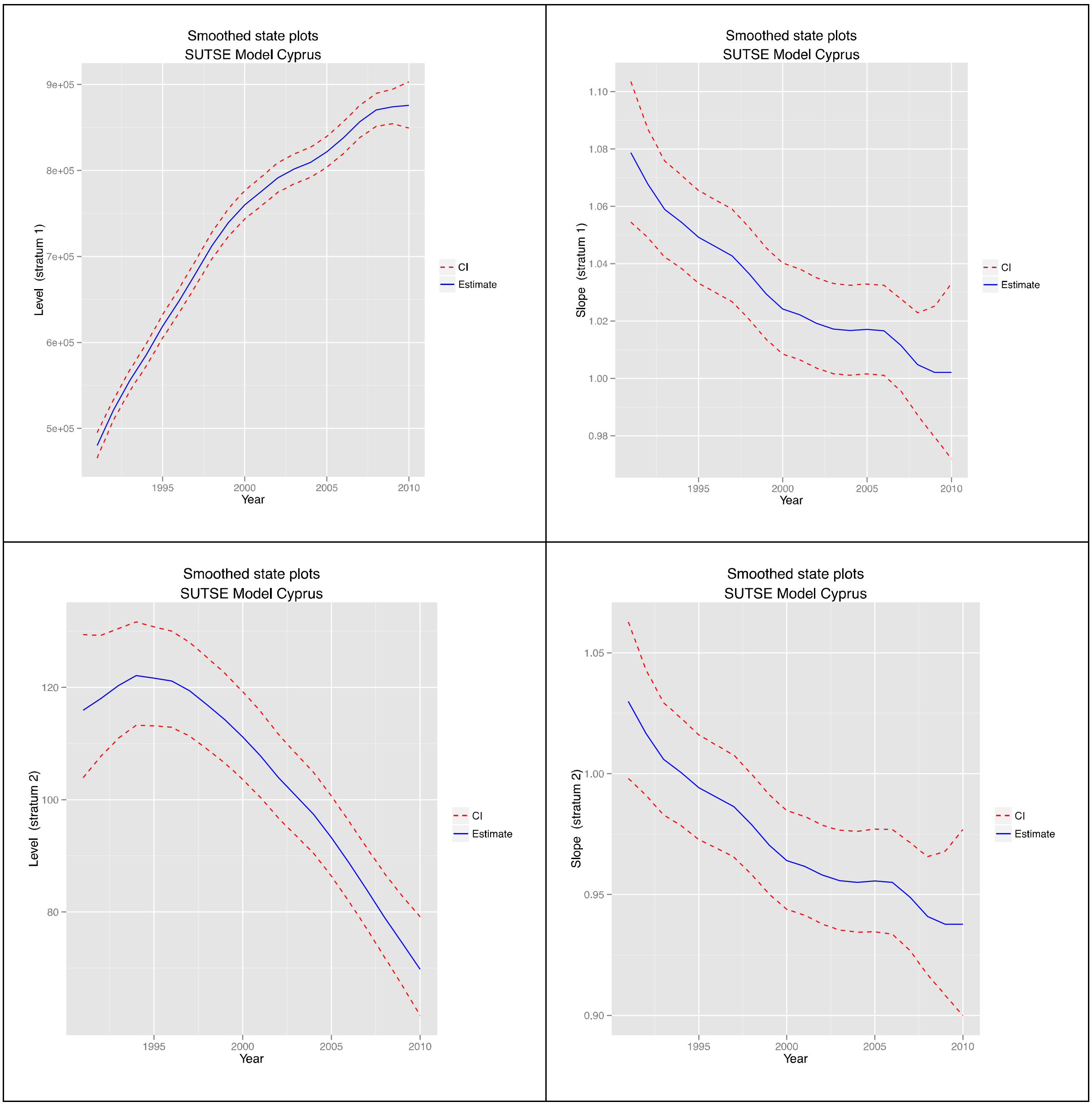


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The slope component varies significantly, while the trend does not. The Cypriot fuel consumption increased from 460 million tn.eq. in 1991 to about 860 million in 2010. As the slope varies significantly, the increase did not take place at the same rate throughout this period. In the early nineties there was an increase of 8%, but since than the yearly increase became less and less and in the most recent years it has practically halted.

2.1.2 Fatalities

The level component varies significantly, whereas the slope does not. The fatalities have dropped from almost 103 in 1991 to 60 in 2010.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

Two state components, the level of exposure and the slope of the fatalities, cannot be considered stochastic. The two levels show a non-significant correlation (p=0.71) and the correlation between the two slopes is also not significant (p=0.13).

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 0.32 which is not significant (p=0.27).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 1.21 and is not significant (p=0.16).

Model title		***SUTSECyprus1***	***SUTSEbetaCyprus1***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	52.96	52.82
	AIC	-105.02	-104.84
Variance of the state components			
	Level exposure	9.22E-05 nsc	9.65E-16 ns
	Level risk	2.55E-04 nsc	3.06E-04 ns
	Slope exposure	1.08E-04 *c	1.12E-04 *
	Slope risk	1.75E-04 nsc	5.74E-19 ns
Correlations between the state components			

level-level	-1	
slope-slope	1	
Observation variance		
Observation variance exposure	3.60E-04 ns	4.12E-04 *
Observation variance risk	1.11E-03 ns	7.76E-04 ns
Beta		1.21 ns

Table 1: Overview of the results for SUTSE models – Cyprus.

3 The LRT Model

The investigation of the SUTSE model did not clearly indicate the presence of a relation between exposure and fatalities in Cyprus. However, there is also reasonable doubt that these two time series are unrelated. The coefficient (beta) that estimates the relation between the two series is not significant but with p=0.16 certainly not small enough to rule out a relation. The nonsignificant relation between the two series, could be due to the few number of measurements. It was therefore decided to base the forecasting procedure on the LRT model.

3.1 Model selection

Three versions of the LRT model were run: the full model, the model with a fixed slope for risk, one where the risk slope and level and the level of exposure were fixed. The residual test for these model variants indicate small violation of the assumptions underlying the Latent Risk model. However, these may be due to the small number of observations. The statistic of the measures that show violations decrease (improve) as we move from LRT1 to LRT3. Furthermore, differencing and other diagnostic tests have been undertaking to investigate possible systematic issues with the data, and none have been presented.

Model title	***LRT 1***	***LRT 2***	***LRT 3***
Model description	LRT for Cyprus – full model	LRT for Cyprus – fixed slope risk	LRT for Cyprus – fixed level exposure, fixed slope and level risk
Model Criteria			
ME10 Fatalities	-2.59	-14.00	-14.00
MSE10 Fatalities	118.25	343.22	343.22
log likelihood	52.96	52.84	52.72
AIC	-105.02	-104.98	-105.05
Model Quality			
Box-Ljung test 1 Exposure	4.70*	4.65*	4.25*

Box-Ljung test 2 Exposure	5.30	5.14	4.76
Box-Ljung test 3 Exposure	5.67	5.46	5.20
Box-Ljung test 1 Fatalities	1.62	1.88	2.16
Box-Ljung test 2 Fatalities	1.91	2.30	2.17
Box-Ljung test 3 Fatalities	2.27	2.50	2.32
Heteroscedasticity Test Exposure	0.47	0.47	0.51
Heteroscedasticity Test Fatalities	2.45	2.22	2.39
Normality Test standard Residuals Exposure	1.98	1.91	1.15
Normality Test standard Residuals Fatalities	5.89	5.65	4.61
Normality Test output Aux Res Exposure	0.92	0.80	0.28
Normality Test output Aux Res Fatalities	3.74	3.51	4.36
Normality Test State Aux Res Level exposure	14.54***	15.16***	10.01**
Normality Test State Aux Res Slope exposure	0.16	0.13	0.10
Normality Test State Aux Res Level risk	2.69	0.74	0.47
Normality Test State Aux Res Slope risk	0.08	0.00	0.00
Variance of state components			
Level exposure	9.22E-05 nsc	8.87E-05 nsc	-
Level risk	6.53E-04 nsc	5.91E-04 nsc	-
Slope exposure	1.08E-04 *c	1.12E-04 *	1.12E-04 *
Slope risk	8.10E-06 nsc	-	-
Correlations between state components			
level-level	-1	-1	
slope-slope	1		
Observation variance			
Observation variance exposure	3.60E-04 ns	3.59E-04 ns	4.12E-04 *
Observation variance risk	1.11E-03 ns	1.15E-03 ns	8.05E-04 ns

Table 2: Overview of the results for LRT models

The comparison of different model versions indicates that fixing the risk slope or level or the exposure level did not lead to a decrease in fit. Based on these observations, the LRT3 model can be selected.

When the last ten years of data are held for prediction, the simpler model has a somewhat better fit, while the other two models have the same fit. Therefore, on the ground of this index, there is not reason to not select the LRT3 model.

3.2 Development of the state components

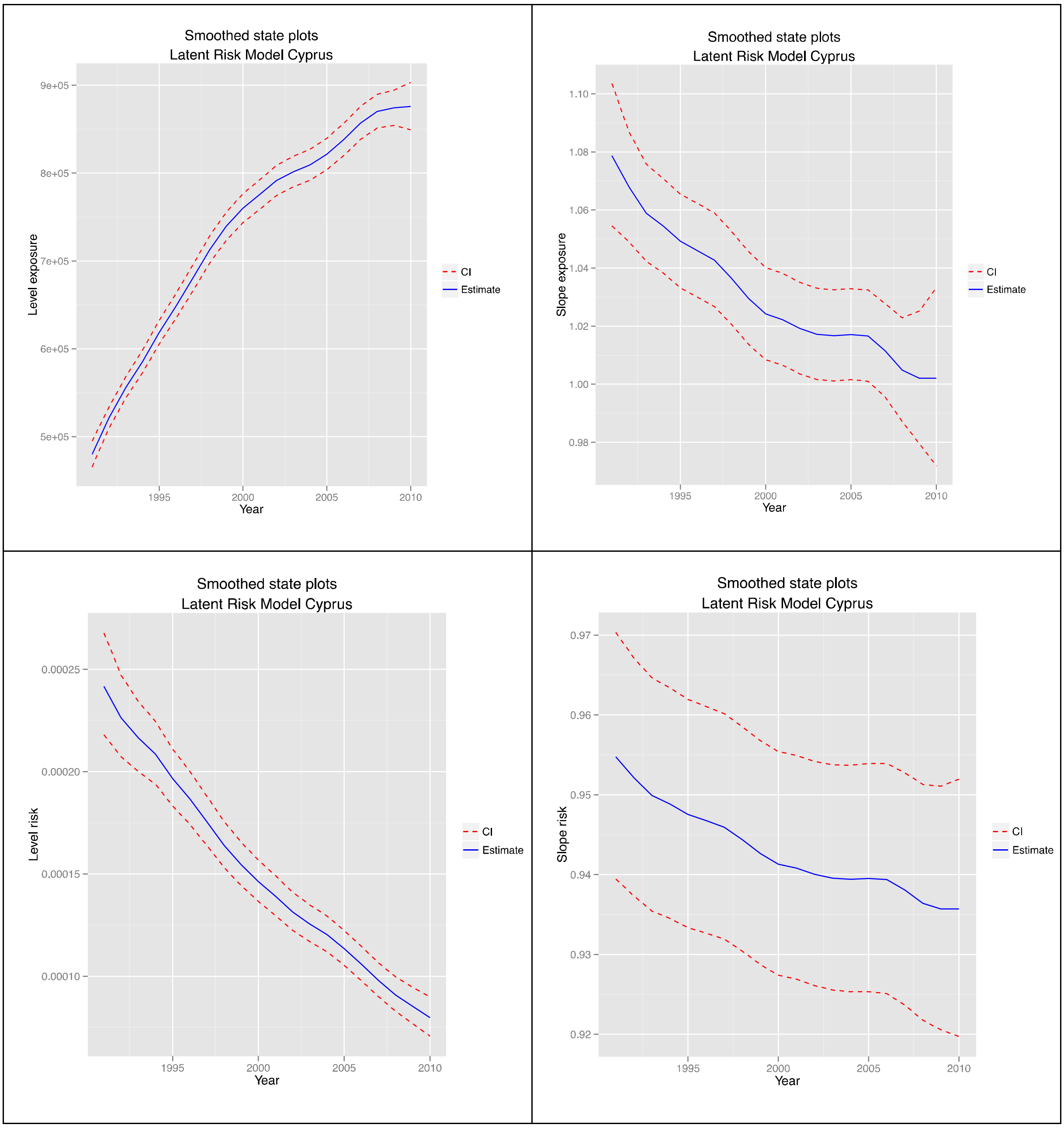


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The fuel consumption in Cyprus increased from 460 thousand tn.eq. of oil in 1991 to almost 870 thousand in 2010. This increase does not take place at the same rate throughout this period however. In the early nineties there was an increase of almost 8%, but since than the annual increase kept decreasing and in the most recent years it has been essentially halted.

3.2.2 Risk

The risk for fatalities has been reduced in Belgium from more than 0.25 per tn.eq. of oil consumed in the early 90s to about 0.08 in the most recent years. This decrease of 4% - 6% yearly is expressed in the negative slope of the risk in the lower left panel of Figure 4.

3.3 Quality of the predictions

To evaluate how well models implemented here have done in the past, the data up to 2000 are used to forecast the fatalities between 2001 and 2010. Figure 5 below shows a comparison between the predicted and actually observed values.

3.3.1 Exposure

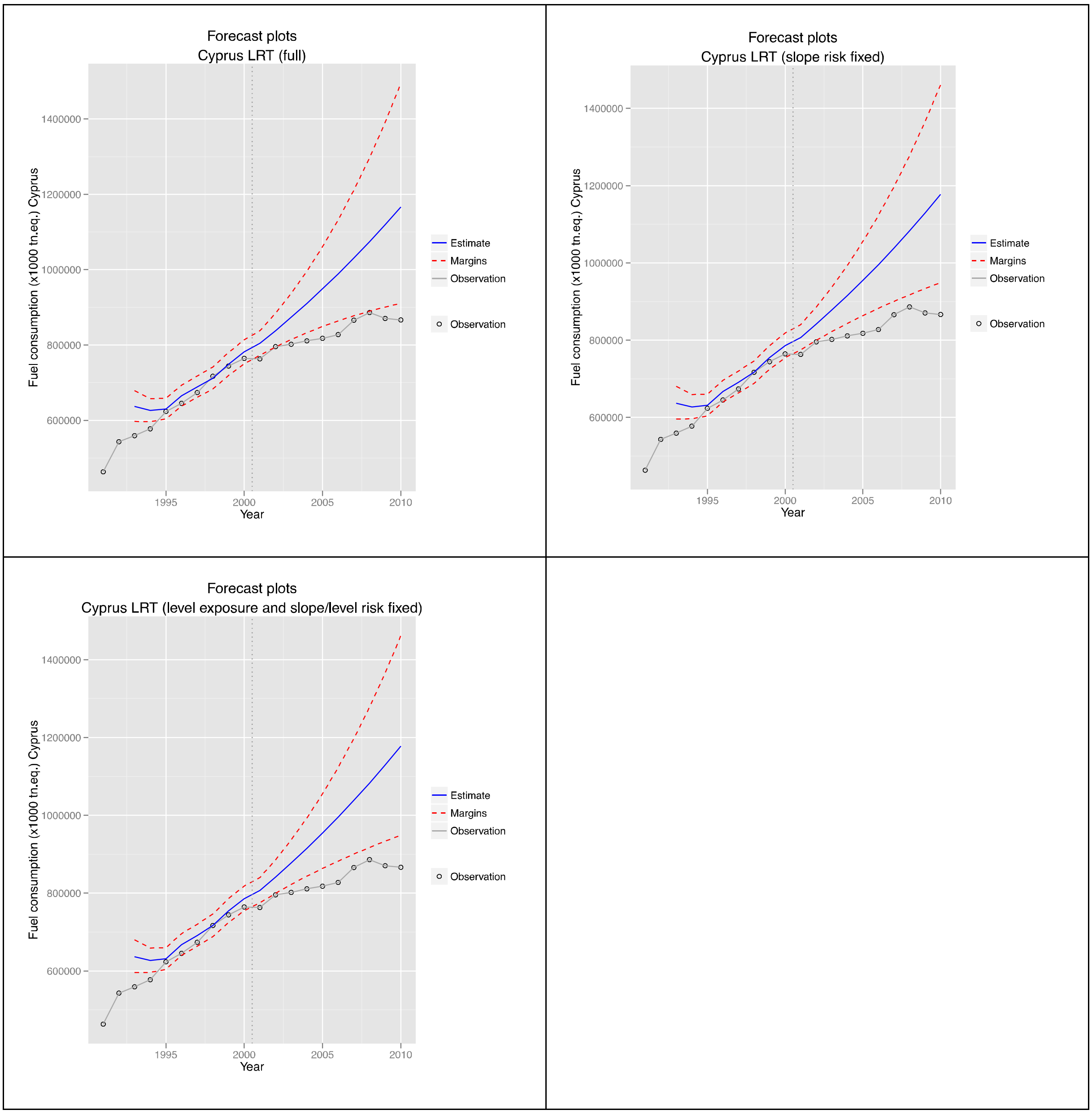


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the exposure numbers in Cyprus.

Up to 2000 Figure 5 shows the predictions (and errors in predictions) that the model would have produced each year if only the prior years had been known. For the years prior to 1995 there is a considerable error in these one-ahead predictions.

For the predicted period 2001-2010, all model variants overestimate the actually observed development.

3.3.2 Fatalities

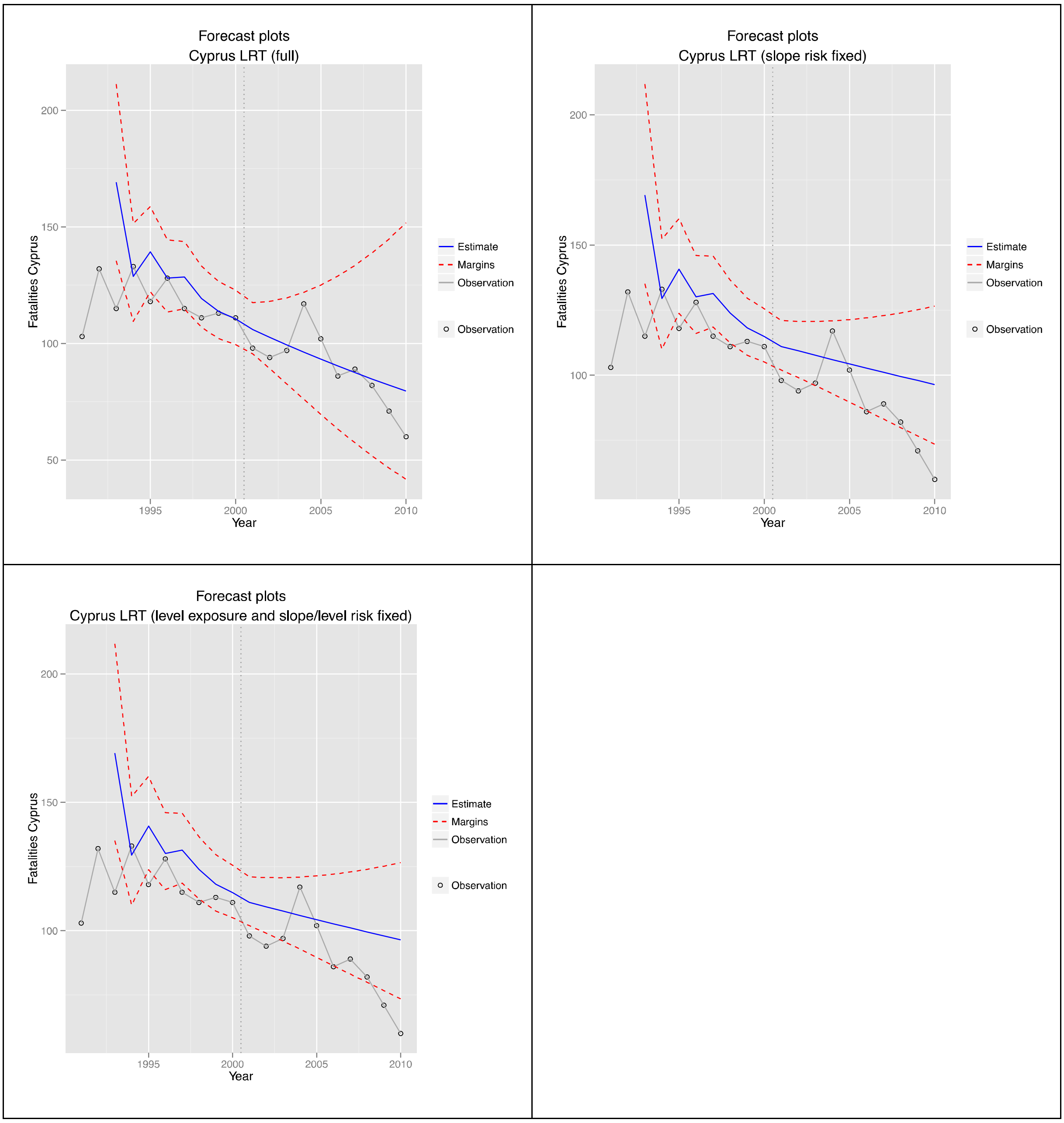


Figure 6: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Cyprus.

In Figure 6, the Cypriot fatalities are forecasted up to 2010 with different variants of the Latent Risk model using data up to the year 2000. The original model LRT1 has larger confidence intervals and manages to include the forecasted values in that. The restricted models LRT2 and LRT3 “miss” the latest values.

4 Forecasts 2011 - 2020

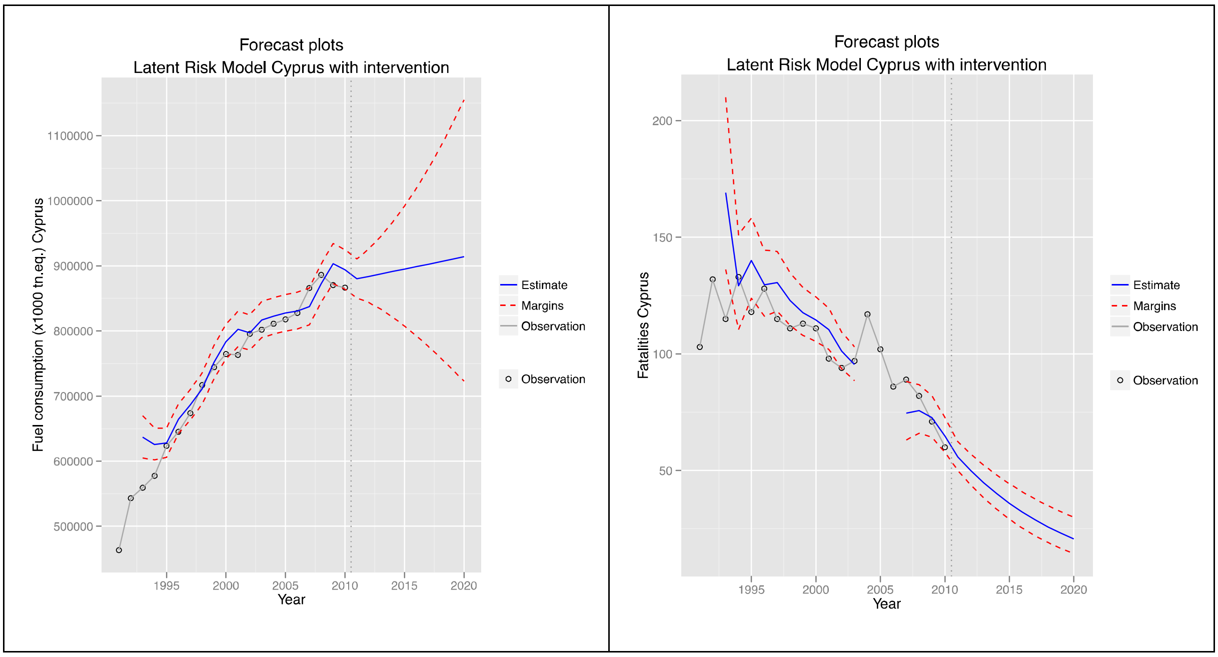


Figure 7: Plot of the fuel consumption (left) and annual fatality numbers (right) for Cyprus forecasted between 2011 and 2020.

The forecasts in Figure 7 and Table 3 provide an indication of the vehicle kilometres and the fatality numbers to be expected between 2011 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Fuel consumption (million tn.eq.)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2011	**880**	823	941	**56**	45	69
2012	**884**	806	969	**50**	39	65
2013	**888**	784	1004	**45**	33	61
2014	**891**	759	1047	**40**	28	57

2015	**895**	731	1096	**36**	24	54
2016	**899**	701	1152	**32**	20	52
2017	**903**	671	1214	**29**	17	49
2018	**906**	639	1285	**26**	14	47
2019	**910**	608	1363	**23**	12	45
2020	**914**	576	1450	**21**	10	43

Table 3: Forecasts of the Latent Risk Model (LRT1 – full model).

5 Scenarios

In Figure 7 it can be seen that there is strong uncertainty about the development of the exposure in Cyprus. Given that the exposure influences the prediction of the fatalities it is interesting to demonstrate how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 8 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

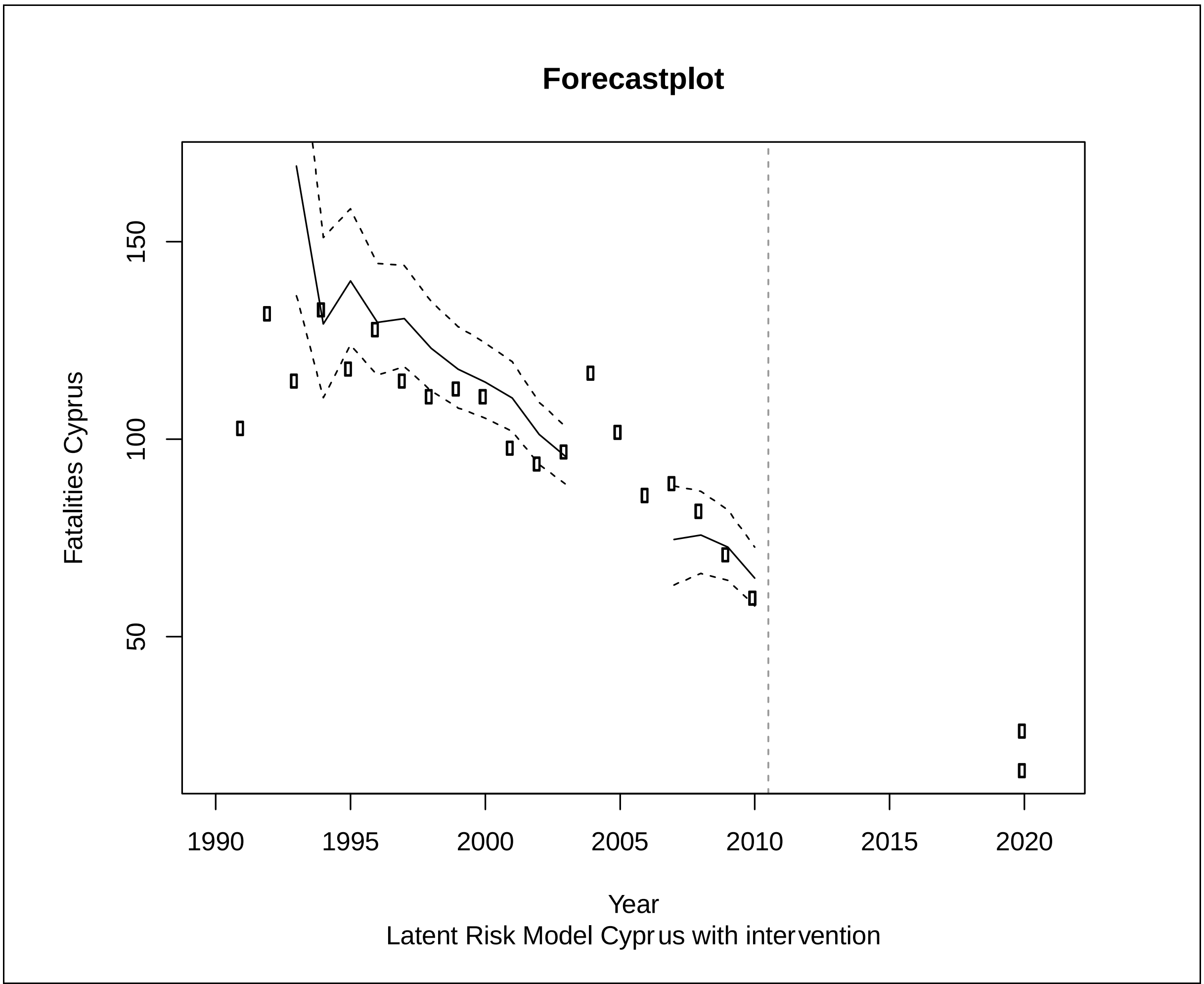


Figure 8: Fatality forecasts Cyprus 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the fuel consumption as predicted from the LRT model plus/minus one standard deviation. Assuming that these predictions are correct, and thus ignoring the uncertainty surrounding the forecasts for the exposure, what would be the consequences for the number of fatalities to be expected in 2020?

The full dot in Figure 7 is the expected number of fatalities given that mobility keeps developing as it has before (prediction 908 million tn.eq. per year). The circles indicate the estimated number of fatalities for an optimistic scenario for exposure (forecast plus one standard deviation: 1155 million tn.eq.) and for a pessimistic scenario (forecasted value minus one standard deviation[6]: 722 million tn.eq.). The prediction that we achieve under these three scenarios are summarized in Table 4.

	Fuel consumption (million tn.ed.)	***Road traffic fatalities***
Situation 2010:	866	60
Prediction for 2020 according to mobility scenarios:		
Continuation of development	908	20
Stronger growth	1155	26
No growth	722	16

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRT 3). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation.

[6] Note that 68% of all cases are between the estimated value +/- one standard deviation (under the assumption of a normal distribution).

CZECH REPUBLIC

1 Raw data

1.1 Exposure

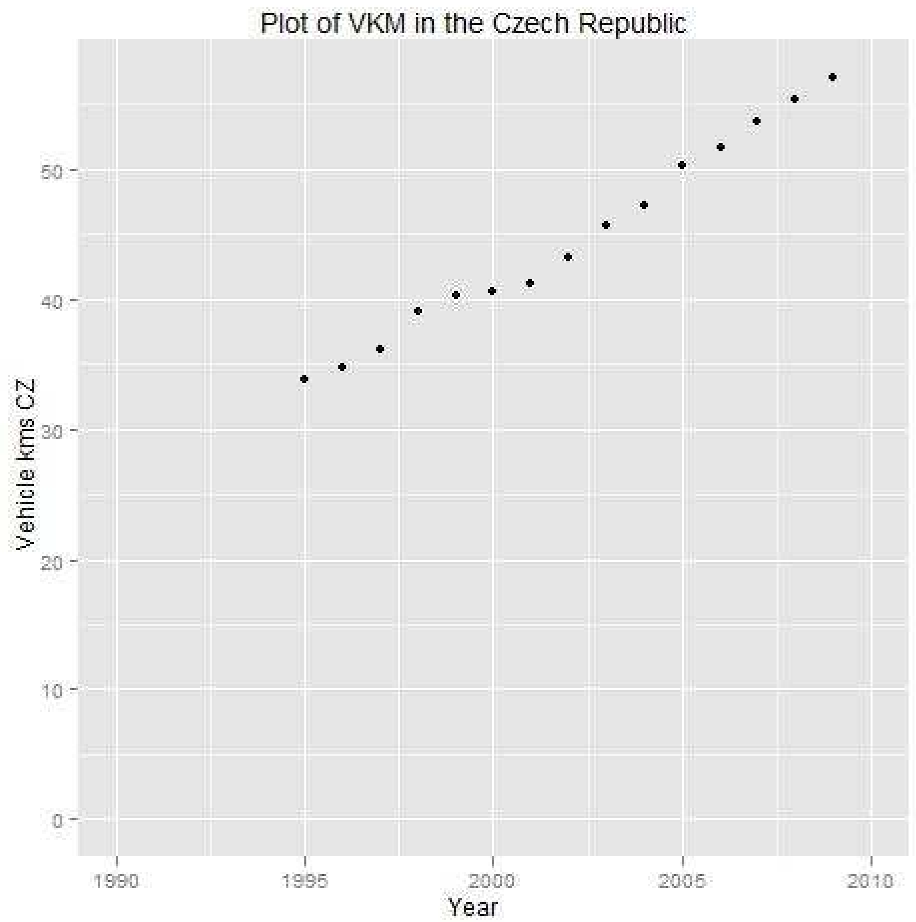


Figure 1: Plot of the annual numbers of vehicle km (in millions) for The Czech Republic from 1995 to 2010.

The annual number of vehicle kilometres is available for the Czech Republic from 1995 to 2009. The vehicle kilometres are measured directly by the traffic census each 5 years, e.g. in

2000, 2005, 2010. In the intermediates years an estimation is done on the basis of partial counting (especially on motorways).

There is a break between 1999 and 2000 where the number of vehicle where the number of vehicle kms stagnates while it increases otherwise[7].

1.2 Fatalities:

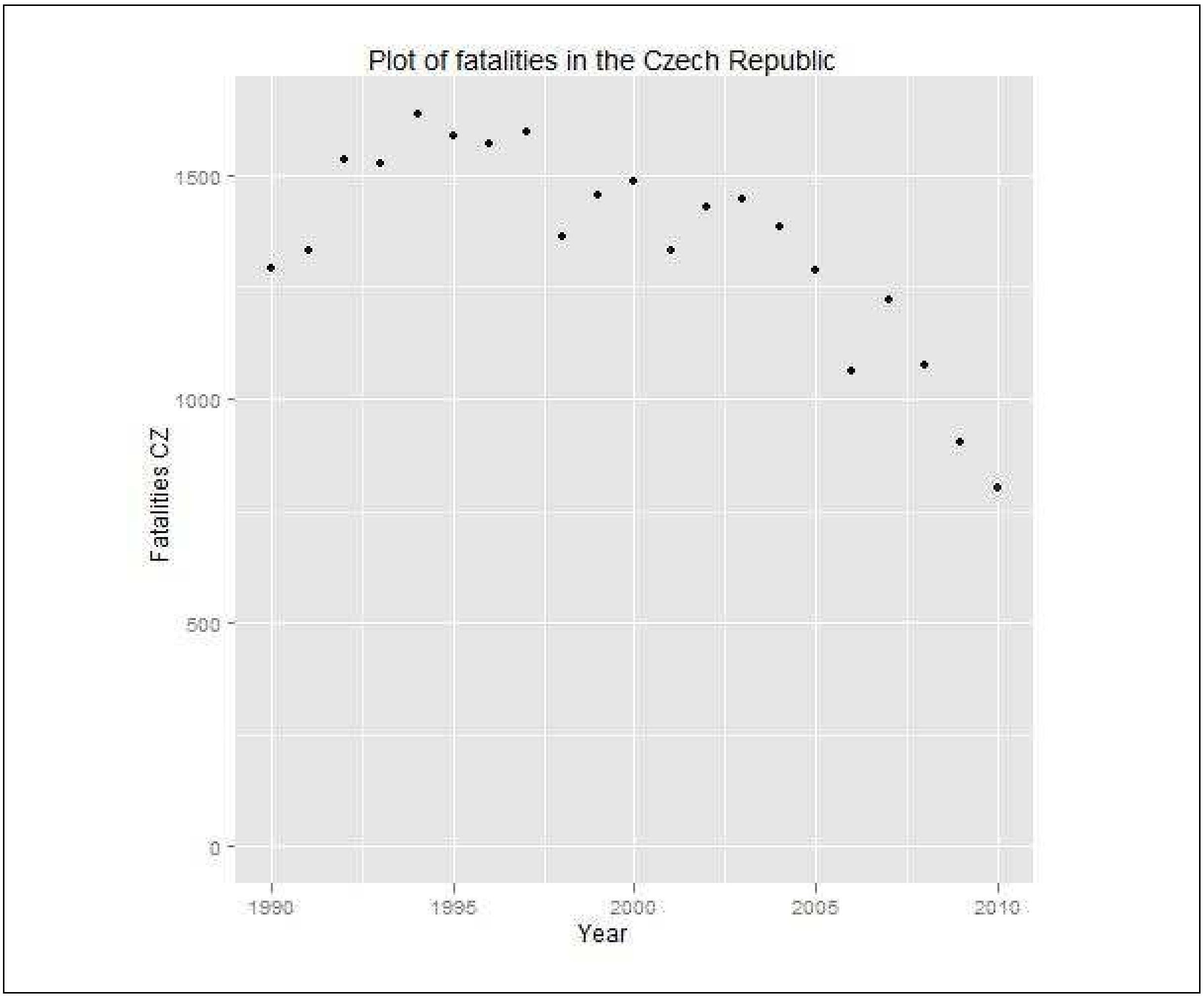


Figure 2: Plot of the annual fatality counts for the Czech Republic from 1990 to 2010.

[7] We do not know what caused this stagnation. It seems to be genuine though, rather than an artefact of measurement (personal communication Jan Tecl, former CARE expert CZ).

We decided to begin our model in 1990, the political system was changed. Moreover it is noteworthy that in 1993, the Czech Republic was split from Slovakia, with which they had formerly formed Chechoslovakia. In the early 90s we notice a strong increase in the number of fatalities, which is related to an increase in traffic volume on the one hand, a change of driver behaviour (less strict police surveillance, more freedom, drivers not used to the new situation) on the other hand. The maximum number of fatalities was registered in 1994 and then a slow decrease started. Some legislative measures were introduced, e.g. speed limits, seat belts, helmets obligation, daily lights and many infrastructural measures in the frame of National safety strategy system. Also a demerit point system was introduced in 2006. Although 2006 showed a very low number of fatalities, in the beginning there were strong problems with the public perception of these measures (anti campaign in the media) and in 2007 there was again a rise in the number of fatalities. Since 2007 a steady decline of number of fatalities can be observed.

2 The SUTSE Model:

2.1 Development of the state components:

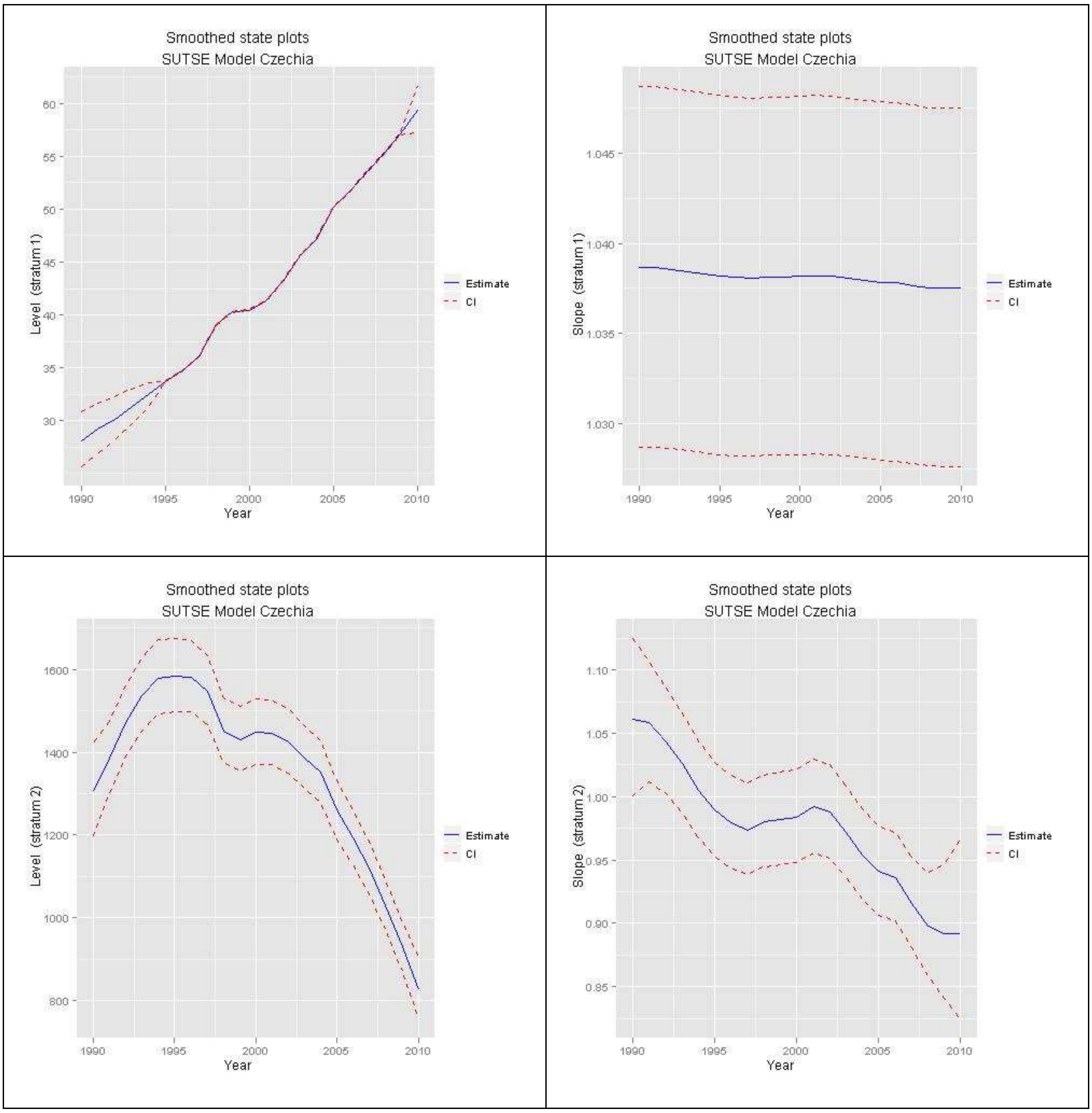


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are

represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend for the number of vehicle kilometres, plotted in the upper left of Figure 7.3 is estimated to have started at 28 billion ($28 * 10^9$) in 1990. The observed series starts in 1995 with 33 billion and ends in 2009 at 57 billion. The trend increase is estimated in a more ore less linear way, which can be seen in the slope in the upper right. The slope indicates the rate of change, with 1 being no change, a slope below 1 signifying a decrease in the trend and a slope above 1 an increase. We see an increase between 3.5 and 4% annually.

For exposure, neither the level nor the slope is significant. This can be explained by the very short series. With p=0.06, the level is approaching significance.

2.1.2 Fatalities

Just as the raw fatality series, the modeled trend shows an increase after 1990 with a peak in 1994. Since then the fatalities have been decreasing. The slope shows a downward development starting with a 5% annual increase in 1990 and ending with a reduction by more than 10% annually between 2008 and 2010. Only around the year 2000 there was a stagnation interrupting this otherwise straight development.

The variance of the slope values over the years is significant, while that of the level is not.

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components:

Both correlations are estimated with a maximal value – that between the levels -1, and that between the slopes 1. However, both correlations involve a non-significant component (slope is non-significant for exposure, and level is non-significant for fatalities). As a consequence these correlations are not meaningful. Neither of them is significant.

2.2.2 Correlation between the irregulars:

Neither the vehicle kilometres nor the number of fatalities show significant irregular disturbances. As a consequence it is not meaningful to test the correlation between these two irregular components, which is indeed not significant.

2.2.3 Estimation of the relationship by means of a coefficient:

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). The beta coefficient for the relationship between the latent developments of the two series is equal to -0.901 and is not significant (p= 0.590).

2.2.4 Conclusion:

None of the test indicate a significant relation between the fatalities and the exposure series. The reason for the non-significant results might lie in the shortness of the exposure series, however.

Model title	***SUTSECz.Rep.1***	***SUTSEbetaCz.Rep1***
Model description	SUTSE full model	SUTSE indipendent components, beta estimated
Model Criteria		
ME10 Fatalities	-584.9	
MSE10 Fatalities	483928.5	
log likelihood	51.61	51.61
AIC	-102.37	-102.46
Model Quality		
Box-Ljung test 1 Exposure	4.40*	4.41*
Box-Ljung test 2 Exposure	4.67	4.69
Box-Ljung test 3 Exposure	4.68	4.71
Box-Ljung test 1 Fatalities	1.21	1.02
Box-Ljung test 2 Fatalities	1.25	1.26
Box-Ljung test 3 Fatalities	1.88	1.78
Heteroscedasticity Test Exposure	0.28	0.29
Heteroscedasticity Test Fatalities	1.74	1.79
Normality Test standard Residuals Exposure	0.16	0.17
Normality Test standard Residuals Fatalities	0.61	0.62
Normality Test output Aux Res Exposure	1.02	1.02
Normality Test output Aux Res Fatalities	1.21	1.19
Normality Test State Aux Res Level exposure	0.44	0.63
Normality Test State Aux Res Slope exposure	0.95	0.27
Normality Test State Aux Res Level risk	0.88	1.32
Normality Test State Aux Res Slope risk	0.03	0.03
Variance of state components		
Level exposure	3.37E-04 nsc	3.37E-04 *
Level risk	2.72E-04 nsc	3.06E-13 ns
Slope exposure	3.04E-08 nsc	6.18E-16 ns
Slope risk	7.25E-04 *c	7.28E-04 ns
Correlations between state components		
level-level	-1	
slope-slope	1	

Observation variance		
Observation variance exposure	1.07E-06 ns	1.15E-06 ns
Observation variance risk	2.22E-03 ns	2.22E-03 ns
Beta		-0.901 ns

Table 1: Model criteria and results for SUTSE models Czech Republic

3 The LLT Model:

3.1 Model selection:

Given that no relationship could be identified between exposure and fatalities on the basis of the data at hand, a Local Linear Trend model was fit to model the fatalities.

In the full model (LLTFat1), the slope is significant but the level is not. Consequently, the level was fixed in LLTFat2 and indeed the model fit of the fixed level model is almost as good as the one of the full model. Fixing the slope (LLTFat3) leads to a reduction in model fit and also to higher prediction errors for models run on data up to 2000 (ME and MSE). While the fixed slope model does still satisfy the model assumptions, these are clearly violated for the model in which the slope and the level are fixed (LLTFat4).

On the basis of model fit and prediction errors, the fixed level model LLTFat 2 is chosen as the forecasting model. This means that the fatalities follow a smooth trend model. It must be noted however, that the different models are very close to each other in terms of model-fit. Even if the slope (which is significant in the full model) is fixed in LLTFat 3, the difference in model fit and predictive quality is minor.

In a smooth trend model, where the slope is allowed to vary, predictions are predominantly based on the most recent development. In this case it means that the models with stochastic slopes (LLTFat1 and LLTFat2) will assume that the strong decrease from the most recent years will continue. A model with a fixed slope will assume the rate of change will return to the average rate of change over the whole time-span. As said before, we have no strong evidence against the fixed slope model for which the predictions are a lot less optimistic.

Model title	***LLTFat1***	***LLTFat2***	***LLTFat3***	***LLTFat4***
Model description	Full LLT fatalities	Fixed level	fixed slope	fixed level & slope
Model Criteria				
ME10	-262	-262	-406	-401
MSE10	114017	114017	238097	218741
log likelihood	21.11	21.11	19.14	10.09
AIC	-41.94	-42.04	-38.10	-20.08

Model Quality				
Box-Ljung test 1	0.92	0.28	0.17	8.53**
Box-Ljung test 2	0.92	0.92	2.05	13.49**
Box-Ljung test 3	1.53	0.92	2.40	18.49***
Heteroscedasticity Test	1.76	1.76	2.11	3.40
Normality Test standard Residuals	0.44	0.44	0.56	2.55
Normality Test output Aux Res	1.49	1.49	0.61	2.15
Normality Test State Aux Res Level	0.46	0.46	0.92	0.58
Normality Test State Aux Res Slope	0.05	0.05	0.00	1.67E-06
Variance of state components				
Level	8.05E-17 ns	-	8.24E-03 *	-
Slope	7.52E-04 *	7.52E-04 *	-	-
Observation variance				
Observation variance	2.38E-03 ns	2.38E-03 *	1.00E-09 ns	1.70E-02 *

Table 2: Overview of the results for the LLT models – Czech Republic.

3.2 Development of the state components:

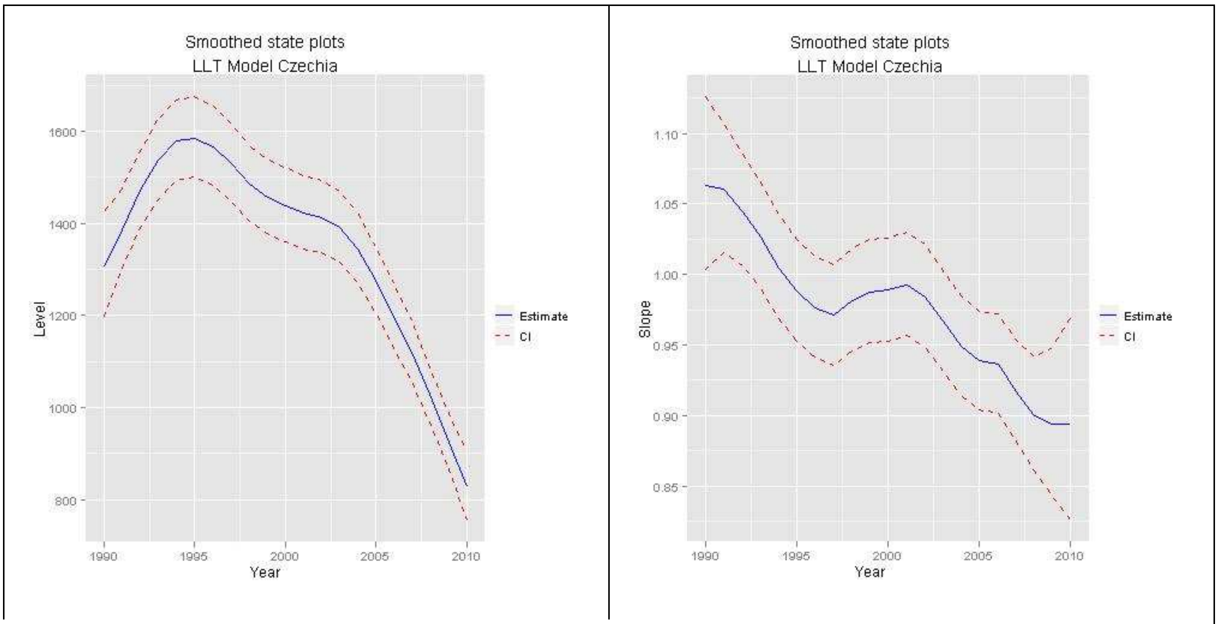


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of LLT2 (fixed level model). The trend (level) development is represented in the left-hand graph, the slope developments in the right-hand graph.

3.2.1 Risk:

The development of road traffic fatalities in the Czech Republic has been undergoing strong changes. The slope shows that the countries fatalities started with an annual *increase* of more than 5% in the 90s and ended with an annual *decrease* of more than 10% in 2010.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 7.5 below shows a plot of the predicted and observed values for the whole series.

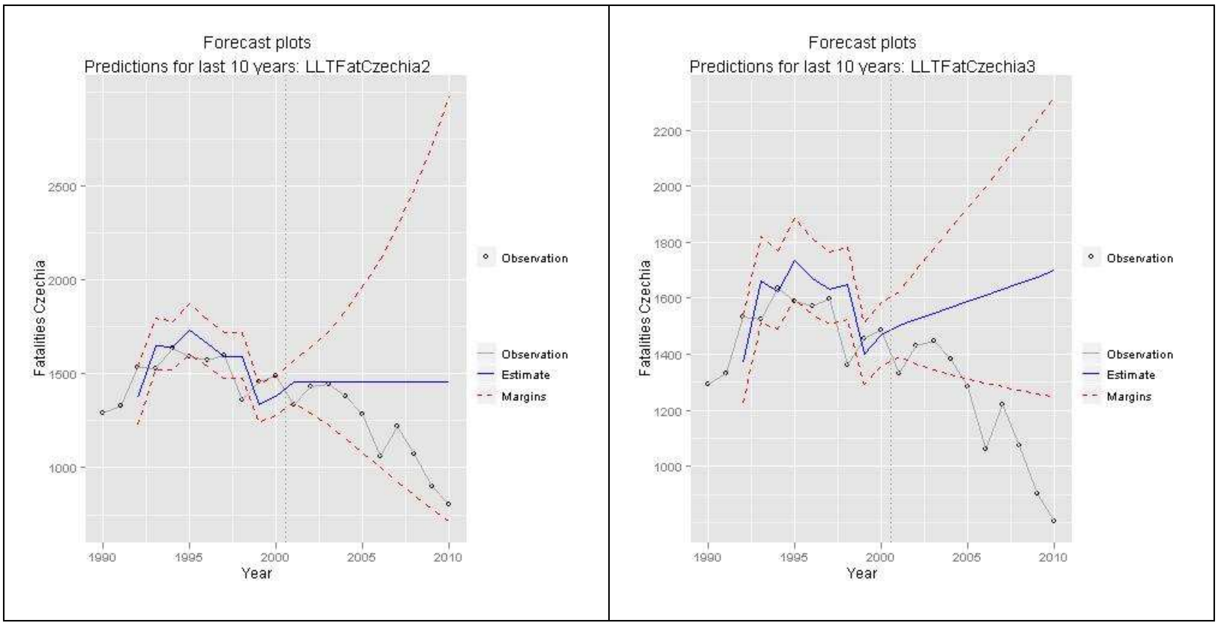


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in the Czech Republic for the fixed level model (LLTFat 2 left-hand graph) and the fixed slope model (LLTfat 3, right hand graph).

On the basis of these plots, it seems clear that LLTFat2, which is plotted on the left is the model that made the best predictions of the fatalities observed since the year 2000.[8]

[8] One must be aware however, that the remaining series on which these predictions are based is extremely short (just 5 years, only 1/3 of the present series) and might not be representative for the present situation.

4. Forecasts 2011 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.*

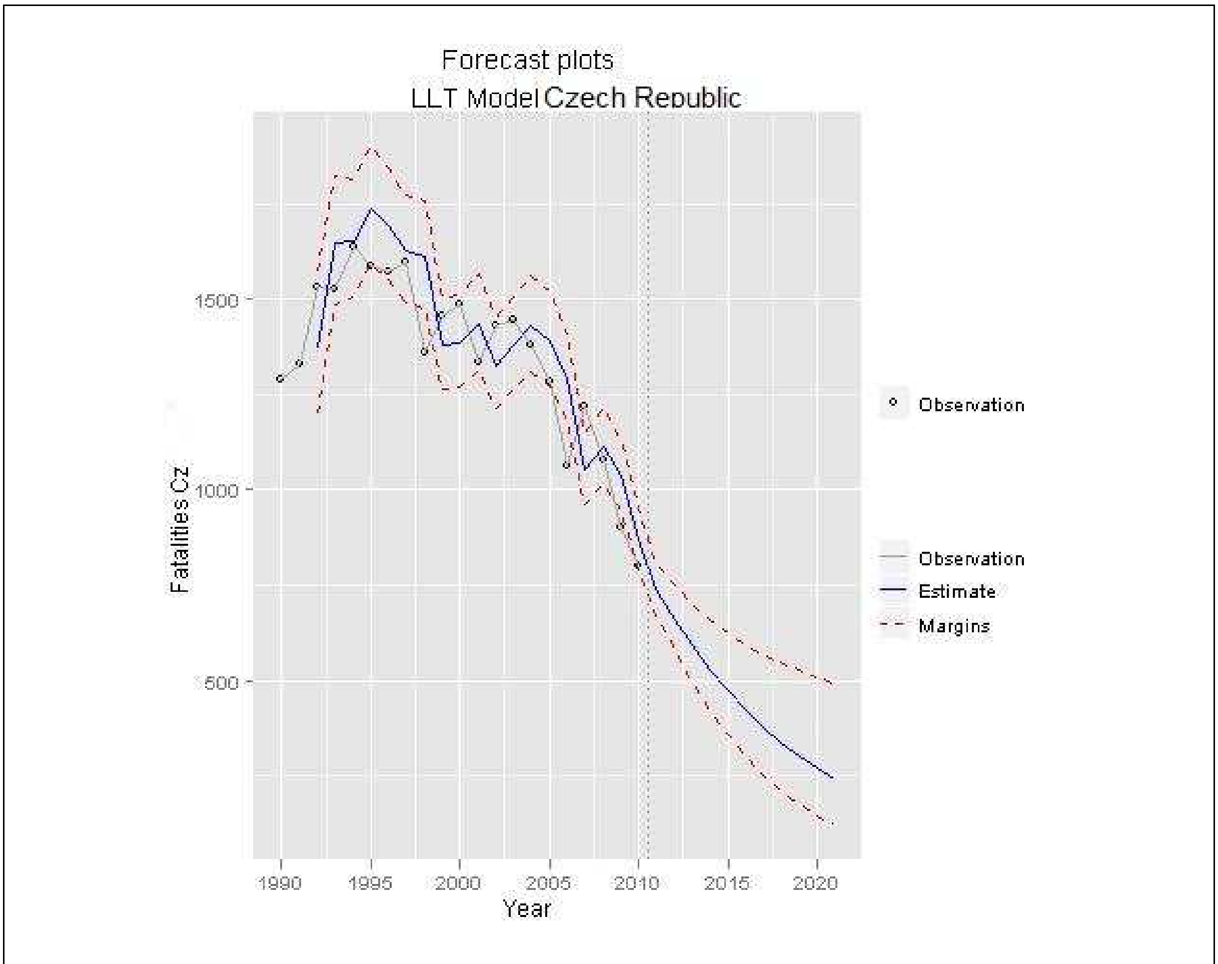


Figure 6: Plot of the annual fatality numbers for the Czech Republic and the forecasts for 2020 (based on Local Linear Trend Model LLTFat2 with a fixed level).

Under this assumption, the annual number of vehicle kilometres should increase up to 87 billion in 2020. And the fatalities should be reduced to 267 in 2020.

	Fatalities	
Year	Predicted	Confidence Interval

2011	**740**	619	885
2012	**662**	516	848
2013	**592**	423	828
2014	**529**	342	820
2015	**473**	273	820
2016	**423**	216	829
2017	**378**	169	846
2018	**338**	132	870
2019	**303**	102	902
2020	**271**	78	942

Table 4: Forecasts of the Local Linear Trend Model with fixed level (LLTFat2).

5 Scenarios

5.1 Nature of the development

In this comparison we will contrast the forecasts for 2020 made by two different models: one with a fixed slope for the fatalities (LLTFat3) and the selected one with a fixed level (LLTFat2).

LLTFat3 is the more pessimistic model, because it assumes that the rate of change for the fatalities is actually constant at -2.5% annually. All deviations from this constant decrease (e.g., the increase in the early 90s and the much stronger decrease since 2007) are attributed to random variations that have no impact on the future rate of change. For the coming years the model consequently assumes a decrease by 2.5% each year, leading to 628 fatalities in 2020.

LLTFat2 is much more optimistic, because it assumes that the rate of change has actually changed over the years. For the future it more or less applies the rate of change from the last few years, namely an decrease of 10% per year, leading to 271 fatalities in 2020.

As can be observed in Figure 7.7, the two models make very different predictions. On the basis of the past observations it is very difficult to differentiate both scenarios, although the reference scenario based on LLTFat2 is slightly more likely.

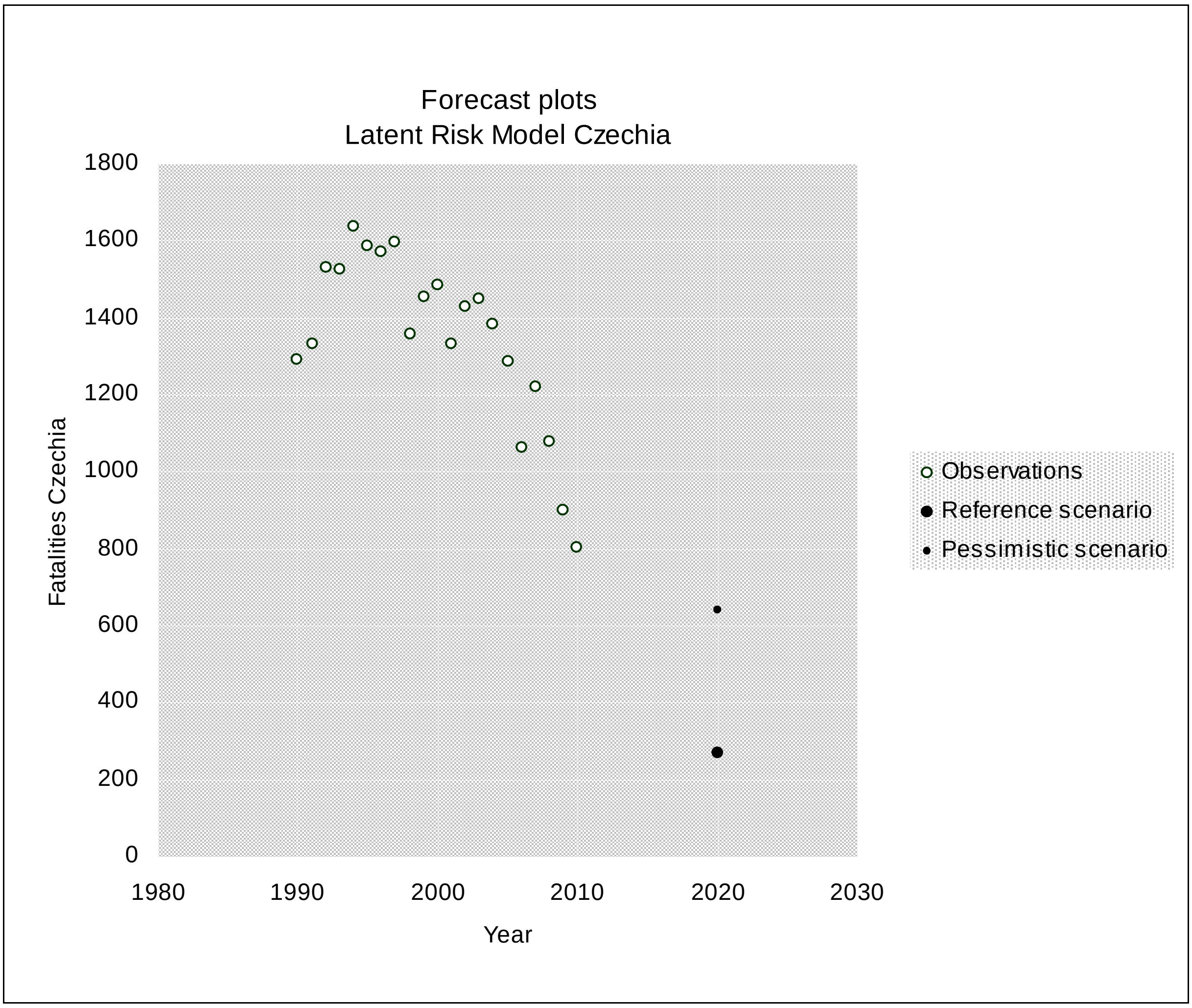


Figure 7: Fatality forecasts Czech Republic 2020 under two different assumptions. ● Reference scenario (LLTfat2): continuation of the trend of most recent years. ◦ Pessimistic scenario (LLTfat3): fall back to mean reduction-rate of the last 20 years.

DENMARK

1 Raw data[9]

1.1 Exposure

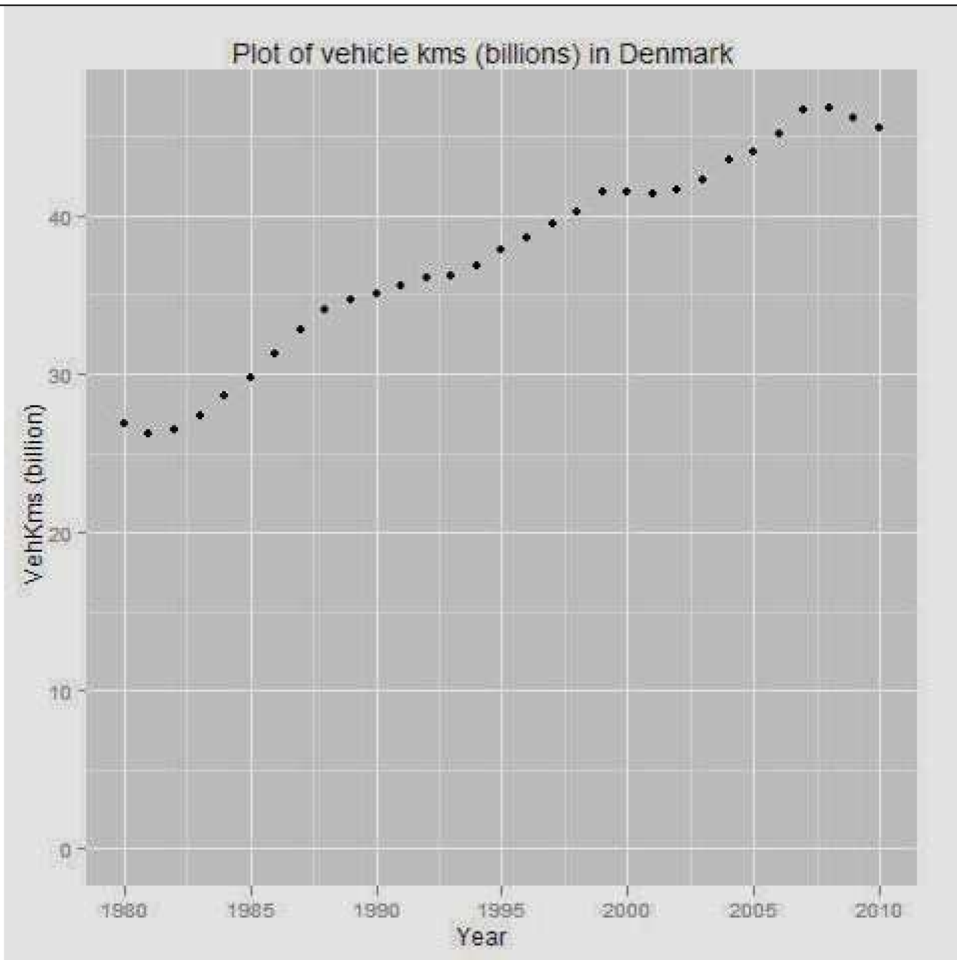


Figure 1: Plot of the annual number of vehicle kilometres (in billion) for Denmark from 1980 to 2010.

Annual vehicle kilometres are available for Denmark from 1980 to 2010. The trend is slightly increasing throughout the years. There are no obvious breaks in the series.

From 2001 to 2004 a new method was used to estimate vehicle kilometres, based on odometer readings collected from the periodical inspection of motor vehicles. This data

[9] Source: Mette Engelbrecht Larsen; Stig Danish Road Directorate, personal communication.

includes driving both in and outside Denmark. This is corrected for by subtracting an estimation of the number of kilometres driven abroad to the total. This estimation is based on an earlier inquiry from 1993.

The vehicle kilometres from 1980 to 2001 have been revised to match the new method, so the entire series is based on the same estimation method.

The vehicle kilometres for the years 2005-2010 are predicted from indicators from the Road Directorate of Denmark.

1.2 Fatalities:

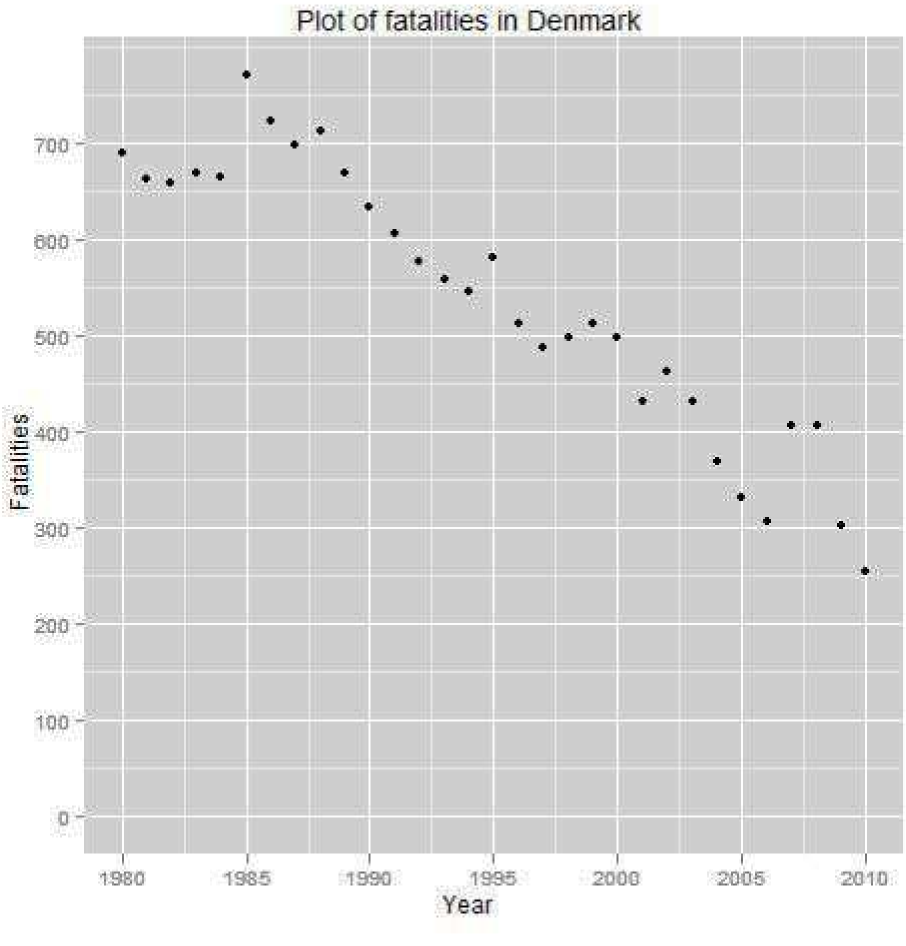


Figure 2: Plot of the annual fatality counts for Denmark from 1980 to 2010.

Fatality data in Denmark is available from 1930 to 2010. However, to match those available for vehicle kilometres, only the fatality counts from 1980 will be taken into consideration.

According to the registration method used in Denmark, an injury is defined as fatal if the person dies from the accident within 30 days. Suicide and deaths not caused by the accident are not included.

Fatality data is collected in cooperation by the Danish Road Directorate, the police and the local regions. The source for fatalities in Denmark is police reports only. Every person involved in an accident who has a Danish social security number is checked against information from the social security register of deaths. Since the country is relatively small, with few fatalities per year and an efficient police reporting system as far as fatalities are concerned, it can be assumed with confidence that the data cover all fatalities due to traffic accidents.

2 The SUTSE Model:

2.1 Development of the state components:

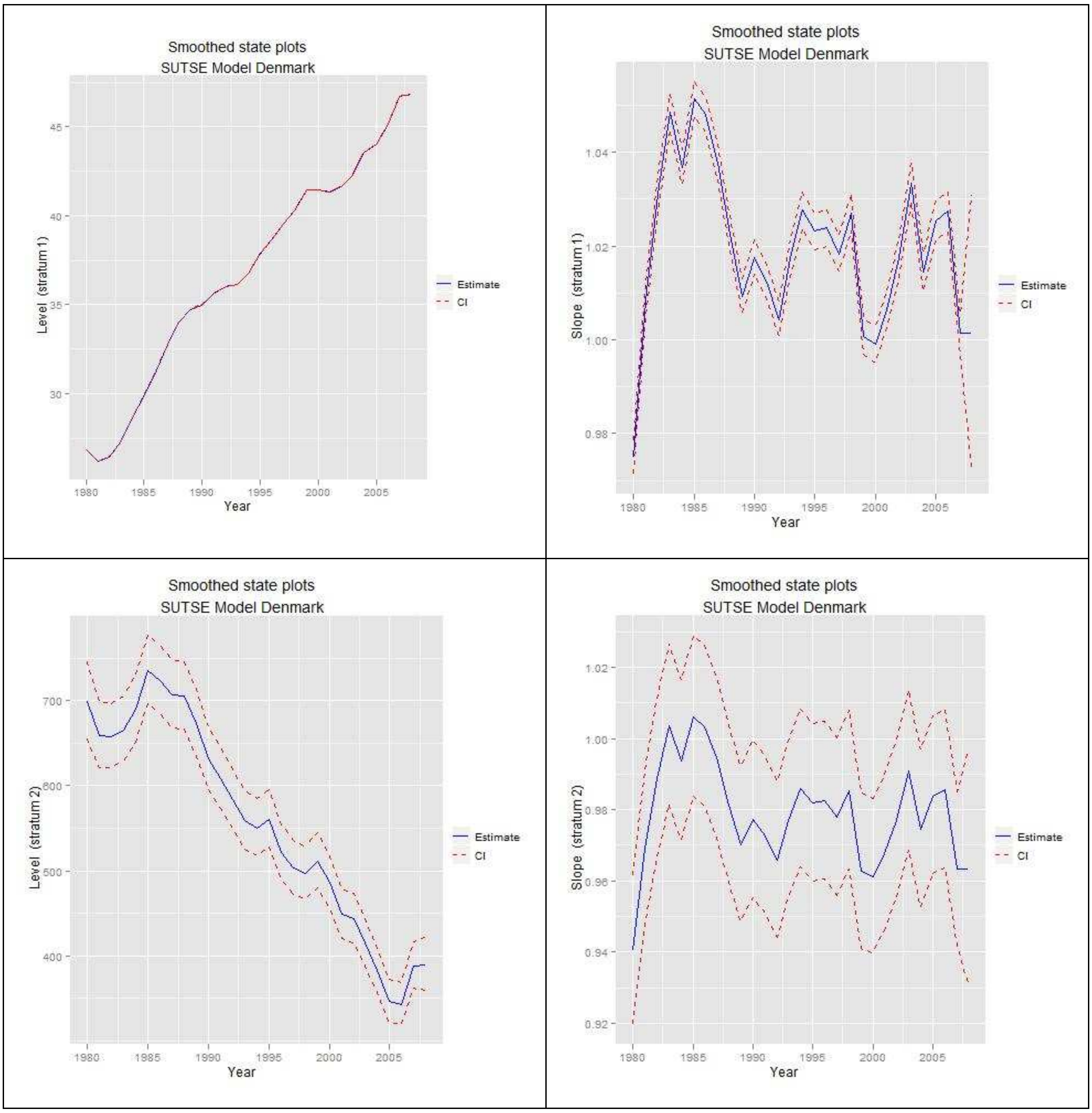


Figure 3: Denmark - Developments of the state components for the exposure (upper graphs) and the fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.2.1 Exposure

The trend for exposure is estimated around 26 billion kilometres at the start of the series and around 46 billion kilometres at the end. There are three visible stagnation periods in the series: 1980-1982; 1989-1992; 1998-2001. The trend is otherwise steadily increasing. It is decreasing however from 2008 onwards.

The various values taken by the slope over the series are plotted in the upper right part of Figure 3. At the start of the series, the slope value was slightly lower than 1, indicating that the vehicle kilometres have been decreasing from 1980 to 1981. Afterwards, the slope values oscillates between 1 and 1.05, and three periods, can be identified, each characterized by a similar pattern for the development of the slope values: first they increase (indicating that the yearly increase in vehicle kilometres becomes stronger), then they decrease back to about 1. Between 2007 and 2008 however, the values of the exposure slopes have decreased in a more dramatic way, to become smaller than 1 between 2008 and 2009. This is the moment where the number of vehicle kilometres started to decrease in Denmark. They did so at the same rate from 2009 to 2010 (annual decrease of about 1%).

According to the results of the SUTSE model, the slope for exposure is the only one to vary significantly over time.

2.2.2 Fatalities

The trend starts with a value of about 690 fatalities in 1980. A strong decrease first took place up to 1982, followed by a transitory increase between 1983 and 1985. From 1985 on the annual fatality numbers have decreased steadily. 255 fatalities have been registered in 2010. As it was the case for the exposure trend, the trend for the fatalities cannot be considered to vary significantly over time.

The development of the slope for the fatalities resembles much that of exposure. Most of the slope values are lower than 1, indicating that the fatality numbers have been decreasing most of the time (the only exception is the 82-85 period). The variation in the values taken by the slope over time is important. For some years the annual reduction is small (around 2,5% for example in the period 94-97), for others it is very important (around 9% at the end of the series, between 2009 and 2010). The variance of the slope values over the years can be considered significant.

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components:

The disturbances of the exposure and fatality slopes can both be considered stochastic. The results also reveal that the correlation between the slope developments for the exposure and fatality series is significant and does not significantly differ from 1. The two series can therefore be considered as being governed by a common slope.

2.2.2 Correlation between the irregulars:

This correlation is equal to .19, and is not significant (p= .66).

2.2.3 Estimation of the relationship by means of a coefficient:

A SUTSE model where the relationship between the two series is estimated on the basis of a fixed regression coefficient does not fit the data better than the current model (see Table 1). This indicates that the relation between the two series does not vary over time. The beta coefficient estimating the relationship between the two series is equal to 1.91, and is significant ($p < .05$).

Model title		***SUTSE Denmark1***	***SUTSEbetaDenmark1***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	134.21	134.21
	AIC	-267.85	-267.91
Hyperparameters			
	Level exposure	1.02E-15 nsc	5.78E-14 ns
	Level risk	1.18E-13 nsc	7.38E-15 ns
	Slope exposure	2.21E-04 *c	2.21E-04 *
	Slope risk	8.04E-04 *c	8.50E-17 ns
Correlations			
	level-level	0.97	
	slope-slope	1	
Observation variances			
	Observation variance exposure	7.60E-07 ns	7.60E-07 ns
	Observation variance risk	3.79E-03 ns	3.79E-03 ns
Beta		/	1.91 (p= 0.006)

Table 1: Model criteria and results for SUTSE models- Denmark.

3 The LRT Model:

3.1 Model selection:

The results of the SUTSE model suggest that the fatality and exposure series are significantly correlated in the case of Denmark. The next step therefore consisted of identifying the version of the Latent Risk Model that would offer the best fit to the data.

Three types of Latent Risk models are fitted. First, the one in which all state components are treated stochastically, one in which the slope for risk is fixed, and finally, one in which both the risk slope and the exposure level are fixed. All three model versions fit the data equally well: the AIC and log-likelihood values can be considered similar. All three model versions also yield significant Box-Ljung tests and a significant heteroscedasticity test for the fatality series. This indicates that the residuals cannot be considered independent and that some dynamic is left unaccounted for in the fatality series. The significant heteroscedasticity test, on the other hand, means that the variance of the residuals is not homogeneous for the whole series.

Inspection of the model's ability to predict the observations for the last ten years (see Section 3.3) allows better understanding the reasons behind this: the model clearly has difficulty accounting for the very large variations in the fatality counts that took place from 2004 onwards (see Figure 5). 2004 is characterised by a very large drop in the number of fatalities, which continues up to 2006. In 2007-2008 however, the fatality numbers suddenly increased, to show a large decrease again from 2009 on.

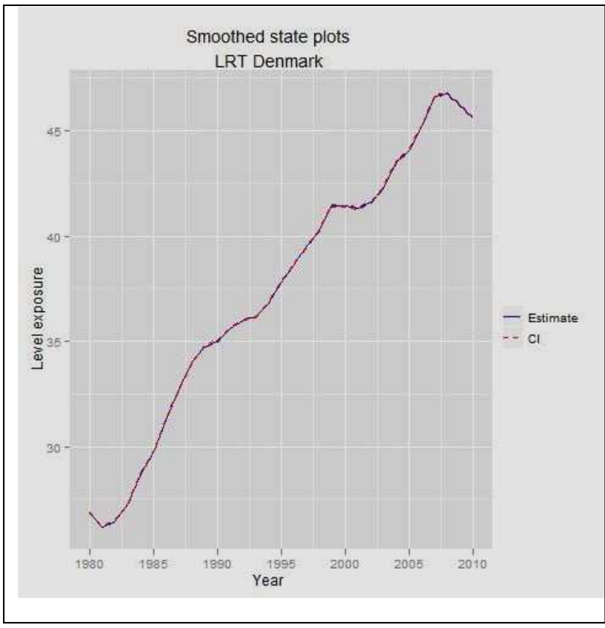
Several additional analyses have been conducted to further explore these wide variations: (1) with 2007-2008 defined as "not available" (thus assuming that these years of large increase are "outlying observations"), and (2) with 2009-2010 defined as missing (assuming that these two years of large decrease are "outlying observations). Both types of analysis allow solving the problems of correlated and heteroscedastic residuals for the fatalities, confirming that this is indeed the last part of the series that lies at the source of the unsatisfying diagnostic tests. However, in the absence of any valid information about the nature of the wide changes that took place in the fatality counts for this period, and having no solid basis to decide that some of them were "outlying" observations, it has been decided to be conservative and present the results for the models based on all the observations. The model selected on this basis is the one in which the risk slope and the exposure level are fixed. It is important to note that the additional analyses that we have conducted consistently led to the selection of the same model. The results indicate that fixing the slopes for risk substantially improves the quality of the predictions.

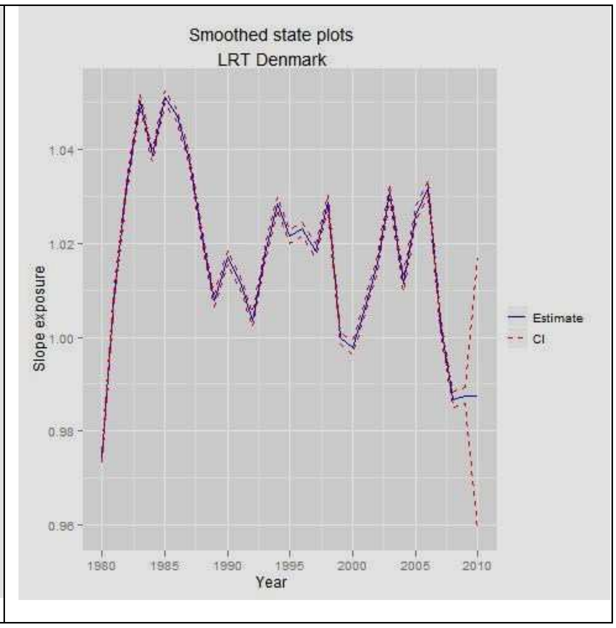
Model title	*LLTDenmark*	*LRT Denmark1*	*LRT Denmark2*	*LRT Denmark3*
Model description	LLT model for fatalities in Denmark	Full LRT model	LRT model with fixed risk slope	LRT model with fixed risk slope and exposure level
Model Criteria				
ME10 Exposure		2.85	2.86	2.85
MSE10 Exposure		11.92	12.05	11.91
ME10 Fatalities	-78.64	-40.15	-26.77	-27.30
MSE10 Fatalities	8718.28	3627.18	2660.08	2689.28
Log-likelihood	36.66	0.46	0.45	0.46
AIC	-73.13	1.17	1.17	1.17
Model Quality				
Box-Ljung test 1 Exposure		0.60	0.74	0.71
Box-Ljung test 2 Exposure		0.68	0.83	0.71
Box-Ljung test 3 Exposure		1.09	1.16	0.83
Box-Ljung test 1 Fatalities	7.20**	8.96**	9.11**	8.32**
Box-Ljung test 2 Fatalities	7.58*	10.09**	10.02**	9.51**
Box-Ljung test 3 Fatalities	9.49*	12.57**	12.69**	12.09**
Heteroscedasticity Test Exposure		1.22	1.00	1.19
Heteroscedasticity Test Fatalities	4.57*	3.85	4.88*	4.10*
Normality Test standard Residuals Exposure		0.25	0.46	0.31
Normality Test standard Residuals Fatalities	4.74	2.99	3.55	1.98
Normality Test output Aux Res Exposure		3.07	2.97	3.13
Normality Test output Aux Res Fatalities	0.77	0.51	0.48	0.91
Normality Test State Aux Res Level exposure		0.40	0.27	0.17
Normality Test State Aux Res Slope exposure		0.22	0.38	0.13
Normality Test State Aux Res Level risk	5.19	0.23	0.73	0.47
Normality Test State Aux Res Slope risk	0.02	0.01	0.00	0.00
Variance of state components				
Level exposure		4.50E-06 nsc	1.46E-05 nsc	
Level risk	5.81E-03 ns	3.74E-03 nsc	4.26E-03 *c	2.38E-03 *
Slope exposure		2.15E-04 *c	1.97E-04 *	2.14E-04 *
Slope risk	3.37E-05 ns	1.68E-04 nsc	-	

Correlations between state components				
level-level		0.98	1	1
slope-slope		1	1	
Observation variance				
Observation variance exposure		8.25E-08 ns	2.21E-08 ns	2.11E-06 ns
Observation variance risk	1.00E-09 ns	1.57E-04 ns	2.90E-05 ns	1.51E-03 ns

Table 2: Overview of the results for the LLT and LRT models - Denmark.

3.2 Development of the state components:





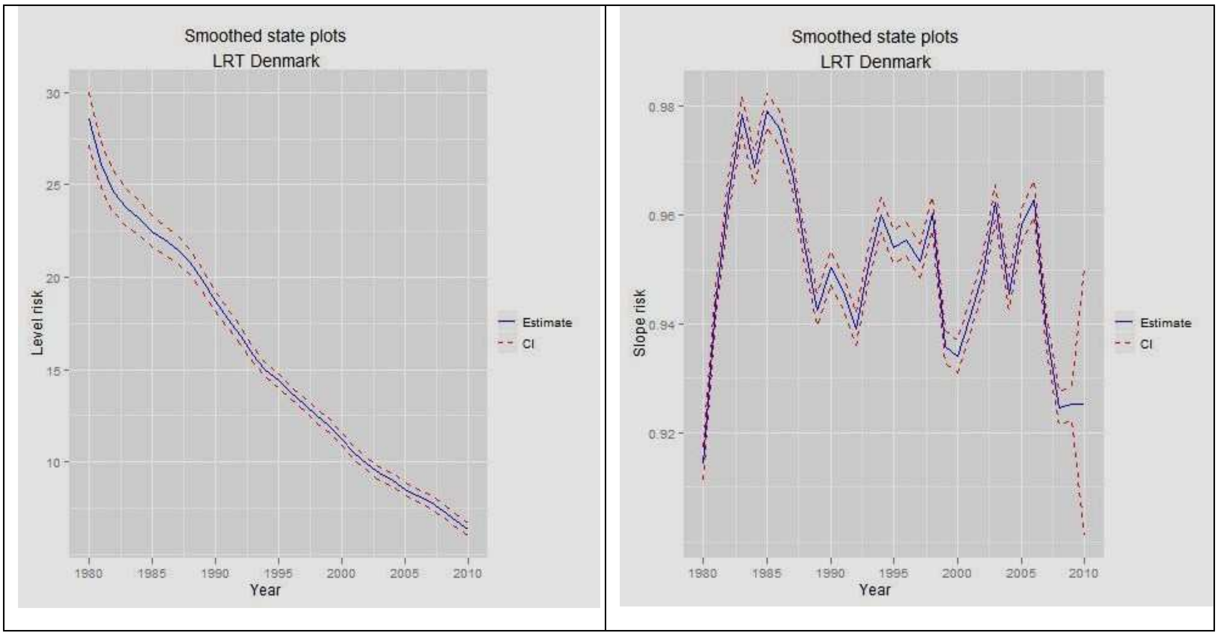


Figure 4: Denmark - Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure:

The slope is the only state component that can be considered stochastic for the exposure series. The values were lower at the start of the series (up to 85) and then started behaving erratically (between 1 and 1.05) for the largest part of the series, indicating that the number of vehicle kilometres have been increasing, but to a varying rate during that period. Since 2008, when the recession started, the number of vehicle kilometres is decreasing again (a 1% decrease has been observed between 2009 and 2010).

The trend for exposure is estimated around 26 billion vehicle kilometres at the start of the series and at about 46 billion kilometres ate the end.

3.2.2 Risk:

None of the state component can be considered stochastic for the risk (although the level appears to be significant in the version of the model where the slope is fixed).

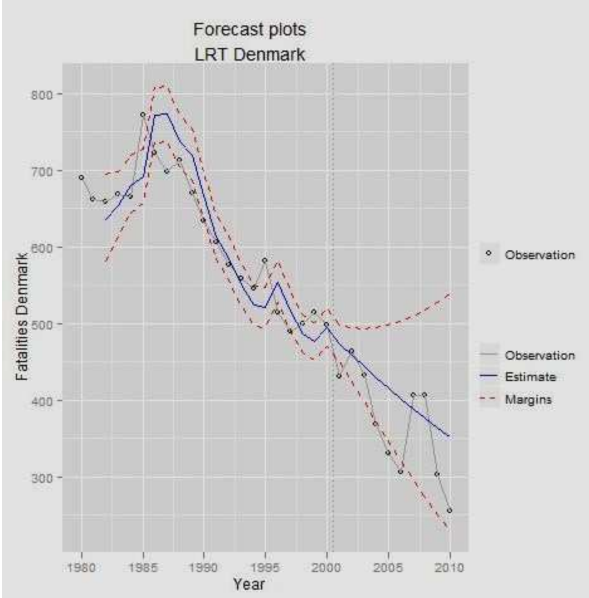
The abrupt increase that was observed at the start of the raw series for the fatalities is not observable anymore once the development of the vehicle kilometres is taken into account. At the start of the series the risk was estimated to be about 27 fatalities per billion kilometres, for the last year observed it was about 3 fatalities per billion kilometres, thus 9 times less.

Although the slope values do not seem to vary significantly over the whole series, they show a declining pattern indicating that the decrease observed at the start of the series became less strong at the end. The risk decrease has been maximal at the start of the series (about

7% yearly decrease in number of fatalities per billion vehicle kilometres). But the annual decrease does not exceed 4% since 2002-2003.

3.3 Quality of the predictions:

The examination of the plots representing the actual and forecasted values for the years 2000 to 2010 reveals that both the LRT with all state components treated stochastically and the one in which the risk slope and exposure trend are fixed have difficulties predicting the low fatality numbers that have been observed from 2004 on. As one can see from Figure 5, the selected model (LRT Denmark 3) performs slightly better in terms of prediction because it overestimates the values for these 4 data less than the full stochastic model does.



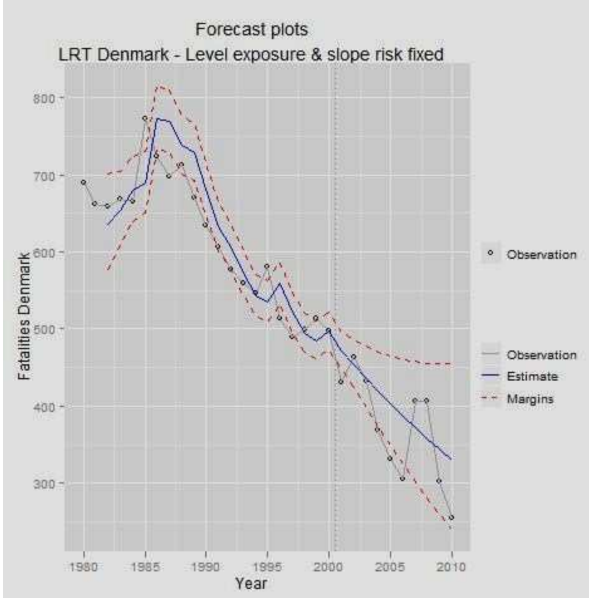


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the 2000 -2010 annual fatality numbers in Denmark for the full LRT model (left-hand graph) and the LRT model with fixed exposure trend, risk trend, and risk slope.

4 Forecasts 2010 – 2020:

The forecasts obtained from the model provide an indication of the vehicle kilometres and fatality numbers to be expected between 2010 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.* Given the strong change observed around 2008-2010 in the exposure series (vehicle kilometres started decreasing), the annual numbers of vehicle kilometres are expected to keep on decreasing to attain some 40 billion vehicle kilometres in 2020.

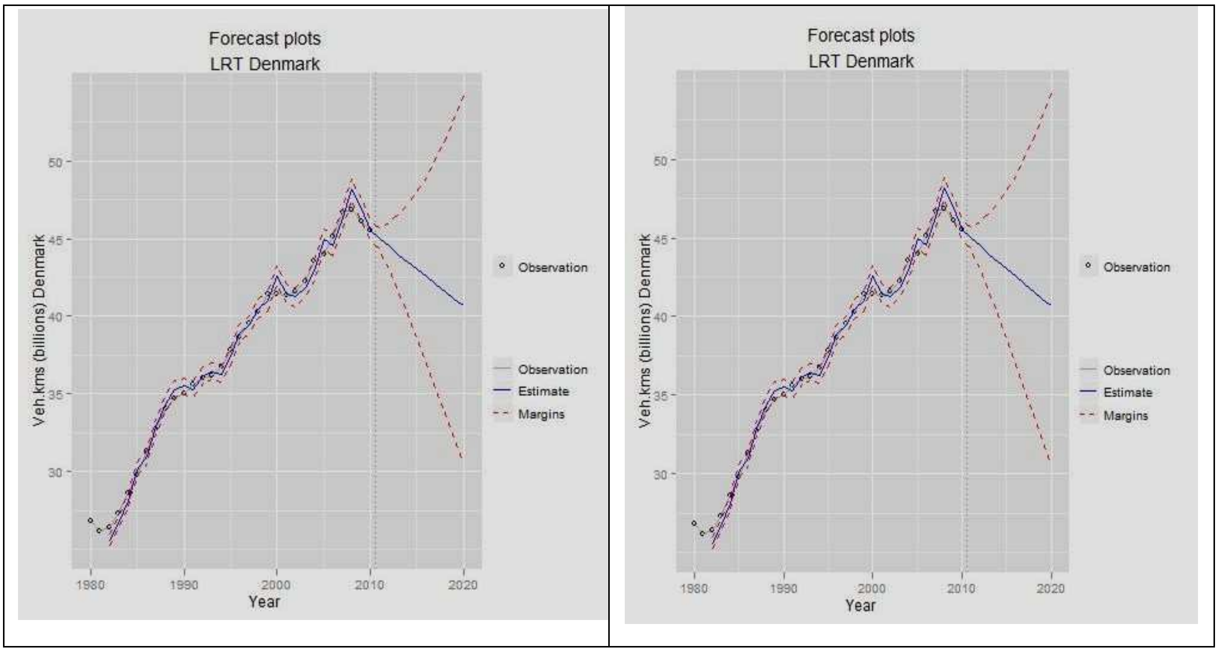


Figure 6: Plot of the vehicle kilometres for Denmark forecasted between 2010 and 2020 on the basis of the full LRT model (left-hand graph) and of the LRT model with a fixed slope for risk and a fixed level for the exposure.

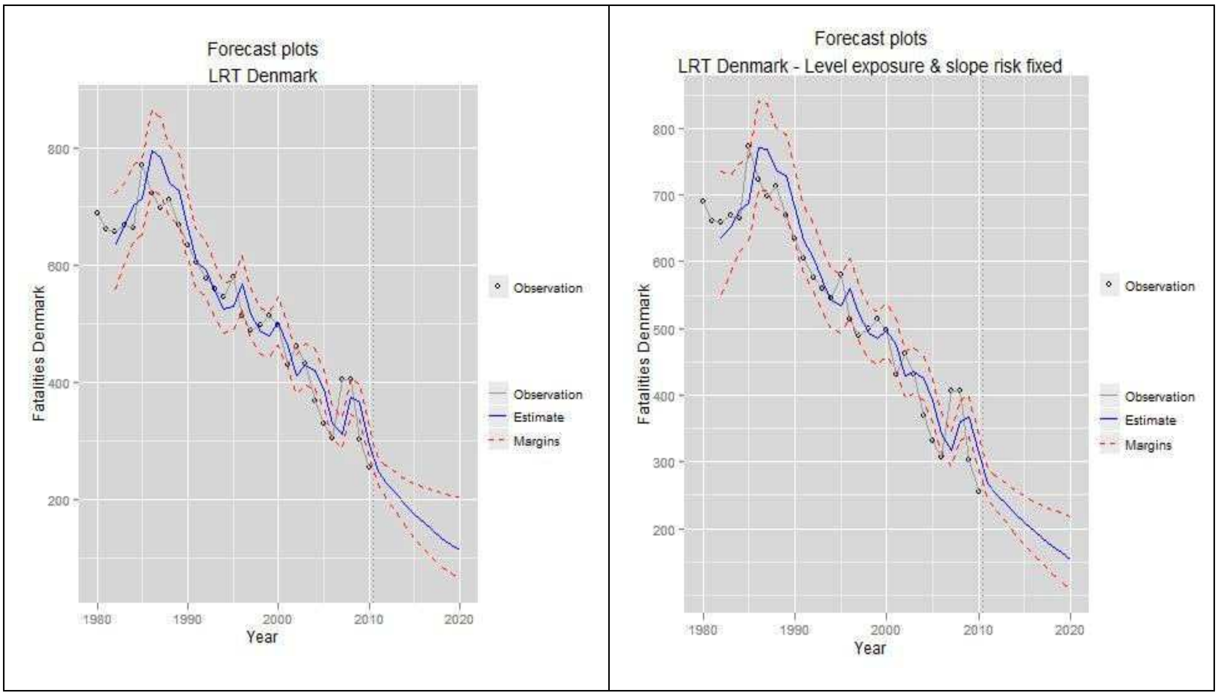


Figure 7: Plot of the annual fatality numbers for Denmark forecasted between 2010 and 2020 on the basis of the full LRT model (left-hand graph) and of the LRT with a fixed risk slope and exposure level.

Still assuming that past developments will extend into the future, the fatality numbers for Denmark should keep on decreasing after 2010 (although at a lower rate than between 1970 and 1990). The predicted value for 2020 is 154 fatalities. Table 3 provides the details of the values forecasted for exposure and fatalities for all years from 2010 to 2020.

	Vehicle kilometres (billion)				Fatalities		
Year	Predicted	Confidence Interval		Year	Predicted	Confidence Interval	
2011	**45**	44	46	2011	**266**	226	314
2012	**44**	42	47	2012	**251**	205	307
2013	**44**	39	49	2013	**236**	185	302
2014	**43**	37	51	2014	**222**	166	298
2015	**43**	35	53	2015	**209**	148	295
2016	**42**	32	56	2016	**197**	132	295
2017	**42**	30	59	2017	**185**	116	295
2018	**41**	27	62	2018	**174**	102	297
2019	**41**	25	66	2019	**164**	90	301
2020	**40**	23	71	2020	**154**	78	306

Table 3: Forecasts of the Latent Risk Model (LRTDenmark3).

5 Mobility Scenarios

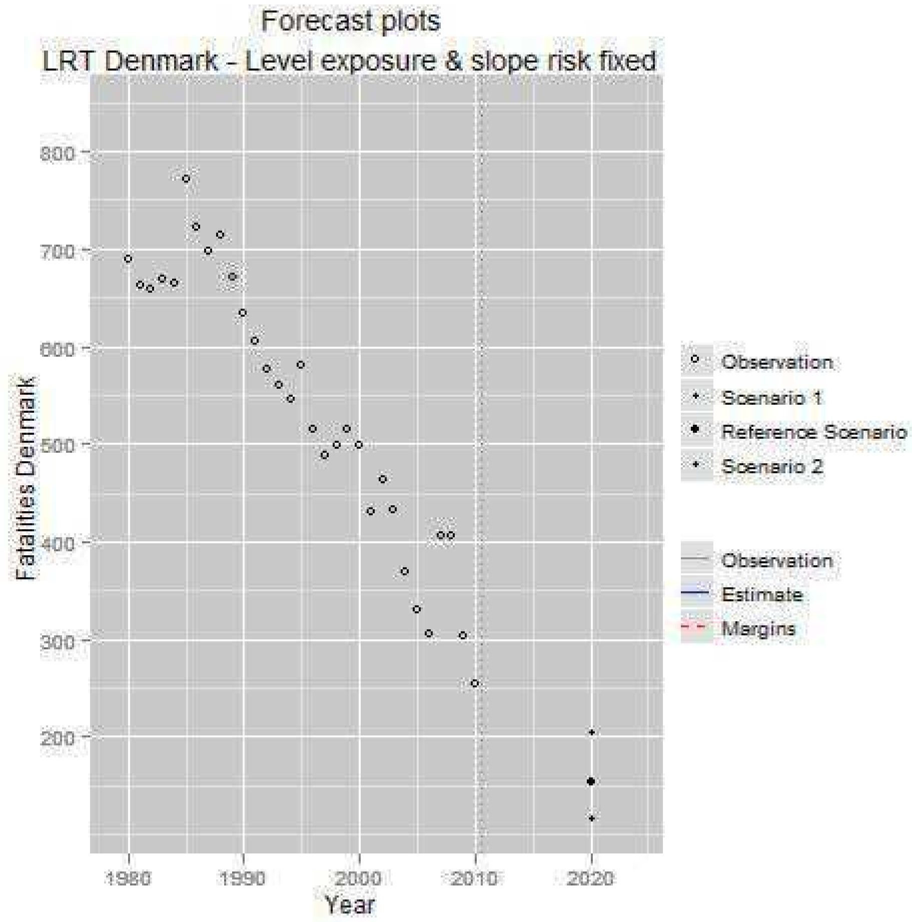


Figure 7: Fatality forecasts Denmark 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT model). ◦ Increase of annual number of vehicle kilometres (LRT estimate + 1 SD). ◦ Stronger decrease of annual number of vehicle kilometres (LRT estimate – 1 SD).

Three scenarios have been calculated to represent different developments of exposure. These scenarios correspond to the number of vehicle kilometres predicted by the model 2020, plus/minus one standard deviation[10]. The values for the exposure scenarios and the estimated number of fatalities under each of them are provided in Table 4, and plotted in Figure.7.

The predicted number of vehicle kilometres for 2020 is 40 billion, a scenario under which one would expect 154 fatalities, and which is represented by a full dot in Figure 7. The circles in

[10] The upper and lower scenarios now include 68% of the cases, assuming a normal distribution.

this figure represent the estimated fatality numbers assuming an increase (forecast plus one standard deviation: 54 billion), or a stronger decrease (forecast minus one standard deviation: 30 billion) in the number of vehicle kilometres. The fatality numbers estimated for each scenario are detailed in Table 4.

	Vehicle kilometres (billions)	***Road traffic fatalities***
Situation 2010:	45.54	255
Prediction for 2020 according to mobility scenarios:		
Continuation of development	40	154
Increase in number of vehicle kilometres	54	206
Stronger decrease than predicted	30	116

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRTDenmark3). Mobility scenarios are based on predicted value +/- one standard deviation.

ESTONIA

1 Raw data:

1.1 Exposure:

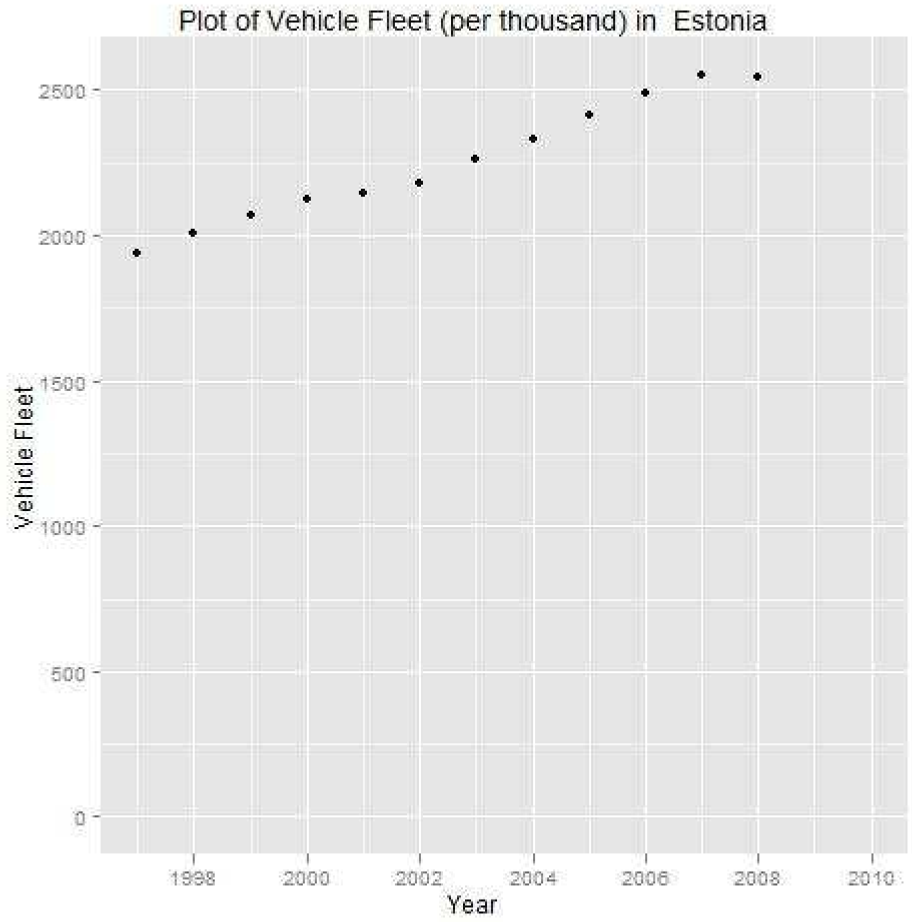


Figure 1: Plot of the annual vehicle fleet (in thousand) for Estonia from 1997 to 2008.

As exposure measure we consider the vehicle fleet (in thousand vehicles). Yearly data are obtained from Eurostat and are available for the period 1997 to 2008.

The plot shows a gradual increase over the years, except in 2008.

1.2 Fatalities:

The plot shows the number of fatalities in Estonia from 1991 to 2010 (data are from IRTAD, except the 2005, 2006, 2007 and 2008 values which are from CARE).

However, given the data restrictions concerning exposure data (see section 1.1.1.), the period 1997 to 2010 is used in the analyses.

In general, there is a decreasing evolution in the number of fatalities. Nevertheless, the numbers in 2002, 2006 and 2007 were rather high.

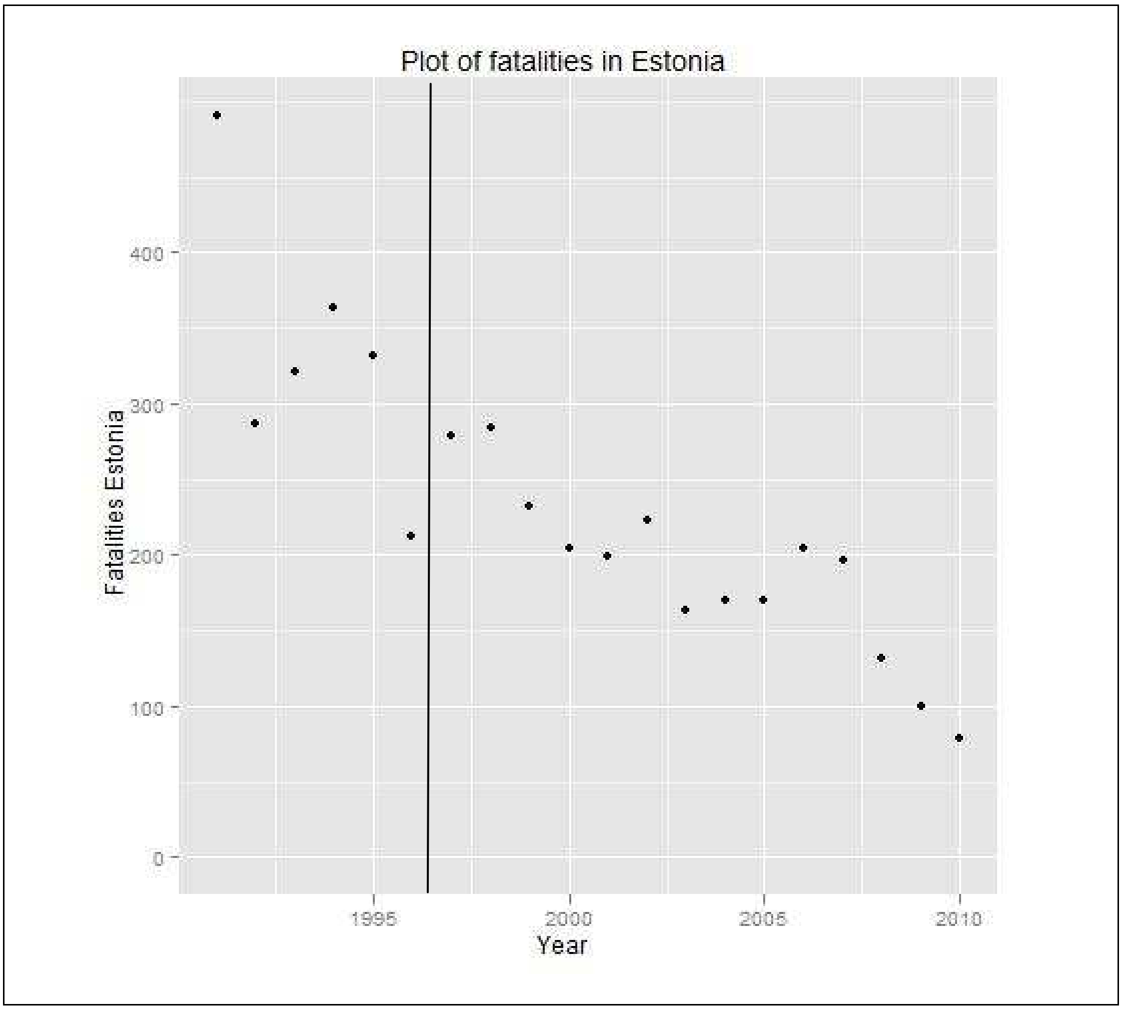


Figure 2: Plot of the annual fatality counts for Estonia from 1991 to 2010.

2 The SUTSE Model:

2.1 Development of the state components:

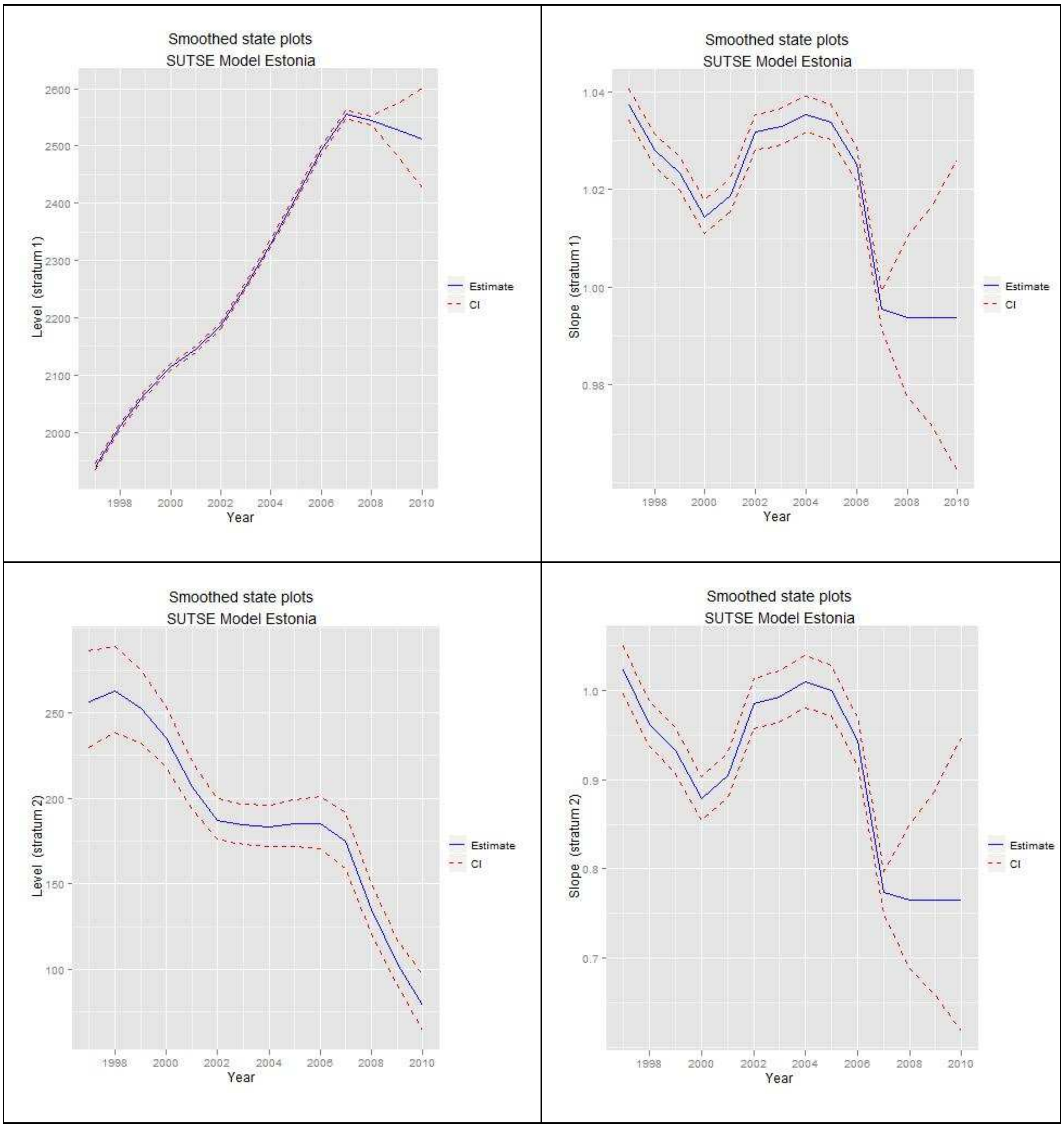


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend in vehicle fleet increased from 1,950,000 in 1997 to 2,550,000 in 2007, after which it decreased. The fluctuating slope implies that the increase up to 2007 did not take place at the same rate throughout this period.

2.1.2 Fatalities

The trend in fatalities has dropped from above 250 1997 to 80 in 2010, but remained constant during the period 2002-2006.

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components

The correlation between the two levels is estimated as 0.69 and the correlation between the two slopes as 1. The correlation between the two levels is not significant (p=1) whereas the correlation between the two slopes is significant (p=0.02).

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -0.81 which is not significant (p=0.33).

2.2.3 Estimation of the relationship by means of a coefficient

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). However, the beta coefficient for the relationship between the latent developments of the two series is equal to 6.79 and is significant (p=0.02).

2.2.4 Conclusion

It can be concluded that the fatalities and vehicle fleet series are related and therefore further modeling will be made using the LRT model.

Model title		***SUTSE Estonia1***	***SUTSEbetaEstonia1***
Model description		SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	26.88	26.88
	AIC	-52.48	-52.62
Hyperparameters			
	Level exposure	9.35E-17 nsc	2.01E-14 ns
	Level fatalities	9.59E-12 nsc	6.91E-12 ns
	Slope exposure	1.31E-04 *c	1.31E-04 *
	Slope fatalities	6.06E-03 *c	2.22E-14 ns
Correlations			
	level-level	0.69	
	slope-slope	1	

Observation variances		
Observation variance exposure	4.98E-06 ns	4.98E-06 ns
Observation variance fatalities	6.84E-03 ns	6.84E-03 ns
Beta	/	6.79 (p= 0.02)

Table 1: Model criteria and results for SUTSE models - Estonia

3 The LRT Model:

3.1 Model selection:

The results of the SUTSE model suggest that the fatality and exposure series are significantly correlated in the case of Estonia. The next step therefore consisted of running LRT models in order to identifying the version of the Latent Risk Model that would offer the best fit to the data.

First, the full LRT model (LRTEstonia1) is run. Taking into account the results concerning both slopes in Table 1 (*c), a LRT model with fixed risk slope is run (LRTEstonia2). Given the fact that the level and slope component of exposure appeared to be non-significant in this second model, the level of exposure was subsequently fixed in the next model (LRTEstonia3). In this model, all remaining components were significant, so no further modelling was required.

Below, the results of the three LRT models are presented. The residual tests for all three model variants do not indicate a violation of the assumptions. In the end, we opt for the most parsimonious model with the lowest prediction errors (see ME10 Fatalities and MSE10 Fatalities), i.e. the LRT model with fixed risk slope and fixed exposure level (LRTEstonia3), as the forecasting model.

Model title	LRT Estonia1	LRT Estonia2	LRT Estonia3
Model description	Full Model	Fixed slope risk	Fixed slope risk and fixed level exposure
Model Criteria			
ME10 Fatalities	83.87	50.07	48.87
MSE10 Fatalities	8251.84	3479.46	3379.49
log likelihood	26.88	24.53	24.53
AIC	-52.48	-48.07	-48.35
Model Quality			
Box-Ljung test 1 Exposure	1.32	0.47	0.10
Box-Ljung test 2 Exposure	2.06	0.58	0.47
Box-Ljung test 3 Exposure	3.56	3.02	0.56
Box-Ljung test 1 Fatalities	2.74	3.21	3.21
Box-Ljung test 2 Fatalities	4.04	3.21	3.21
Box-Ljung test 3 Fatalities	5.32	3.61	3.62
Heteroscedasticity Test Exposure	0.73	0.31	0.31
Heteroscedasticity Test Fatalities	0.85	2.35	2.35
Normality Test standard Residuals Exposure	0.83	0.35	0.35
Normality Test standard Residuals Fatalities	0.37	0.62	0.62
Normality Test output Aux Res Exposure	0.45	0.12	0.13
Normality Test output Aux Res Fatalities	1.26	1.86	1.84
Normality Test State Aux Res Level exposure	0.45	0.24	0.24
Normality Test State Aux Res Slope exposure	0.00	0.22	0.24
Normality Test State Aux Res Level risk	0.28	0.65	0.66
Normality Test State Aux Res Slope risk	0.03	0.04	0.04
Variance of state components			
Level exposure	7.78E-17 nsc	1.64E-08 nsc	-
Level risk	2.64E-13 nsc	2.24E-02 *c	2.23E-02 *
Slope exposure	1.31E-04 *c	1.63E-04 ns	1.63E-04 *
Slope risk	4.41E-03 *c	-	-
Correlations between state components			
level-level	0.99	-0.69	
slope-slope	1		
Observation variance			
Observation variance exposure	4.98E-06 ns	1.04E-09 ns	1.39E-09 ns
Observation variance risk	6.84E-03 ns	2.91E-08 ns	2.19E-07 ns

Table 2: Overview of the results for LRT models - Estonia

3.2 Development of the state components:

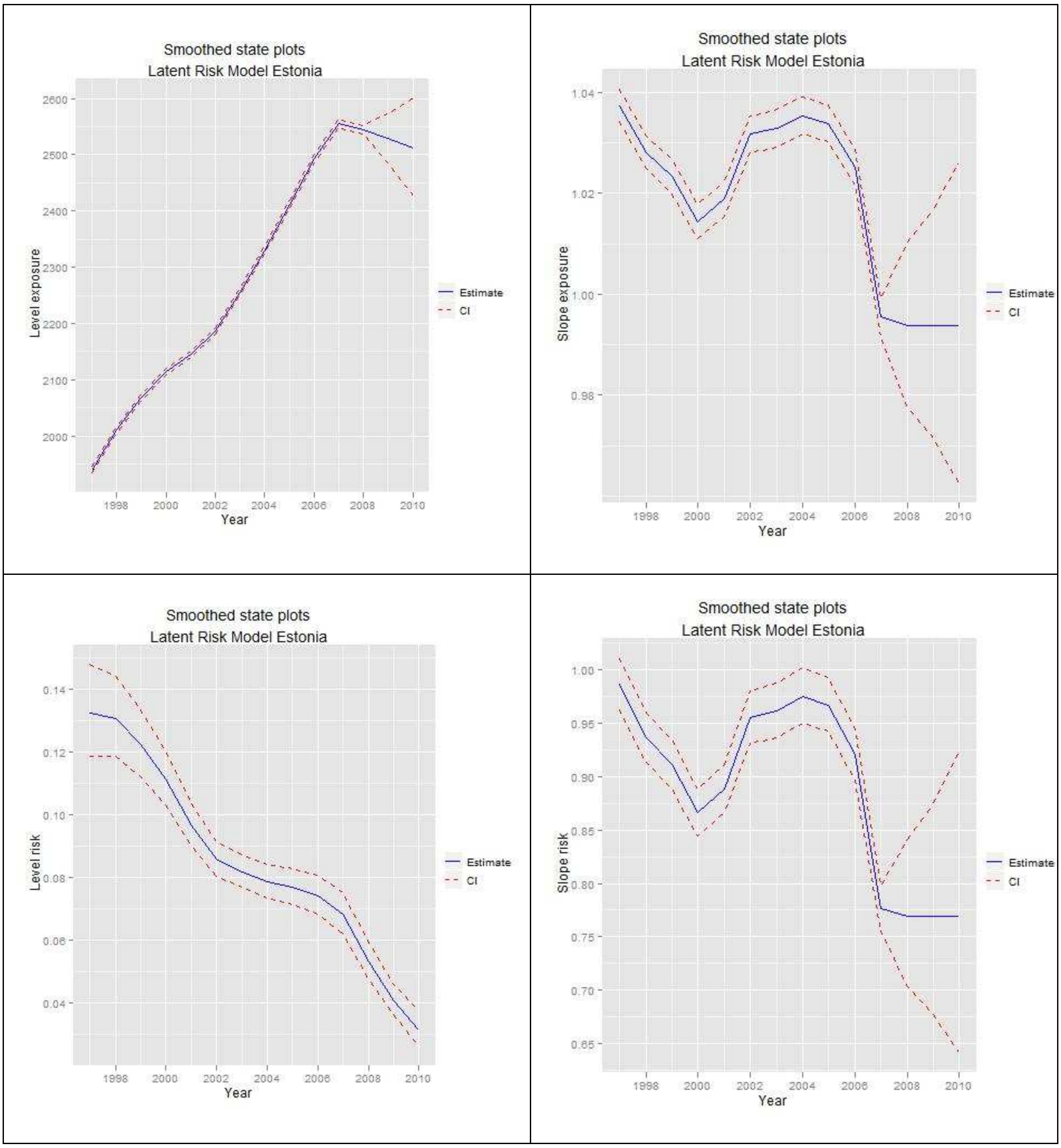


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the full LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The trend in vehicle fleet increased from 1,950,000 in 1997 to 2,550,000 in 2007, after which it decreased. The fluctuating slope implies that the increase up to 2007 did not take place at the same rate throughout this period.

3.2.2 Risk

The risk for fatalities in Estonia has reduced from 0.13 per thousand vehicles in 1997 to around 0.03 in 2010. This decrease (fluctuating, yet on average almost 11% per year) is expressed in the negative slope of the risk in the lower right-hand subfigure of Figure 4. Finally, note that during the period 2002-2006 the trend in risk decreased while the trend in fatalities (Figure 3) remained constant.

3.3 Quality of the predictions:

Next, we evaluate how well the selected LRT model has done in the past. Given the rather short data series (from 1997 onwards) the first 7 data points are used to predict the fatalities between 2004 and 2010. Figure 5 below shows a comparison between the predicted and actually observed values. It can be seen that the actual high number of fatalities in 2006 and 2007 are outside the prediction margins.

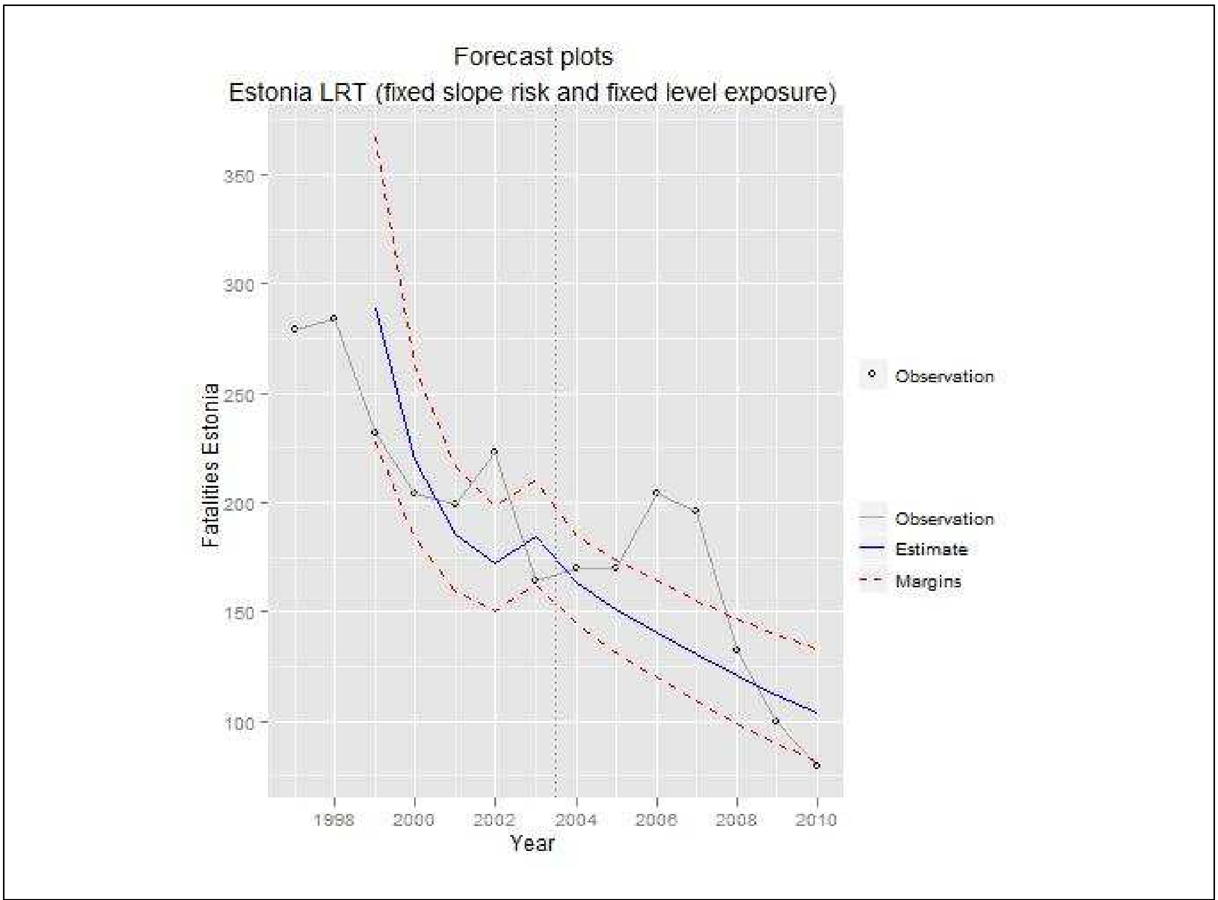


Figure 5: Plot comparing the model predictions (straight line) with the actual observations ("bullets") for the 2004-2010 annual fatality numbers in Estonia for the LRT model with fixed slope risk and fixed level exposure.

4 Forecasts 2011 – 2020:

The forecasts in Figure 6 and Table 3 provide an indication of the vehicle fleet and the fatality numbers to be expected between 2011 and 2020 provided that *the trends keep on following throughout these years the developments that they have shown in the past*.

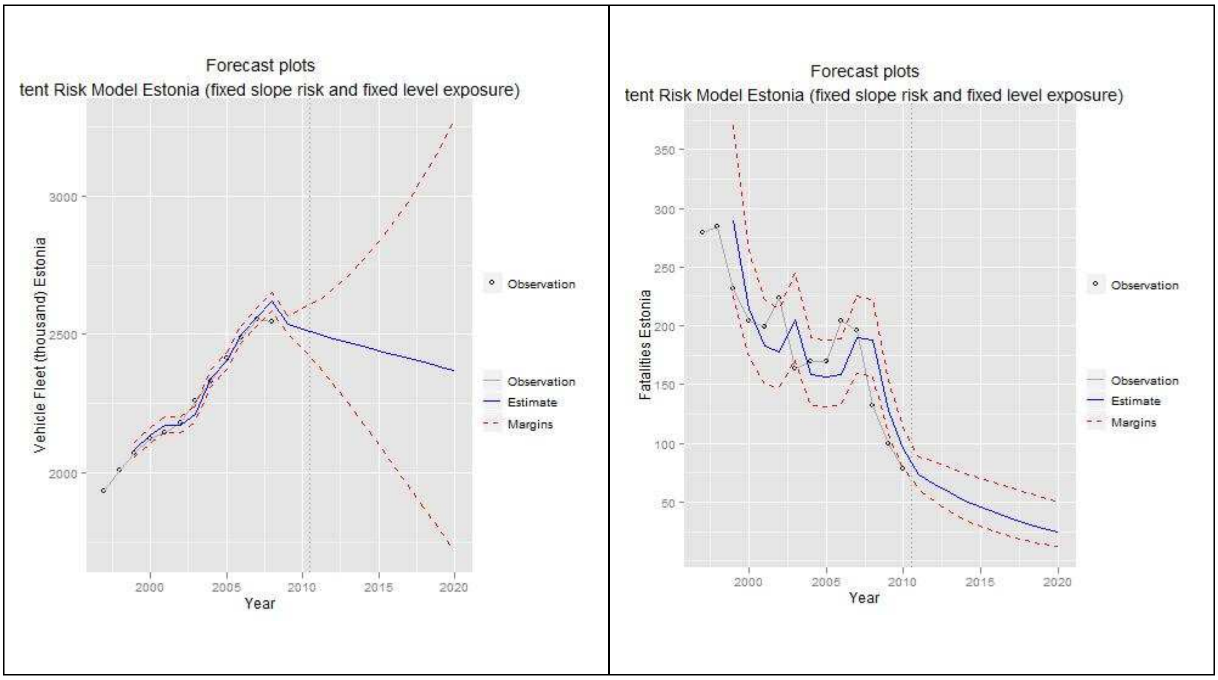


Figure 6: Plot of the vehicle fleet (left-hand graph) and annual fatality numbers (right-hand graph) for Estonia forecasted up to 2020 on the basis of the LRT model with a fixed slope for risk and a fixed level for the exposure.

Still assuming that past developments will extend into the future, the fatality numbers for Estonia should keep on decreasing after 2010. The predicted value for 2020 is 25 fatalities. Table 3 provides the details of the values forecasted for exposure and fatalities for all years from 2011 to 2020.

	Vehicle Fleet (thousand)				Fatalities		
Year	Predicted	Confidence Interval		Year	Predicted	Confidence Interval	
2011	**2501**	2278	2745	2011	**74**	51	107
2012	**2486**	2169	2849	2012	**65**	40	108
2013	**2471**	2054	2973	2013	**58**	31	108
2014	**2456**	1937	3116	2014	**51**	25	108
2015	**2442**	1818	3280	2015	**46**	19	107
2016	**2427**	1700	3466	2016	**40**	15	106
2017	**2413**	1583	3677	2017	**36**	12	105
2018	**2399**	1470	3914	2018	**32**	10	104

2019	**2384**	1360	4180	2019	**28**	8	103
2020	**2370**	1254	4479	2020	**25**	6	103

Table 3: Forecasts of the Latent Risk Model (LRTEstonia3)

5. Scenarios

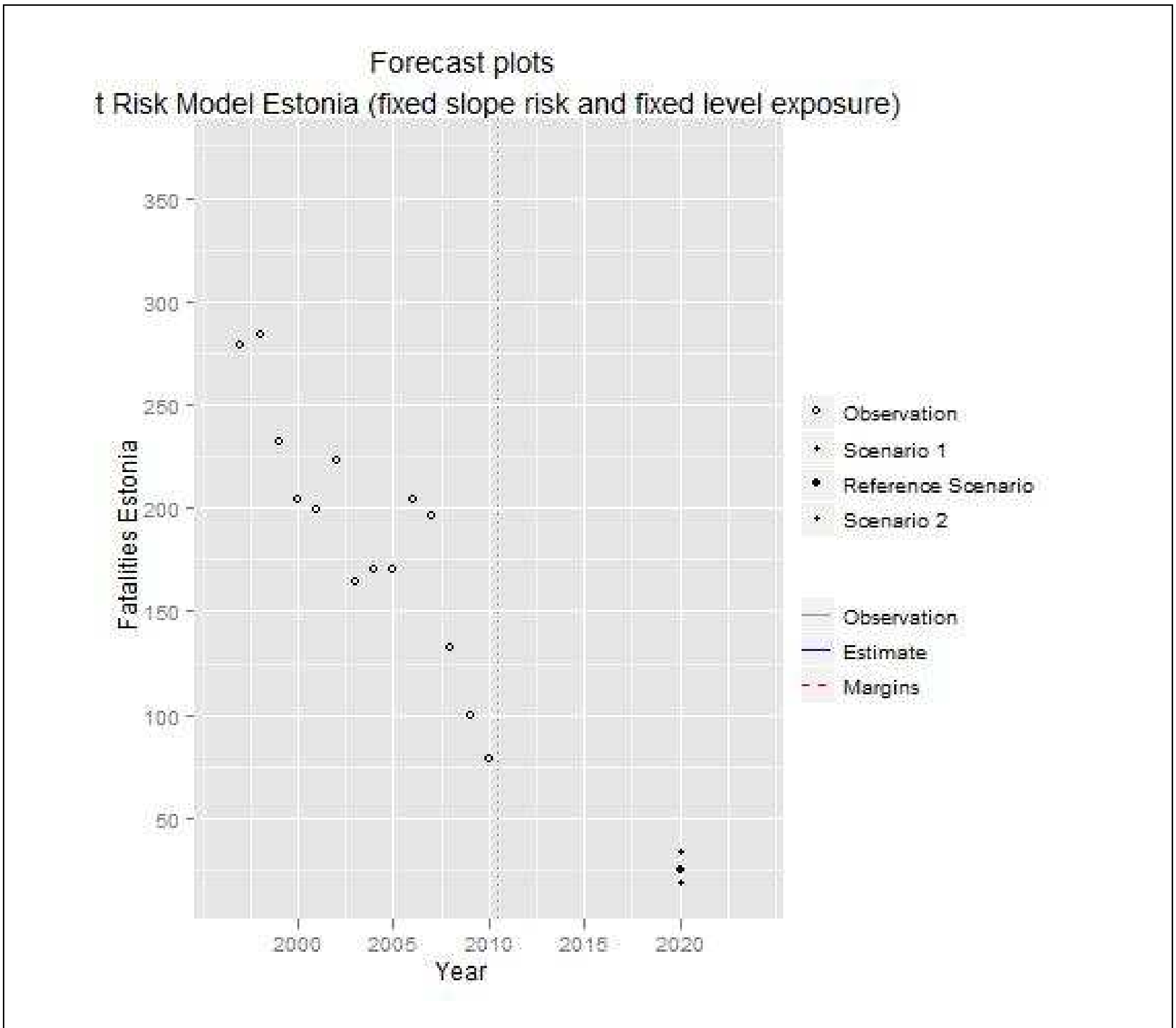


Figure 7: Fatality forecasts for Estonia by 2020 under 3 mobility scenarios. ●Continuation of development (as estimated by LRT model). ◦ Increase in number of vehicles (LRT estimate + 1 SD). ◦ Stronger decrease than predicted in number of vehicles (LRT estimate – 1 SD).

Three scenarios have been calculated to represent different developments of exposure. These scenarios correspond to the number of vehicles predicted by the model 2020, plus/minus one standard deviation[11]. The values for the exposure scenarios and the estimated number of fatalities under each of them are provided in Table 4, and plotted in Figure 7.

The predicted number of vehicles for 2020 is 2,370,000, a scenario under which one would expect 25 fatalities, and which is represented by a full dot in Figure 7. The circles in this figure represent the estimated fatality numbers assuming an increase (forecast plus one standard deviation: 3,274,000), or a stronger decrease (forecast minus one standard deviation: 1,716,000) in the number of vehicles. The fatality numbers estimated for each scenario are detailed in Table 4.

	Vehicle fleet (tousand)	***Road traffic fatalities***
Most recent situation:	2544 (2008)	79 (2010)
Prediction for 2020 according to mobility scenarios:		
Continuation of development	2370	25
Increase in number of vehicles	3274	34
Stronger decrease than predicted	1716	19

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRTEstonia3). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation.

[11] The upper and lower scenarios now include 68% of the cases, assuming a normal distribution.

FINLAND

1 Raw data:

1.1 Exposure:

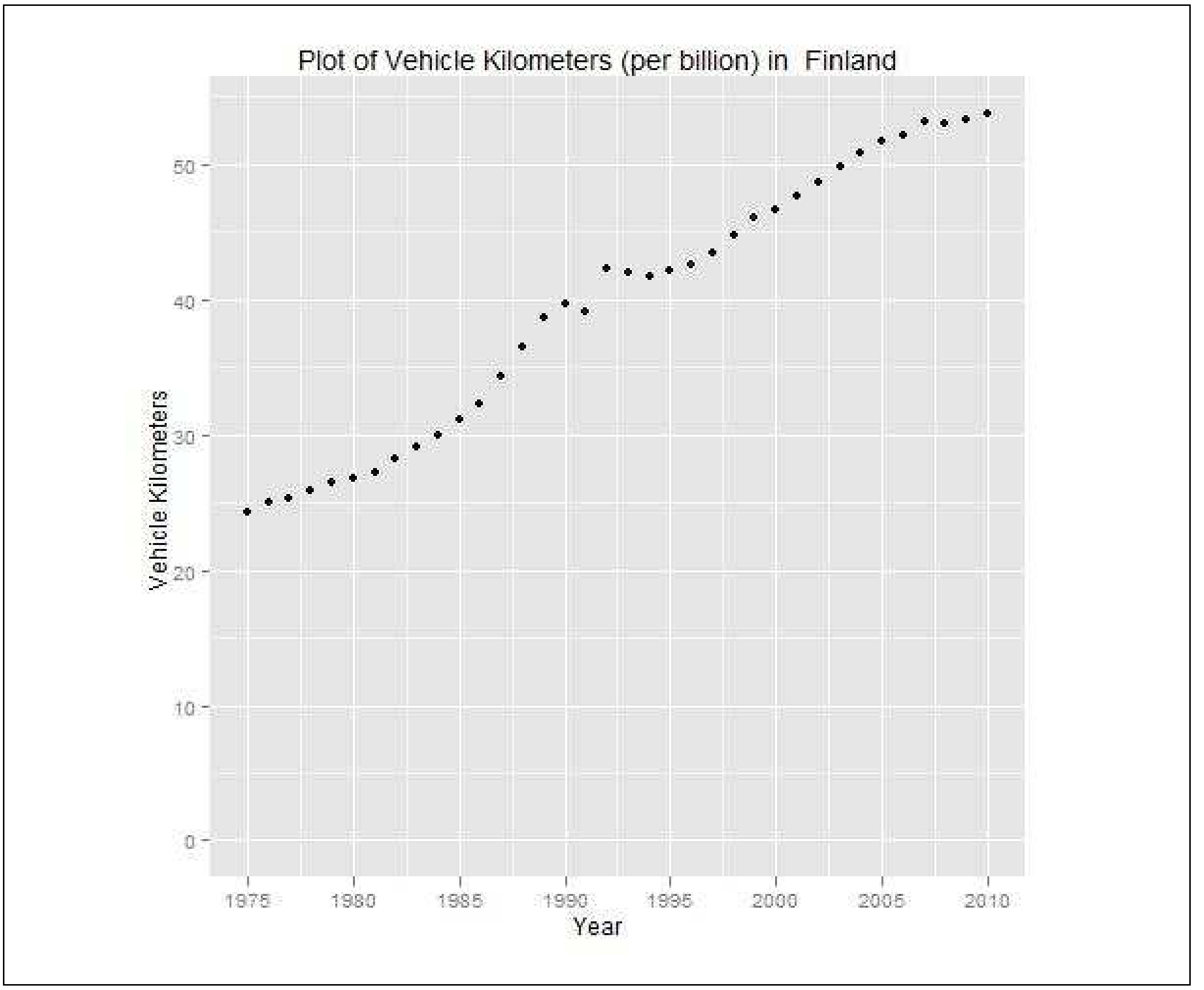


Figure 1: Plot of the annual number of vehicle kilometres (in billion) for Finland from 1975 to 2010.

As exposure measure we consider the number of motor vehicle kilometres. Yearly data are obtained from IRTAD and shown for the period 1975 to 2010.

The plot shows a gradual increase over the years. The period 1990-1995 shows a somewhat different evolution.

1.2 Fatalities:

The plot below shows the number of fatalities in Finland from 1975 to 2010. Data are from CARE and IRTAD.

In general, there is a decrease in the number of fatalities over the years, especially from the 90s onwards. Before, there was much more variation in the number of fatalities.

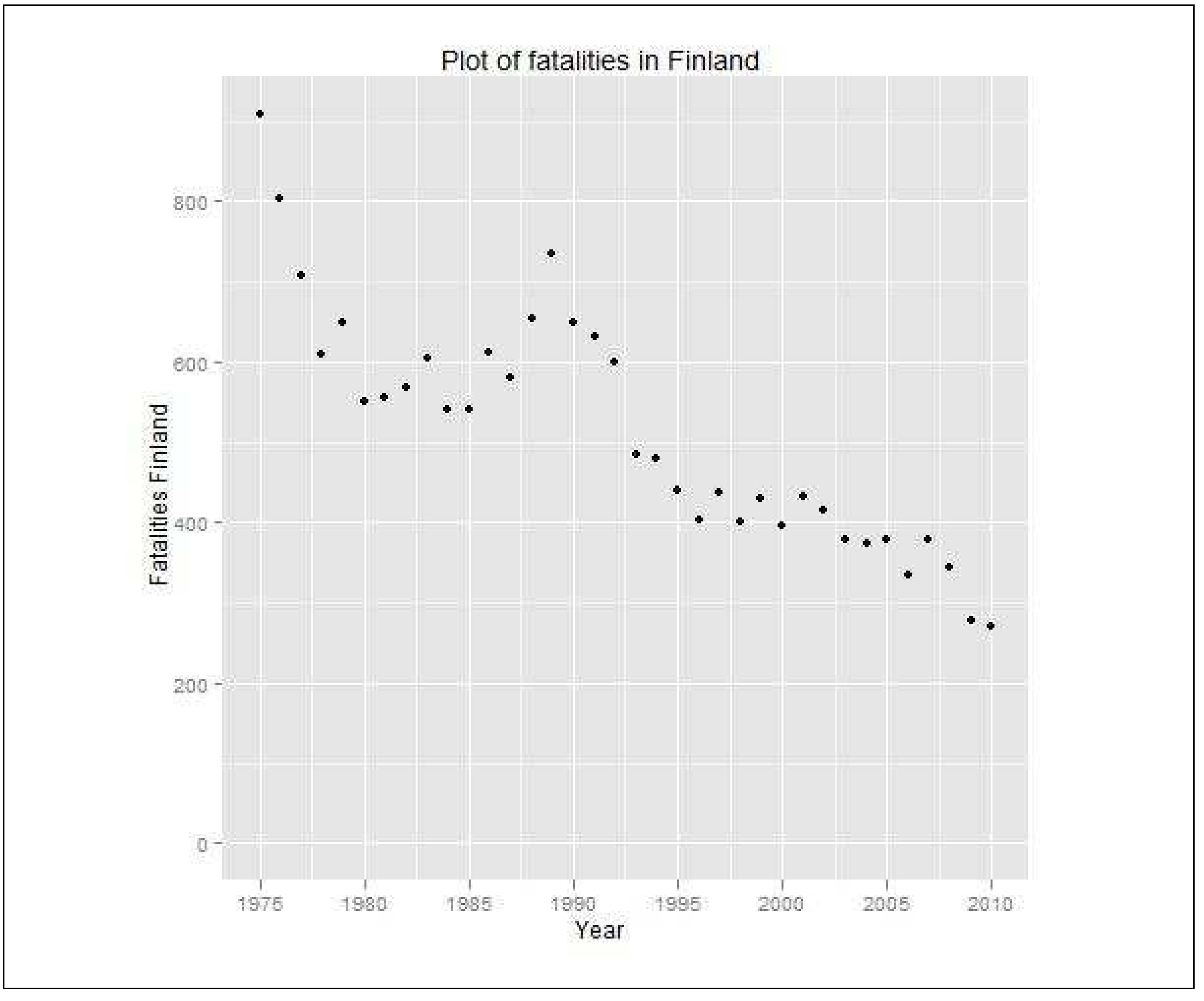


Figure 2: Plot of the annual fatality counts for Finland from 1975 to 2010.

2 The SUTSE Model:

2.1 Development of the state components:

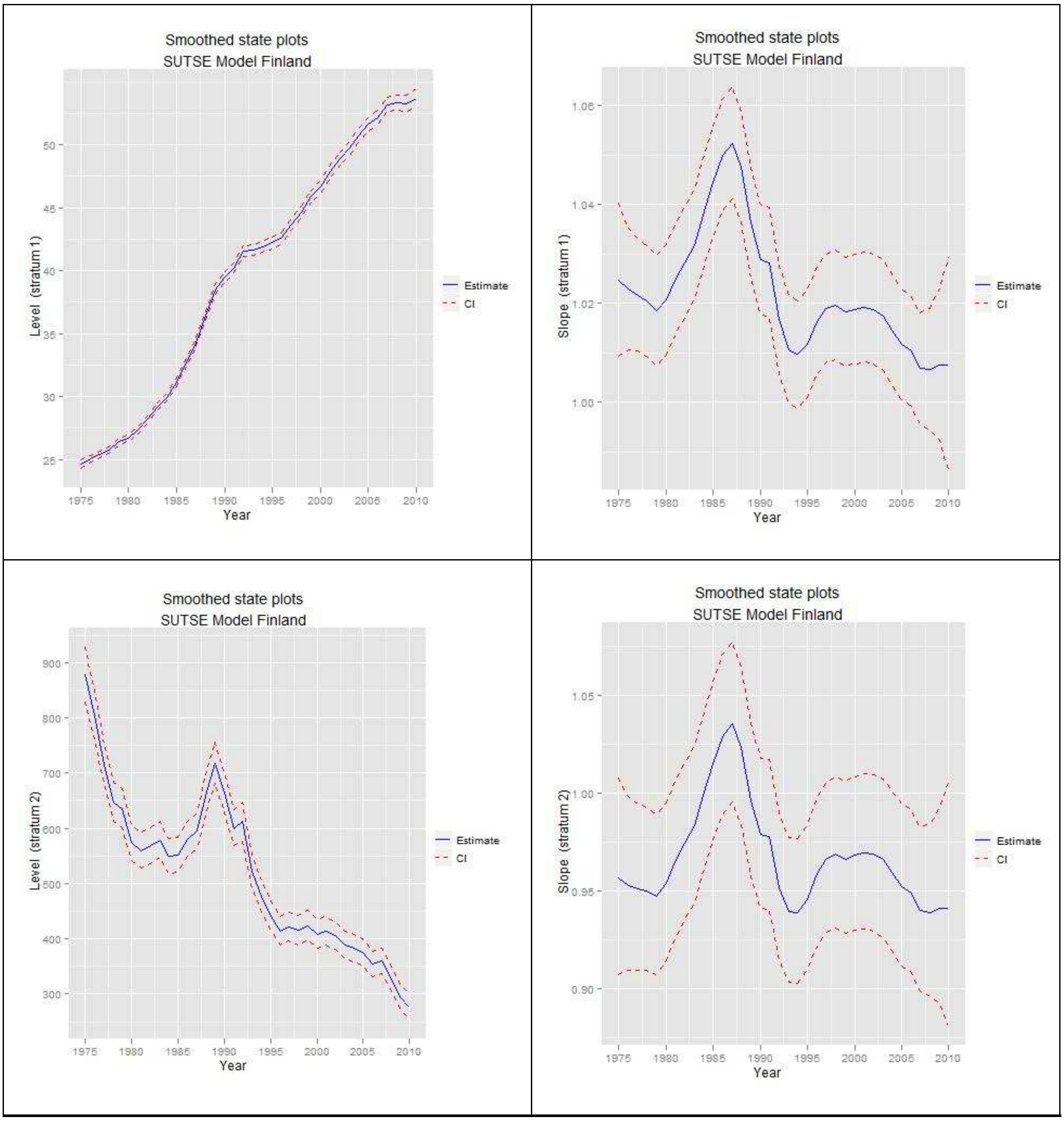


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend in vehicle kilometres increased from 25 billion in 1975 to 53 billion in 2010. The slope values exceeding 1 imply that the number of vehicle kilometres has systematically increased from one year to another, in particular between 2 and 4% per year until 1991 and between almost 1 and 2% in the years afterwards.

2.1.2 Fatalities

The trend in fatalities has dropped from 880 in 1975 to 280 in 2010. However, there was an increase in the period 1984-1989.

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components

The correlation between the two levels is estimated as 1 and the correlation between the two slopes as 0.97. The correlation between the two levels (p=0.69) and between the two slopes (p=0.30) is not significant.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -0.28 which is not significant (p=0.81).

2.2.3 Estimation of the relationship by means of a coefficient

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). However, the beta coefficient for the relationship between the latent developments of the two series is equal to 3.37 and is highly significant (p=0.00).

2.2.4Conclusion

It can be concluded that the fatalities and vehicle kilometres series are related and therefore further modeling will be made using the LRT model.

Model title	***SUTSE Finland1***	***SUTSEbetaFinland1***
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	155.76	155.69
AIC	-311.01	-310.93
Hyperparameters		
Level exposure	7.68E-05 nsc	3.50E-05 ns
Level fatalities	3.85E-03 nsc	1.21 E-03 ns
Slope exposure	5.92E-05 *c	7.22E-05 *
Slope fatalities	4.14E-04 nsc	6.10E-05 ns
Correlations		
level-level	1	
slope-slope	0.97	
Observation variances		
Observation variance exposure	7.32E-05 ns	8.60E-05 *
Observation variance fatalities	9.69E-05 ns	6.24E-04 ns
Beta	/	3.37 (p= 0.00)

Table 1: Model criteria and results for SUTSE models – Finland.

3 The LRT Model:

3.1 Model selection:

The results of the SUTSE model suggest that the fatality and exposure series are significantly correlated in the case of Finland. The next step therefore consisted of running LRT models in order to identifying the version of the Latent Risk Model that would offer the best fit to the data.

First, the full LRT model (LRTFinland1) is run. Given the existence of non-significant components, a more parsimonious model was created, i.e. LRTFinland2 in which the slope of the risk was fixed (see also the results in Table 1). In this second model, no non-significant components appeared anymore, so no other variants of the LRT model were run.

Below, the results of the two LRT models are presented. Note that the residual tests indicate a violation of the assumptions, especially concerning the normality with respect to exposure. However, given that we have no detailed information and that similar variation could happen in the future, no intervention is added to the model.

In the end, we opt for the most parsimonious model, also having the lowest prediction errors (see ME10 Fatalities and MSE10 Fatalities), i.e. the LRT model with fixed risk slope (LRTFinland2), as the forecasting model.

Model title	LRT Finland1	LRT Finland2
Model description	Full Model	Fixed slope risk
Model Criteria		
ME10 Fatalities	-0.91	0.04
MSE10 Fatalities	2.33	0.68
log likelihood	47.57	37.56
AIC	2754.94	1938.26
Model Quality		
Box-Ljung test 1 Exposure	0.43	1.73
Box-Ljung test 2 Exposure	0.43	1.74
Box-Ljung test 3 Exposure	0.68	2.01
Box-Ljung test 1 Fatalities	4.87*	5.83*
Box-Ljung test 2 Fatalities	5.10	5.89
Box-Ljung test 3 Fatalities	5.33	5.92
Heteroscedasticity Test Exposure	0.54	0.30
Heteroscedasticity Test Fatalities	0.62	0.55
Normality Test standard Residuals Exposure	7.50*	2.80
Normality Test standard Residuals Fatalities	1.66	1.42
Normality Test output Aux Res Exposure	57.97***	61.51***
Normality Test output Aux Res Fatalities	0.82	0.48
Normality Test State Aux Res Level exposure	19.03***	15.03***
Normality Test State Aux Res Slope exposure	0.13	0.18
Normality Test State Aux Res Level risk	1.63	1.98
Normality Test State Aux Res Slope risk	0.01	0.38
Variance of state components		
Level exposure	7.68E-05 nsc	1.97E-04 *c
Level risk	2.84E-03 nsc	2.98E-03 *c
Slope exposure	5.92E-05 *c	2.38E-05 *
Slope risk	1.71E-04 nsc	-
Correlations between state components		
level-level	1	
slope-slope	0.91	1
Observation variance		
Observation variance exposure	7.32E-05 ns	4.25E-05 ns
Observation variance risk	9.69E-05 ns	4.94E-04 ns

Table 2: Overview of the results for LRT models - Finland.

3.2 Development of the state components:

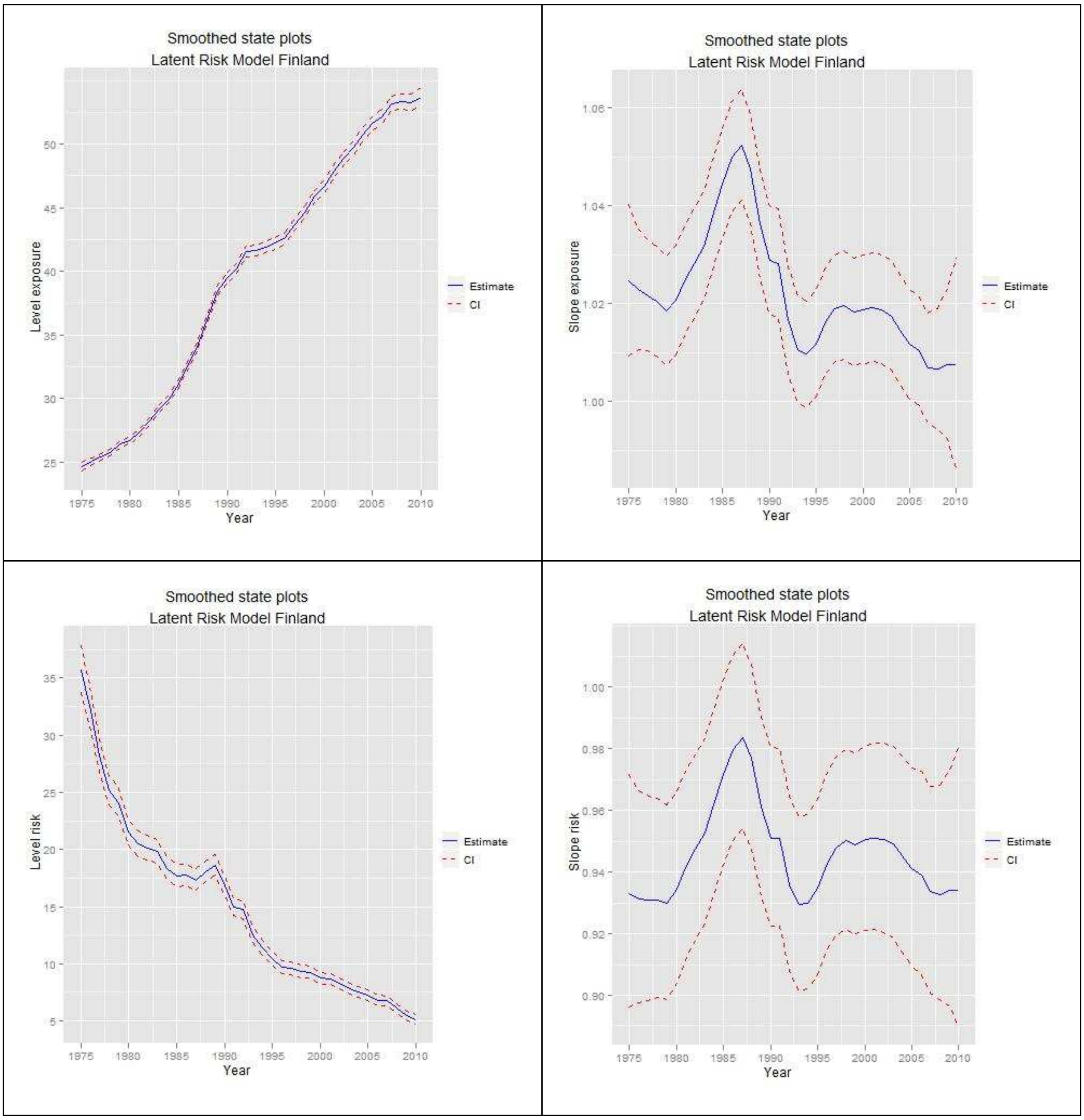


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the full LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The trend in vehicle kilometres increased from 25 billion in 1975 to 53 billion in 2010. The slope values exceeding 1 imply that the number of vehicle kilometres has systematically increased from one year to another, in particular between 2 and 4% per year until 1991 and between almost 1 and 2% in the years afterwards.

3.2.2 Risk

The risk for fatalities in Finland has reduced from 35 per billion vehicle kilometres in 1975 to 5 in 2010. This decrease (fluctuating, yet on average around 5.3% per year) is expressed in the negative slope of the risk in the lower right-hand subfigure of Figure 4.

3.3 Quality of the predictions:

Next, we evaluate how well the selected LRT model has done in the past. The data up to 2000 is used to predict the fatalities between 2001 and 2010. Figure 5 below shows a comparison between the predicted and actually observed values. It can be seen that the actual number of fatalities lies within the prediction margins.

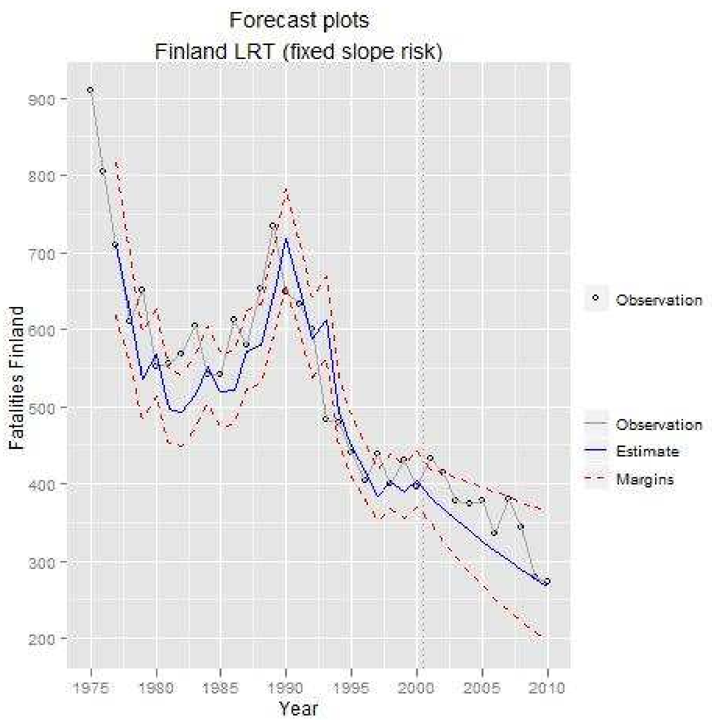


Figure 5.: Plot comparing the model predictions (straight line) with the actual observations ("bullets") for the 2001-2010 annual fatality numbers in Finland for the LRT model with fixed risk slope.

4 Forecasts 2011 – 2020:

The forecasts in Figure 6 and Table 3 obtained from the model provide an indication of the vehicle kilometres and fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.*

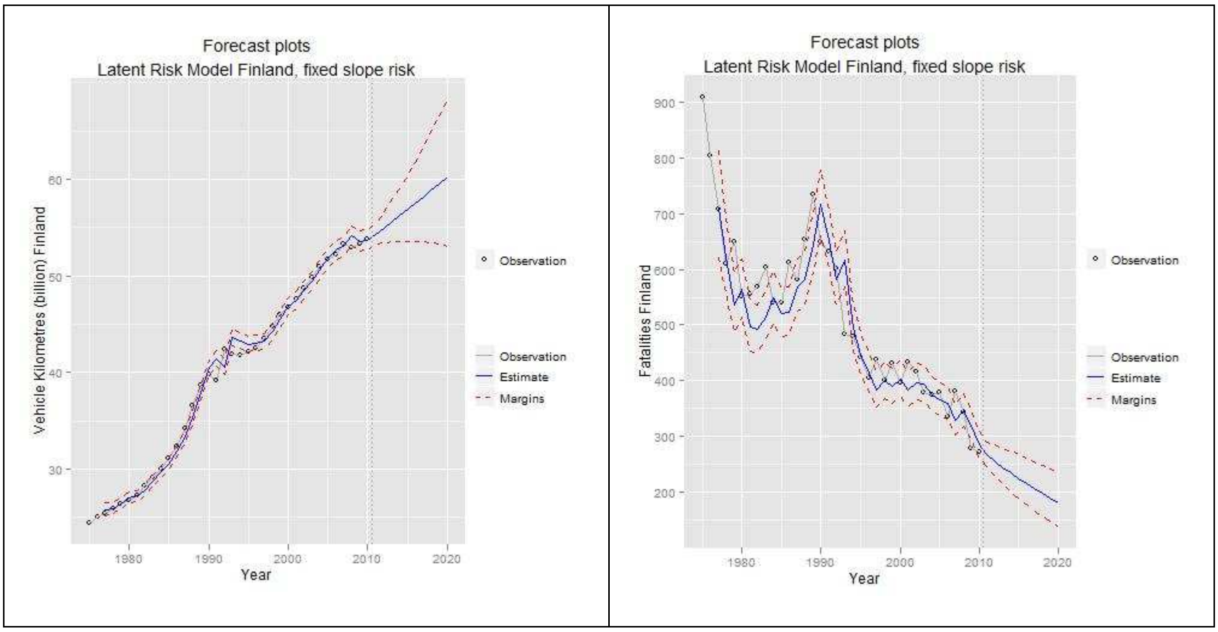


Figure 6: Plot of the vehicle kilometres (left-hand graph) and annual fatality numbers (right-hand graph) for Finland forecasted up to 2020 on the basis of the LRT model with fixed risk slope.

Still assuming that past developments will extend into the future, the fatality numbers for Finland should keep on decreasing after 2010. The predicted value for 2020 is 180 fatalities. Table 3 provides the details of the values forecasted for exposure and fatalities for all years from 2011 to 2020.

	Vehicle kilometres (billion)				Fatalities		
Year	Predicted	Confidence Interval		Year	Predicted	Confidence Interval	
2011	**54**	52	56	2011	**267**	226	315
2012	**55**	52	58	2012	**255**	205	317
2013	**56**	52	60	2013	**244**	188	318
2014	**56**	51	62	2014	**234**	173	317
2015	**57**	51	64	2015	**224**	159	316
2016	**58**	50	66	2016	**215**	147	314
2017	**58**	49	69	2017	**205**	135	312
2018	**59**	49	71	2018	**197**	125	311
2019	**60**	48	74	2019	**188**	115	309
2020	**60**	47	77	2020	**180**	106	307

Table 3: Forecasts of the Latent Risk Model (LRTFinland2)

5 Scenarios

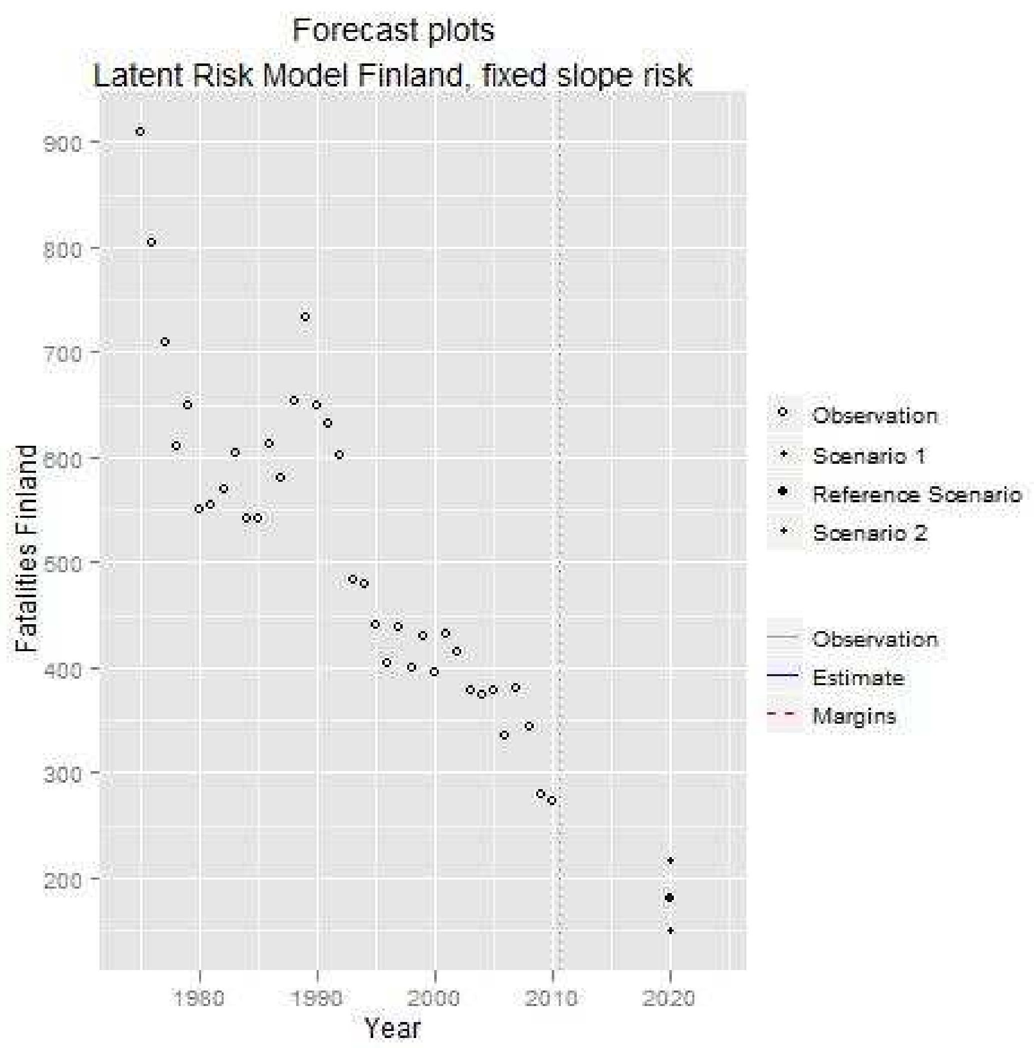


Figure 7: Fatality forecasts for Finland by 2020 under 3 mobility scenarios. ●Continuation of development (as estimated by LRT model). ◦ Stronger increase in number of vehicle kilometres (LRT estimate + 1 SD). ◦ Stagnation in number of vehicle kilometres (LRT estimate – 1 SD).

Three scenarios have been calculated to represent different developments of exposure. They correspond to the number of vehicle kilometres predicted by the model 2020, plus/minus one standard deviation[12]. The values for the exposure scenarios and the estimated number of fatalities under each of them are provided in Table 4, and plotted in Figure 7.

[12] The upper and lower scenarios now include 68% of the cases, assuming a normal distribution.

The predicted number of vehicle kilometres for 2020 is 60 billion, a scenario under which one would expect 180 fatalities, and which is represented by a full dot in Figure 7. The circles in this figure represent the estimated fatality numbers assuming a stronger increase (forecast plus one standard deviation: 68 billion), or a stagnation in the number of vehicle kilometres (forecast minus one standard deviation: 53 billion). The fatality numbers estimated for each scenario are detailed in Table 4.

	Vehicle kilometres (billions)	***Road traffic fatalities***
Situation 2010:	53.82	272
Prediction for 2020 according to mobility scenarios:		
Continuation of development	60.19	180
Stronger increase than predicted	68.20	217
Stagnation in number of vehicle kilometres	53.12	150

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRTFinland2). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation.

FRANCE

1 Raw data

1.1 Exposure

The selected exposure measure are the vehicle kilometres (in billions) per annum (see Figure 1), which are considered from 1957 onwards.

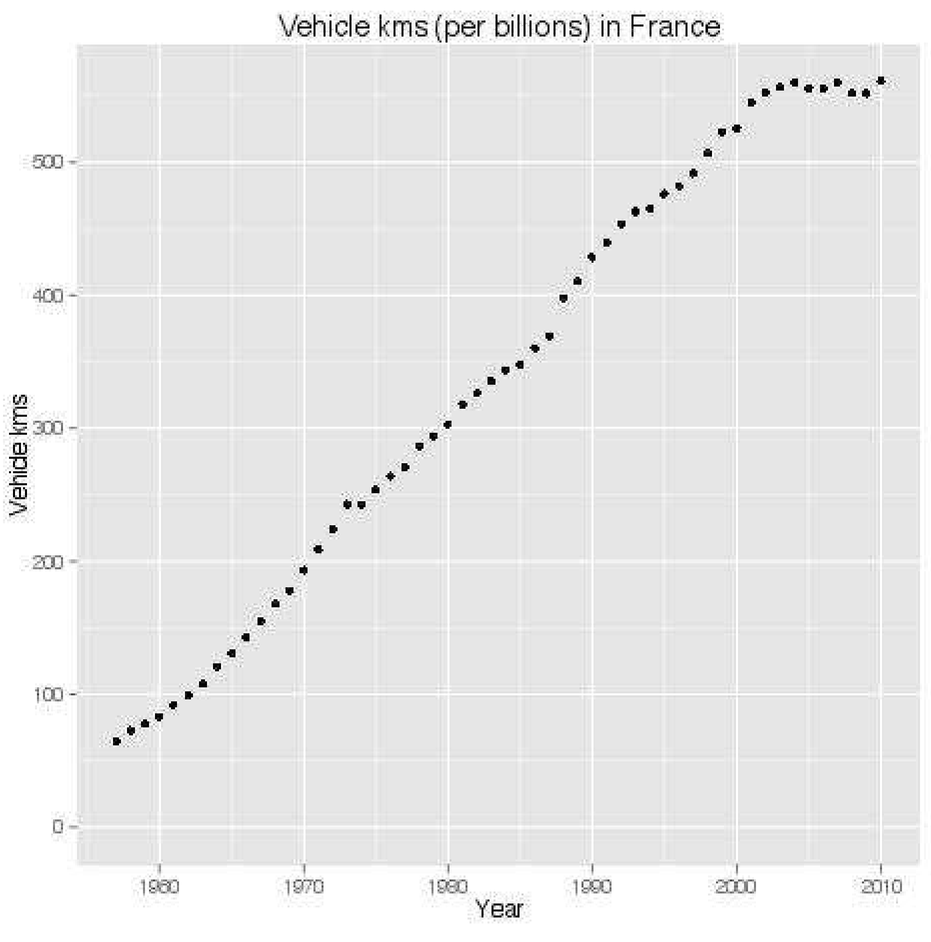


Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for France from 1957 to 2010.

Between 1957 and 1973 the vehicle kilometres show a regular increase, stopped by the first energy crisis in 1974. A second period of increase, smaller in intensity than the previous one, started in 1975 up to 2005 during 30 years. In 1988, an increase in the level is due to an increase in the goods transport by road. Since 2006 due to a slowing down of the economic activity, the mobility stagnates and even declines.

These estimates are produced by a model relating the vehicle fleets and the yearly average distances driven to the fuel sales.

1.2 Fatalities

In Figure 2, the Belgian road accident fatalities from 1957 to 2010 are plotted. There has been change in the definition of the number of fatalities, from 3 days after the accident, to 6 days and then 30 days. Multiplicative factors have been applied to count fatalities up to 30 days after the accident.

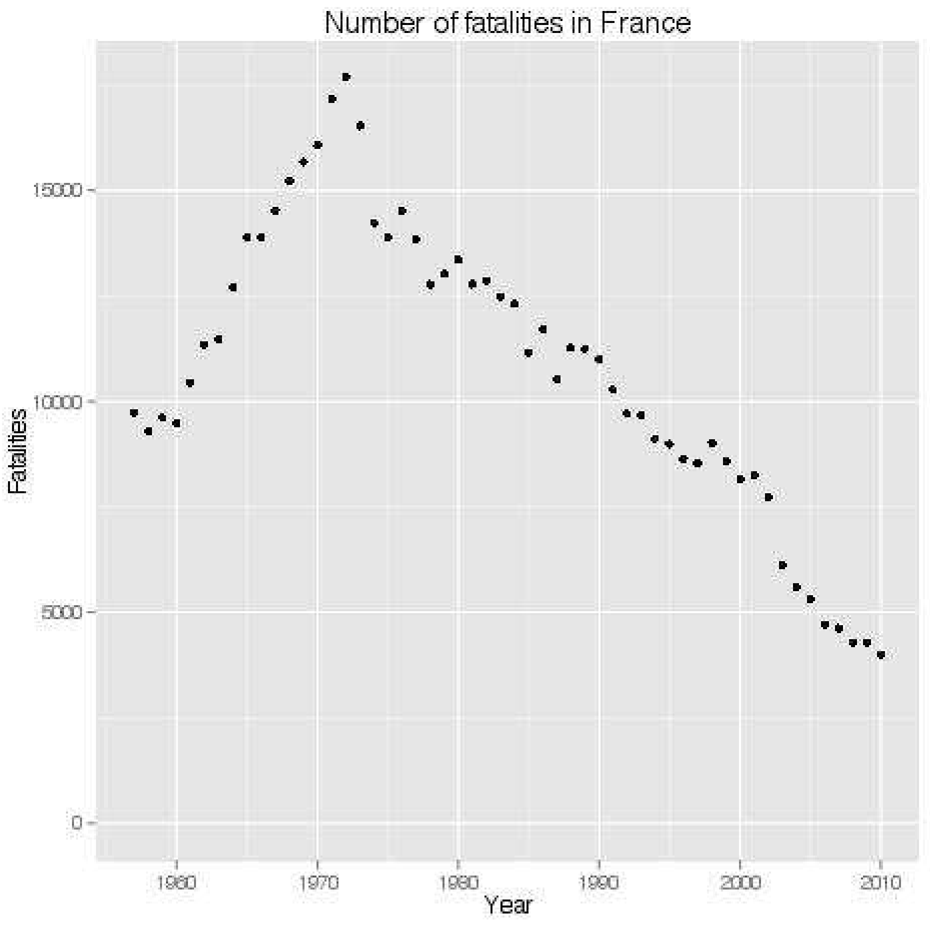


Figure 2: Plot of the annual fatality counts for France from 1957 to 2010.

The increase in the number of fatalities is strongly marked from 1960 to 1972 during the large diffusion of automobile in the society. From 1975 to 2002, the number of fatalities is decreasing regularly. In 1973 and 1974, there is a sharp decrease due to the introduction of speed limits on rural roads and seat belt use law. The inversion in the trend is due to the change in the mobility trend due to the first energy crisis. In 2003, the automatic control speed enforcement by cameras have been introduced which has a strong impact on the level. Since then, the trend is still decreasing as previously.

2 The SUTSE Model

2.1 Development of the state components

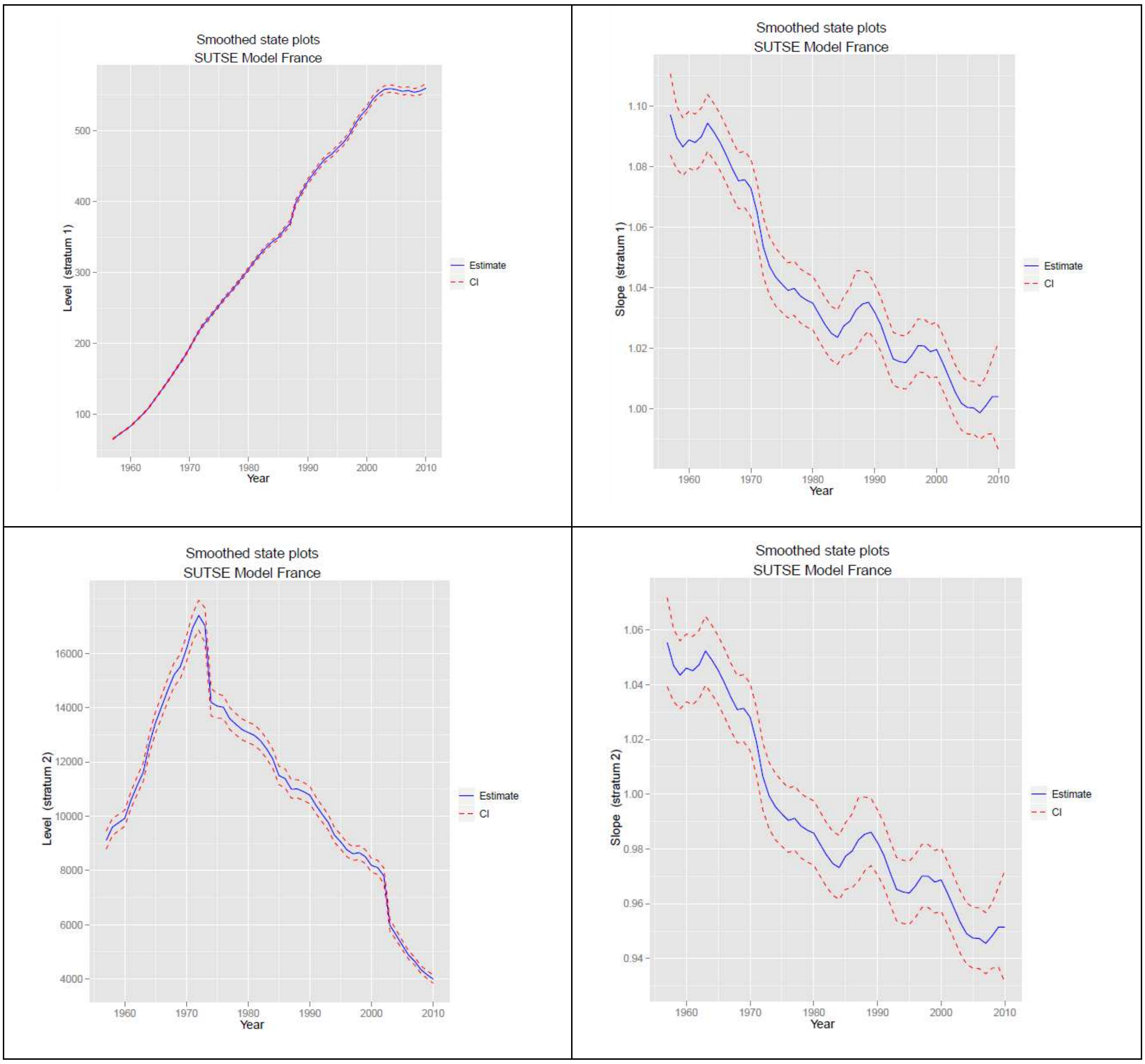


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

As the slope varies significantly, the increase did not take place at the same rate throughout this period. In the early sixties there was an increase of 8%, but since then the yearly increase became less and less and in the most recent years it has been only half a percent annually.

2.1.2 Fatalities

As there is a perfect correlation between the slopes, the evolution of the relative rate of the number of fatalities follows the same pattern, but on a different scales, starting with an increase of 4% to end to a decrease of -5%, crossing the zero line in 1973. There are also some up and down movements in the 80 and 90's.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

The slopes are corrrelated to one. There is a common component slope between exposure and fatalities. The levels components are not significant.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -.20 which is not significant (p=0.7).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 1.2 and is significant, but not significantly different from 1(p= 0.102 H0beta=1).

Some interventions have been introduced. In 1974 and 2004 as a level break for fatalities, and in 1988 as level break in exposure plus an irregular intervention in 1973.

Model title		***SUTSEFrance***	***SUTSEbetaFrance***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	259.40	
	AIC	-518.60	
Variance of the state components			
	Level exposure	3.81E-05 nsc	

Level risk	5.05E-04 nsc	
Slope exposure	4.23E-05 *c	
Slope risk	5.78E-05 *c	
Correlations between the state components		
level-level	0-1	
slope-slope	1	
Observation variance		
Observation variance exposure	5.25E-05 *	
Observation variance risk	6.93E-04 *	
Beta		beta= 1.20

Table 1: Overview of the results for SUTSE models – France.

3 The LRT Model

The investigation of the SUTSE model clearly indicate the presence of a relation between exposure and fatalities in France. An LRT model is a good candidate as the coefficient relating exposure to fatalities on a logarithmic scales is not different from 1.

3.1 Model selection

Two versions of the LRT model were run: the full model, the model with a fixed slope for risk and a fixed level of exposure. The residual test for both model variants don not indicate a violation of the assumptions underlying the Latent Risk model.

Model title	LRT 1	LRT 2
Model description	LRT for France – full model	LRT for France – fixed slope risk and level exposure
Model Criteria		
log likelihood	260.5	258.71
AIC	-520.6	-517.24
Model Quality		
Box-Ljung test 1 Exposure	3.98*	0.3
Box-Ljung test 2 Exposure	6.6*	2.9
Box-Ljung test 3 Exposure	7.8	6.7
Box-Ljung test 1 Fatalities	2.6	2.5
Box-Ljung test 2 Fatalities	2.7	3.1
Box-Ljung test 3 Fatalities	3.6	3.3
Heteroscedasticity Test Exposure	0.6	0.5
Heteroscedasticity Test Fatalities	0.8	0.7
Normality Test standard Residuals Exposure	0.6	0.8
Normality Test standard Residuals Fatalities	0.1	0.2
Normality Test output Aux Res Exposure	8.4*	5.9
Normality Test output Aux Res Fatalities	0.6	0.6
Normality Test State Aux Res Level exposure	1.2	0.6
Normality Test State Aux Res Slope exposure	0.2	0.5
Normality Test State Aux Res Level risk	1.0	0.6
Normality Test State Aux Res Slope risk	6.4*	4.7
Variance of state components		
Level exposure	2.66E-05 nsc	-
Level risk	3.68E-04 *c	6.52E-04 *
Slope exposure	4.42E-05 *c	5.31E-05 *
Slope risk	1.35E-06 nsc	-
Correlations between state components		
level-level	0-1	
slope-slope	0-1	
Observation variance		
Observation variance exposure	5.72E-05 *c	6.43E-05*
Observation variance risk	5.53E-04 *c	0.00*

Table 2: Overview of results for the LRT model - France

The second model has a bigger AIC and is selected. The exposure follows a smooth trend model and the fatalities the same smooth trend model plus a deterministic trend, which is given by the risk trend.

3.2 Development of the state components

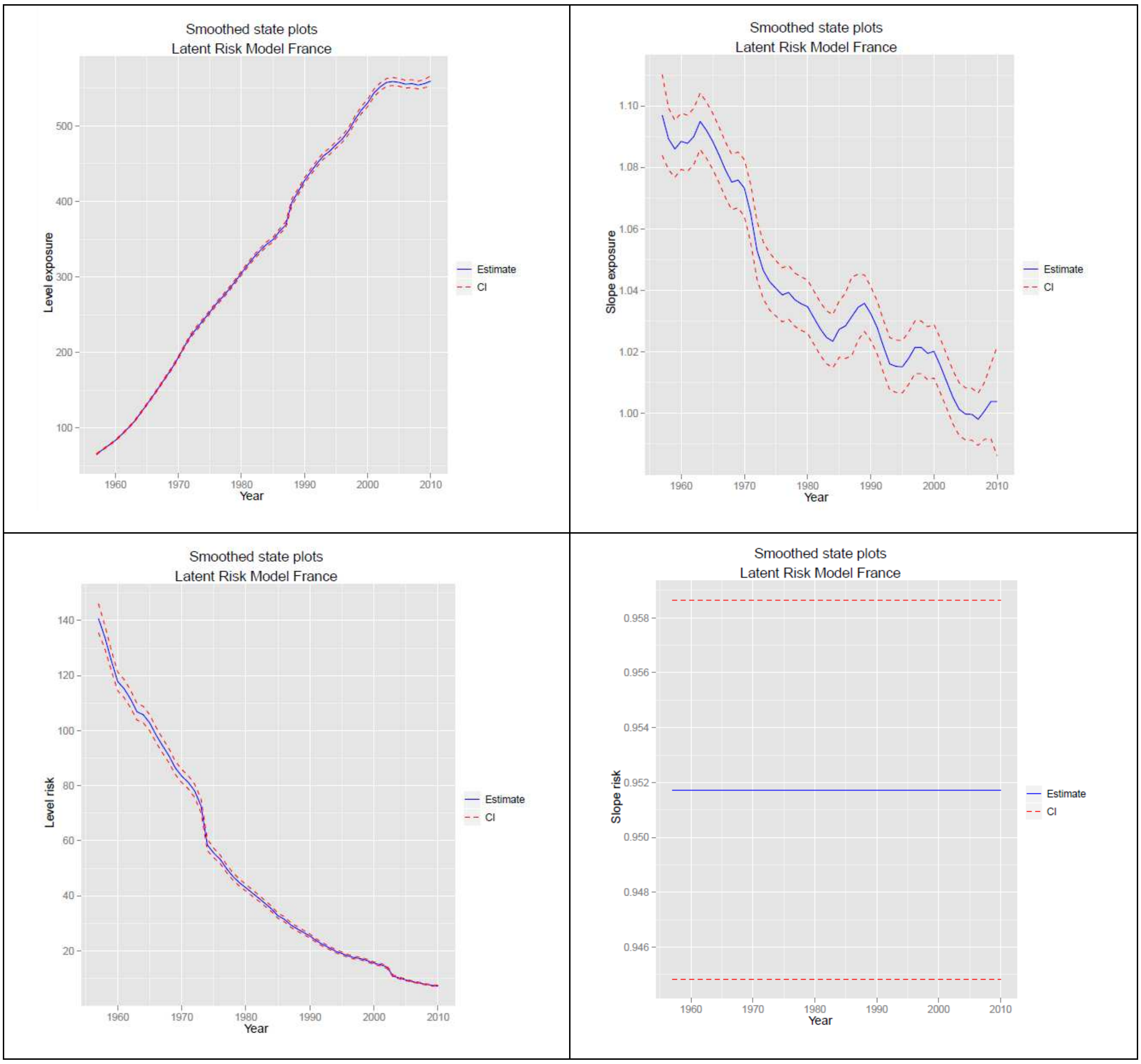


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the right-hand graphs, the slope developments in the left-hand graphs.

3.2.1 Exposure

The evolution of exposure is identical to the SUTSE model. As the slope varies significantly, the increase did not take place at the same rate throughout this period. In the early sixties there was an increase of 8%, but since then the yearly increase became less and less and in the most recent years it has been only half a percent annually. The increase of the level in 1988 is 4,7% due to the intervention and the punctual increase in 1973 is 4,1%.

3.2.2 Risk

The risk for fatalities has been reduced in France from 140 per billion vehicle kilometres in the early 60s to less than 15 per billion vehicle kilometres in the most recent years. This decrease of 4,8% yearly is expressed in the negative slope of the risk in the lower left panel of Figure 4. The decrease in the level is -16,2 % in 1974 and -22% in 2003.

3.3 Quality of the predictions

As the model is governed both by a deterministic trend for risk all over the period and by a smooth trend for exposure, we do not explore the quality of the forecasts. We could be sufficiently confident in the model to provide robust predictions, if of course no exogenous intervention occurs.

4 Forecasts 2011 - 2020

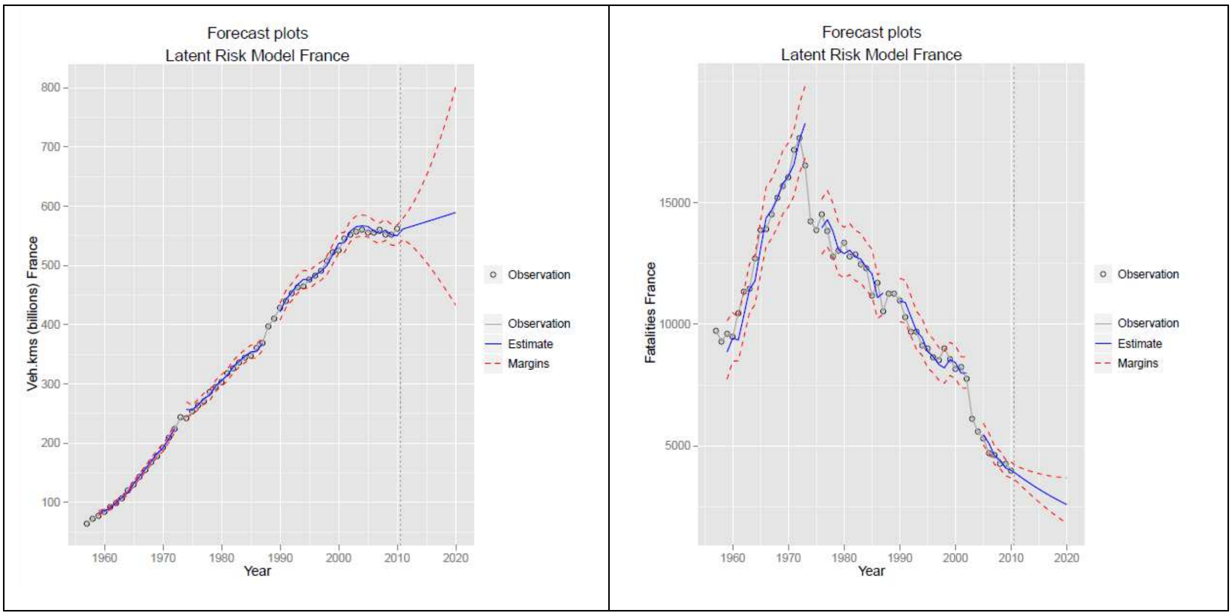


Figure 7: Plot of the vehicle kilometres (right-hand graph) and annual fatality numbers (left-hand graph) for France forecasted between 2011 and 2020.

The forecasts in Figure 7 and Table 3 provide an indication of the vehicle kilometres and the fatality numbers to be expected between 2011 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Vehicle kilometres (billion)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2011	**561**	544	579	**3833**	3532	4159
2012	**564**	537	593	**3667**	3306	4068
2013	**567**	528	610	**3509**	3089	3986
2014	**571**	517	629	**3357**	2880	3914
2015	**574**	505	651	**3213**	2679	3852
2016	**577**	492	676	**3074**	2486	3801
2017	**580**	478	703	**2941**	2301	3759
2018	**583**	464	733	**2814**	2126	3726
2019	**586**	449	766	**2693**	1959	3701
2020	**589**	433	801	**2576**	1802	3684

Table 3: Forecasts of Latent Risk Model (LRT 2).

5 Scenarios

In Figure 7 it can be seen that there is strong uncertainty about the development of the exposure in France. Given that the exposure influences the prediction of the fatalities it is interesting to demonstrate how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 8 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

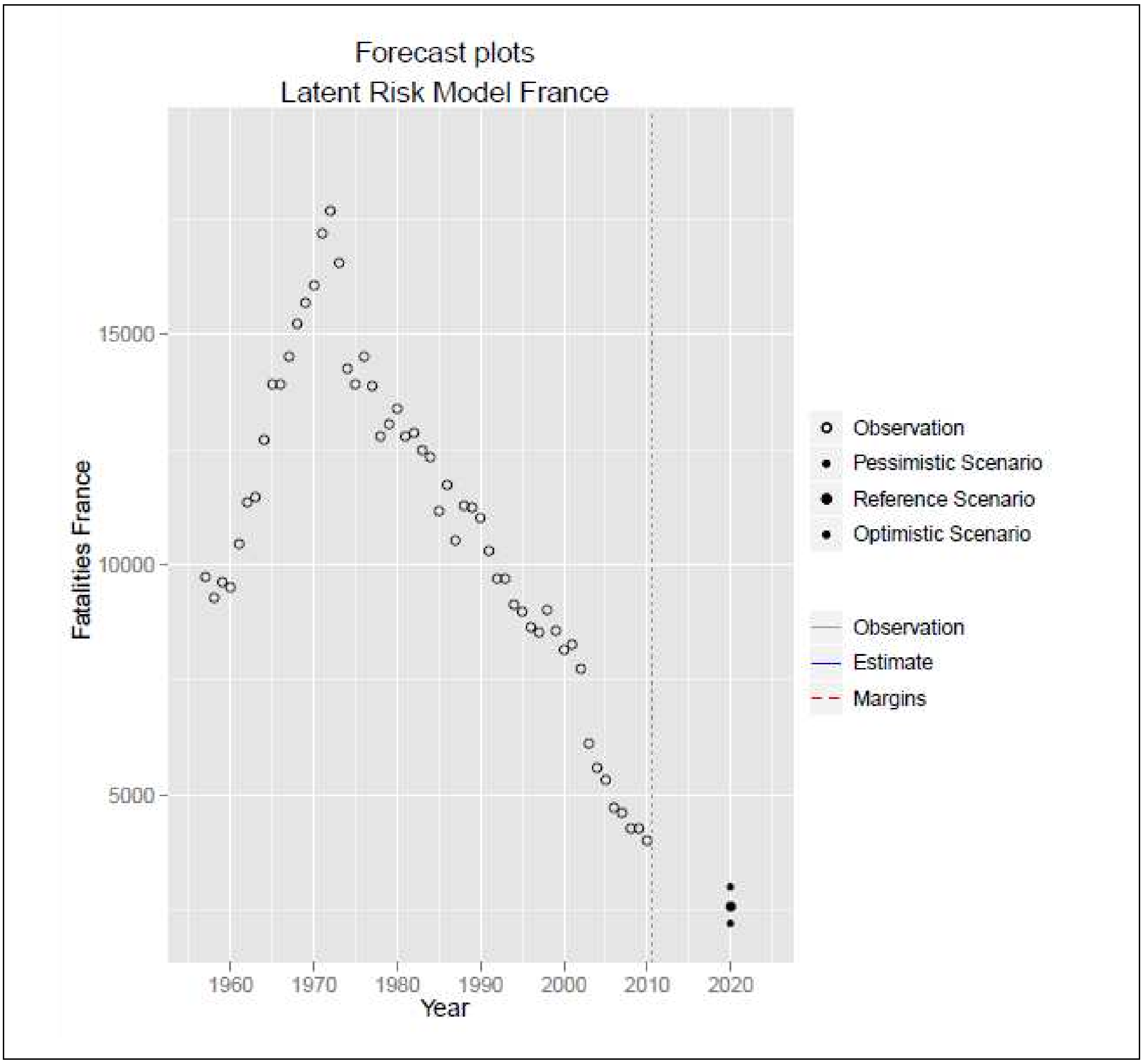


Figure 8: Fatality forecasts France 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the vehicle kilometres as predicted from the LRT model plus/minus one standard deviation. Assuming that these predictions are correct, and thus ignoring the uncertainty surrounding the forecasts for the exposure, what would be the consequences for the number of fatalities to be expected in 2020?

The full dot in Figure 7 is the expected number of fatalities given that mobility keeps developing as it has before (prediction 589 billion veh.km per year). The circles indicate the estimated number of fatalities for an optimistic scenario for exposure (forecast plus one standard deviation: x billion veh.km) and for a pessimistic scenario (forecasted value minus one standard deviation: x billion veh.km). The prediction that we achieve under these three scenarios are summarized in Table 4.

	Vehicle kilometres (billions)	***Road traffic fatalities***
Situation 2010:	561.3	3994*
Prediction for 2020 according to mobility scenarios:		
Continuation of development	589	2576
Stronger growth		2206
No growth		3008

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRT 2). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation. * Fatalitiy value for 2010 based on fatalities on the spot.

GERMANY

1 Raw data

In October 1990, the German Democratic Republic (GDR/East Germany) joined the Federal Republic of Germany (FRG/West Germany). Given that the registration of fatalities, the development of road safety, and the development of the traffic volume are not comparable between the two prior “Germanies” and the present re-united Germany, we start our series in 1991. Additionally, the analysis of a series starting in 1970 to which the West German pre-1991 data have been added will be presented for diagnostic purposes (see Section 10.3).

1.1 Exposure

The selected exposure measure are the vehicle kilometres (in billions) per annum (see Figure 10.1), which are considered from 1991 onwards.

Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for Germany from 1991 to 2010.

Between 1991 and 1998 the vehicle kilometres show a strong and more or less linear increase from 574 to 670 billion vehicle kilometres. After a period of fluctuations between 1999 and 2005, the development settles back into a regular increase, which is however less pronounced. The effect of the recession in 2008 can be seen from the stagnation in the number of vehicle kilometres. In 2010, the mobility is estimated at almost 705 billion kilometres (provisional estimate).

1.2 Fatalities

The German road accident fatalities from 1991 are plotted in Figure 10.2.

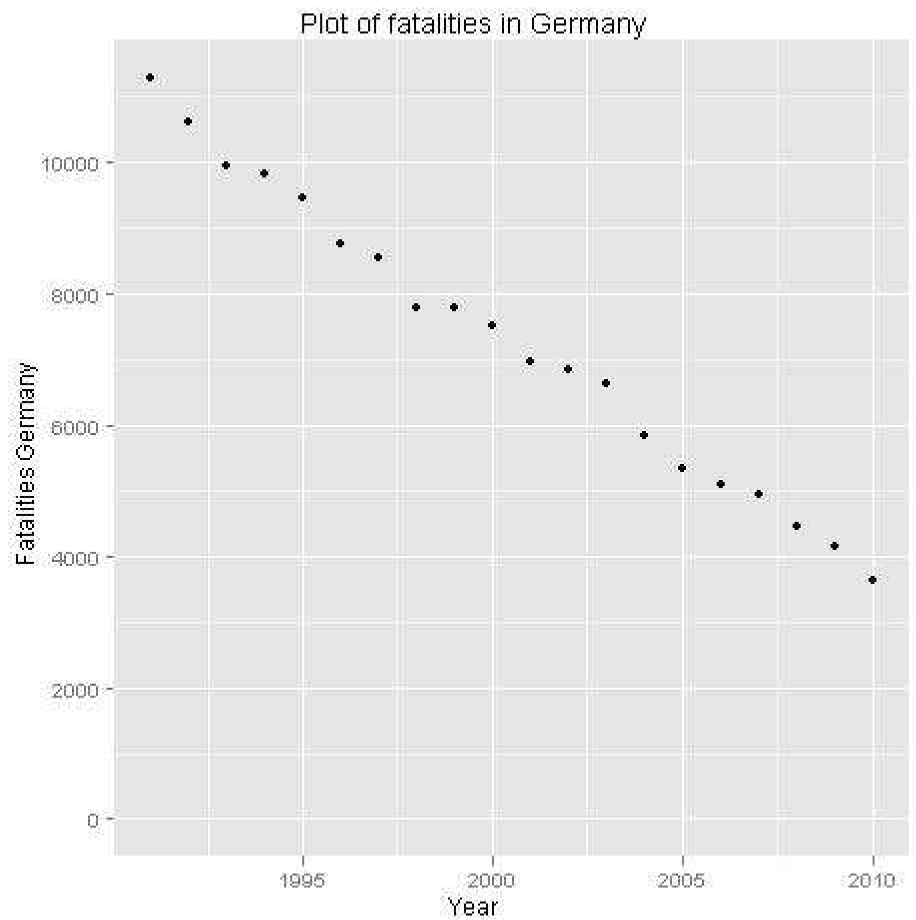


Figure 2: Plot of the annual fatality counts for Germany from 1991 to 2010.

The development of the number of fatalities from 1991 is almost a linear decrease from more than 11000 fatalities in 1991 to less then 4000 in 2010. The average annual decrease is 402.

2 The SUTSE Model

2.1 Development of the state components

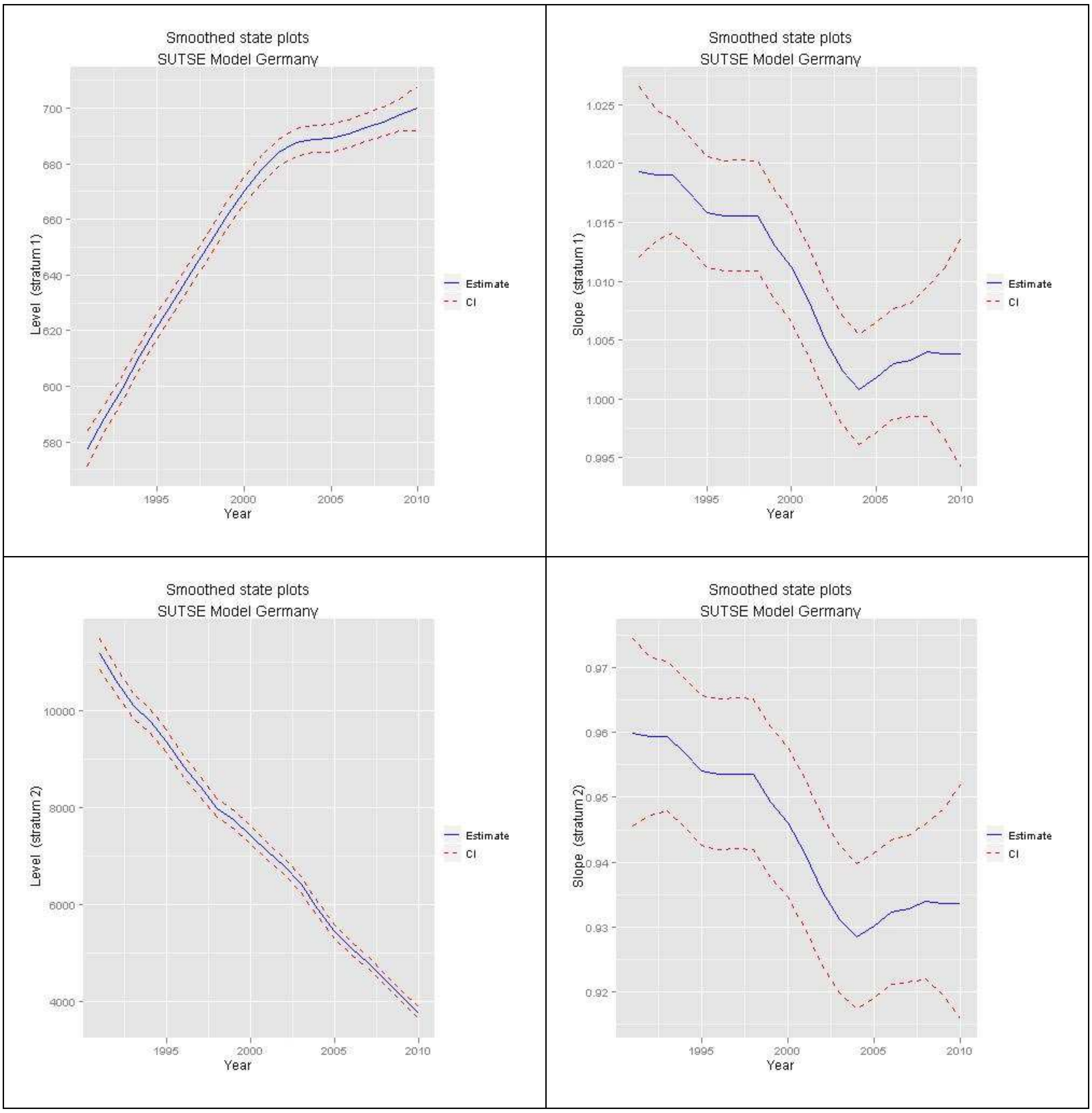


Figure 3: Germany - Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The slope component varies significantly, while the level does not. The German vehicle kilometres increased from 574 billion in 1970 to almost 705 billion in 2010. The slope varies significantly, indicating that the increase did not take place at the same rate throughout this period. In the early nineties there was an increase of 1.5 and 2% annually, then there was a big drop in the rate of change and since 2002 the growth in traffic volume has been less than half a percent annually.

2.1.2 Fatalities

As we have a very regular decrease in fatalities and a very short series, neither the level nor the slope of the fatalities vary significantly. On average the German fatalities have been decreasing by 16% annually.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

Neither the level nor the slope of the fatalities can be considered stochastic. The observed correlations of 1 between the levels and the slopes are therefore not necessarily meaningful, and indeed they are not significant. With such short series it becomes very difficult to see a significant relation. For the correlation between the slopes p=.2, which is not significant but no strong evidence against a correlation as well.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -.18 which is not significant (p=0.69).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 1.85 and is not significant (p=0.17)

The results of the restricted SUTSE/LRT model are exactly the same as those for the full SUTSE model, indicating that the relation between fatalities and exposure does not vary over time.

Model title	***SUTSEGermany1***	***SUTSEbetaGermany1***
Model description	SUTSE full model	SUTSE indipendent components, beta estimated
Model Criteria		
log likelihood	92.37	92.37
AIC	-183.84	-183.84
Variance of state components		
Level exposure	4.58E-07 nsc	4.58E-07 nsc
Level risk	3.45E-04 nsc	3.45E-04 nsc
Slope exposure	1.11E-05 *c	1.11E-05 *c
Slope risk	3.67E-05 nsc	3.67E-05 nsc
Correlations between state components		
level-level	1	1
slope-slope	1	1
Observation variance		
Observation variance exposure	6.12E-05 *	6.12E-05 *
Observation variance risk	2.55E-04 ns	2.55E-04 ns
Beta		1.85
		p= 0.17

Table 1: Overview of the results for SUTSE models – Germany**.**

3 Analysis of West German data

As with many countries that experienced a structural change during the fall of the Warsaw Pact at the beginning of the 90s, the series since then is extremely short for the purpose of running time-series analyses and it is difficult to differentiate between structurally different models.

For Germany, a much longer series is available for the western part of the country, which shows a strong continuity with the present-day development for the whole country. The East-German series is much shorter and, more importantly, it is suspected that the degree of registration was not the same as now.

The West-German data might be a good source of information concerning the structure of the development. They are publicly available from 1970 to 1998. Since 1990, we also have data for the reunited Germany. The models below were run on West Germany data from 1970 to 1990 and on data for the whole of Germany from 1991 to 2010 together. All models

Model title	***SUTSE Ger(W)1***	***SUTSEbeta Ger(W)1***	***LRT Ger(W)1***	***LRT Ger(W)1a***	***LLTFat Ger(W)***
Model description	SUTSE full model	SUTSE independent components, beta estimated	Full model	Full model + I1974exp; 1981exp	Full model
Model Criteria					
log likelihood	173.19	173.19	173.2	166.4	68.1
AIC	-345.94	-345.94	-345.9	-332.4	-136.1
Model Quality					
Box-Ljung test 1 Exposure	0.19	0.19	0.19	0.31	
Box-Ljung test 2 Exposure	0.4	0.4	0.4	0.34	
Box-Ljung test 3 Exposure	1.51	1.51	1.51	1.11	
Box-Ljung test 1 Fatalities	2.49	2.49	2.49	1.78	0.88
Box-Ljung test 2 Fatalities	3.16	3.16	3.16	2.59	1.43
Box-Ljung test 3 Fatalities	3.16	3.16	3.16	2.68	1.43
Heteroscedasticity Exp.	0.25*	0.25*	0.25*	0.60	
Heteroscedasticity Fat.	0.17**	0.17**	0.17**	0.17**	0.23*
Norm stand. Residuals Exp.	15.89***	15.88***	15.89***	1.11	
Norm stand. Residuals Fat.	3.45	3.45	3.45	7.79*	1.86
Norm. output Aux Res Exp.	0.08	0.08	0.08	0.24	
Norm. output Aux Res Fat.	0.27	0.27	0.27	0.15	3.21
Norm Aux Res Level exp.	16.69***	16.69***	25.31***	1.42	
Norm Aux Res Slope exp.	0.47	0.47	0.21	1.1	
Norm Aux Res Level risk	7.99*	7.99*	7.99*	6.58*	2.23
Norm Aux Res Slope risk	0.58	0.58	0.58	0.44	0.00
Variance of state components					
Level exposure	4.51E-04 ns	4.51E-04 ns	4.51E-04 *	7.31E-05 nsc	
Level risk	1.64E-03 *	1.64E-03 *	1.29E-03 *	1.34E-03 *c	1.93E-03 *
Slope exposure	1.69E-05 *c	1.69E-05 *c	1.69E-05 *c	3.07E-05 *c	
Slope risk	8.01E-06 nsc	8.01E-06 nsc	1.64E-06 nsc	2.90E-06 nsc	1.05E-06 ns
Correlations between state components					
level-level	0.46	0.46	-0.1	0.6	
slope-slope	1	1	-1.0	-1.0	
Observation variance					
Observation var. exposure	2.45E-05 ns	2.45E-05 ns	2.45E-05 ns	5.85E-05 ns	
Observation var. risk	6.37E-04 ns	6.37E-04 ns	6.37E-04 ns	4.39E-04 ns	5.19E-04 ns
Beta	0.776(*)				
Interventions					
level exp 1991: reunification	0.14 *	0.14 *	0.14 *	0.13 *	
level risk 1991: reunification	0.41 *	0.41 *	0.28 *	0.28 *	
level exp 1981: 2nd oil crisis				-0.09 *	
level exp 1974: 1rst oil crisis				-0.06 *	

Table 2: Overview of the results for models on West Germany (1970-1990) and Germany (1991-2010) together. In all models German re-unification is modeled by the inclusion of a level intervention for exposure as well as (fatality) risk in 1991.

were run with level interventions in 1991 for exposure as well as fatalities/risk in order to model the addition of the East-German data after the re-unification of Germany. For LRTGer(W)2 additional interventions were added to model the two oil crises.

The model quality tests show that modelling the German re-unification by simply including two interventions is not quite sufficient. The model has strong problems with heteroscedasticity and with the normality of the standard residuals. This becomes somewhat better in LRTGer(W)2 where two additional interventions are included in 1974 and 1981 to model the decrease of the exposure due to the first and second oil crisis respectively. However, the model tests still indicate problems and thus confirm the notion that a mixture of pre-1991 West German data and post 1990 data from the whole of Germany is not an ideal base for forecasts. It is nevertheless interesting to look at the model structure that comes forward when using a longer series. The beta test, which had a significance level of p=0.17 is now (marginally) significant with p=.058, suggesting that there is indeed a relation between the vehicle kilometres on the one hand and the number of fatalities on the other. In the LRT models, the tests on the state components suggest that not only the slope of exposure, but also the level of the risk show significant variation. Given that with 40 data points the state components have a “fair chance” to become significant, it is instructive to see that the variances of the exposure level and risk slope remain non-significant when estimated on the basis of this longer series.

4 The LRT Model

The investigation of the SUTSE model on the German data since 1991 did not clearly indicate the presence of a relation between exposure and fatalities in Germany. Yet the non significant relation between the two could be due to the small number of observations. We do not have a reason to suspect that the exposure measurement does *not* reflect the mobility in Germany. When additionally considering the West German pre 1991 data, a significant relation became apparent. As a consequence it is safer to use the LRT model which takes the development of the exposure into account for the forecast of the fatalities.

4.1 Model selection

Model title	***LRTGermany1***	***LRTGermany2***	***LRTGermany3***	***LRTGermany4***	***LRTGermany5***
Model description	Full model	fixed slope risk	fixed level exposure slope risk	fixed level exposure, level risk	fixed level exposure, level & slope risk
Model Criteria					
ME10 Exposure	-33.2	-45.3	-46.8	-33.2	-46.8
MSE10 Exposure	1677.3	2939.2	3085.2	1677.3	3085.2
ME10 Fatalities	-484.5	-390.9	-379.1	-484.5	-379.1
MSE10 Fatalities	383594.8	279455.7	271090.6	383594.1	271090.5
log likelihood	92.4	91.9	91.9	92.0	89.1
AIC	-183.8	-183.2	-183.2	-183.4	-177.8
Model Quality					
Box-Ljung test 1 Exp.	3.11	3.21	0.90	0.79	0.64
Box-Ljung test 2 Expo.	4.46	5.11	3.08	2.86	2.49
Box-Ljung test 3 Exp.	5.91	6.72	5.27	4.73	4.85
Box-Ljung test 1 Fatalities	2.29	0.7	0.70	1.12	1.26
Box-Ljung test 2 Fatalities	2.30	0.78	0.75	2.04	1.28
Box-Ljung test 3 Fatalities	3.01	1.53	1.38	2.08	2.01
Heteroscedasticity Exp.	0.95	0.94	1.04	0.93	1.11
Heteroscedasticity Fat.	1.23	1.24	1.28	1.68	2.26
Norm. Stand. Res. Exp.	0.15	0.2	0.32	0.24	0.39
Norm. Stand. Res. Fat.	0.93	1.03	1.08	1.17	2.04
Norm. output Aux Res Exp	1.19	1.22	1.06	1.13	0.64
Norm. output Aux Res Fat	0.56	0.66	0.66	0.44	1.21
Norm. Aux Res Level exp	0.39	0.15	0.21	0.47	0.24
Norm. Aux Res Slope exp	0.44	0.16	0.18	0.28	0.22
Norm. Aux Res Level risk	0.7	0.92	0.87	0.81	0.95
Norm. Aux Res Slope risk	0.60	0.02	0.01	0.62	0.00
Variance of state components					
Level exposure	4.58E-07 nsc	4.24E-06 nsc	-	-	-
Level risk	3.20E-04 nsc	5.67E-04 *c	6.71E-04 *	-	-
Slope exposure	1.11E-05 *c	1.07E-05 *	1.20E-05 *	1.20E-05 *c	1.35E-05 *
Slope risk	7.38E-06 nsc	-	-	3.33E-05 *c	-
Correlations between state components					
level-level	1.0	1.0		0.4	
slope-slope	1.0				
Observation variance					
Observation variance exposure	6.12E-05 *	5.90E-05 *	5.95E-05 *	5.98E-05 *	6.16E-05 *
Observation variance risk	2.55E-04 ns	1.09E-04 ns	9.94E-05 ns	4.25E-04 *	8.63E-04 *

Table 3: Overview of the results for LRT models – Germany 1991-2010

The model quality tests indicate no problem with any of the models. The slope of exposure is the only state component that shows significant variation and the restricted models show that indeed all models fixing different combinations of the non-significant states have almost equally good fits. The model fits the post-91 data equally well to a model when the slope of the risk is fixed as when the level of the risk is fixed (together with the level of exposure). The model in which all three non-significant parameters are fixed (LRTGermany5) shows a very slight decrease in fit. Altogether, it must be stated that the fit information does not indicate differences between the models that would allow selecting one of them with any rate of confidence.

The prediction errors also give little indication which model to select, although for the prediction of the last 10 years, it seems beneficial to fix the slope (i.e. models LRTGermany3 and LRTGermany5).

A slight preference to fix the risk slope rather than the risk level (and not both of them) is in accordance with what is observed in the models where the West German pre-1991 data have been added. In this longer series, the risk level was significant but the risk slope was not. The model selected for the forecast is therefore model LRTGermany3 with the level of exposure and the slope of the risk fixed.

4.2 Development of the state components

4.2.1 Exposure

The German vehicle kilometres increased from 574 billion in 1991 to almost 705 billion in 2010. The slope varies significantly, indicating that the increase did not take place at the same rate throughout this period. In the early nineties there was an increase between 1.5 and 2% annually, then there was a big drop in the rate of change and since 2002 the growth in traffic volume has been less than half a percent annually. The level does not vary significantly.

4.2.2 Risk

The risk for fatalities has been reduced in Germany from more than 18 per billion vehicle kilometres in the early 90s to less than 6 per billion vehicle kilometres since 2008. This decrease has taken place in an almost linear way with a rate of decrease of 9.3-9.4% yearly. This is reflected in the slope that is strongly negative but shows no significant variation.

For exposure, the level was not significant and was fixed. For the risk, neither the slope nor the level were significant but only the slope was fixed. The slopes as well as the levels of exposure and risk are correlated at 1. As three of the states were however not significant in themselves, common components were not considered.

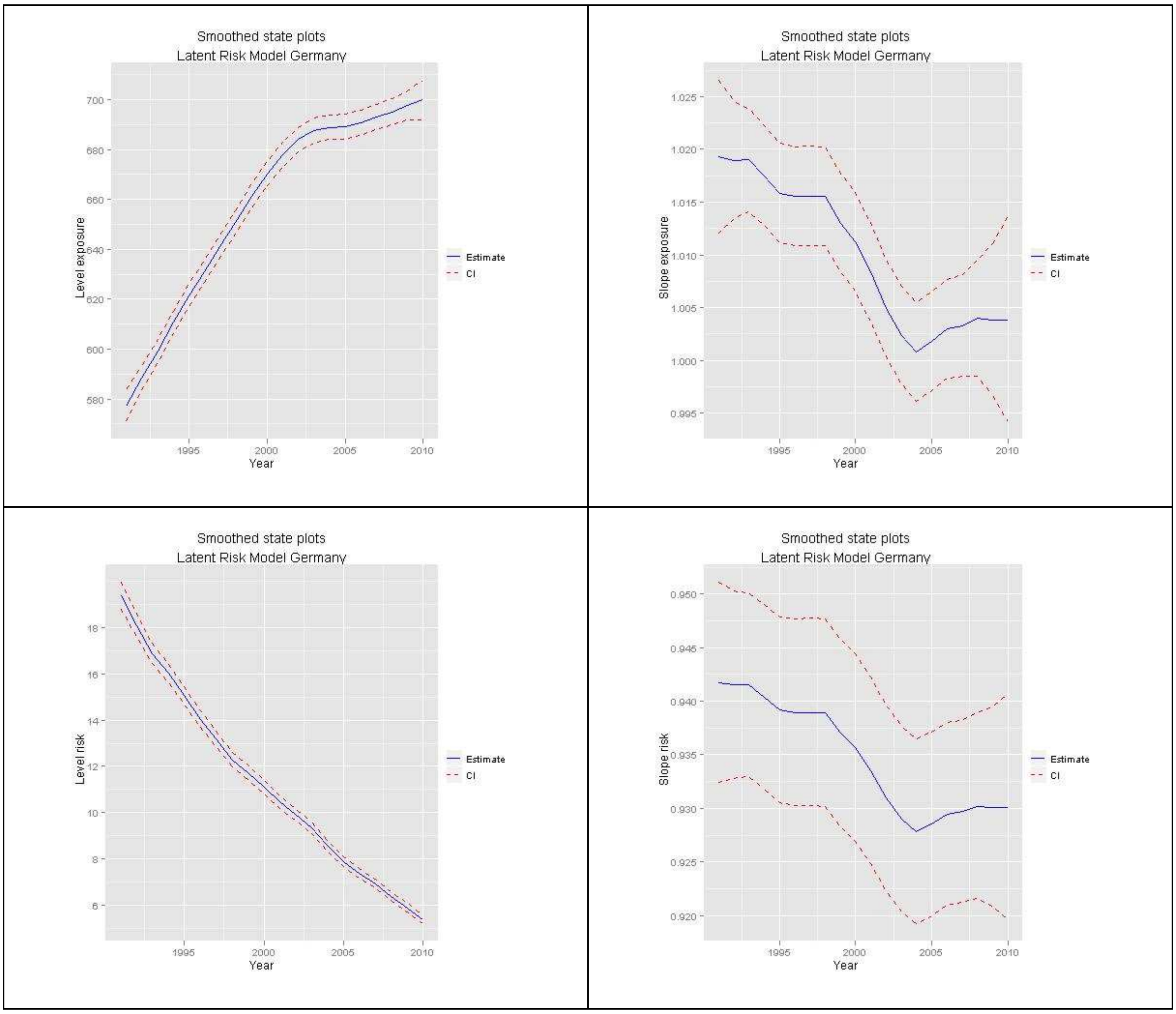


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the right-hand graphs, the slope developments in the left-hand graphs.

4.3 Quality of the predictions

To evaluate how well models implemented here have done in the past, the data up to 2001 are used to forecast the fatalities between 2002 and 2010. Figure 10.5 below shows a comparison between the predicted and actually observed values.

4.3.1 Fatalities

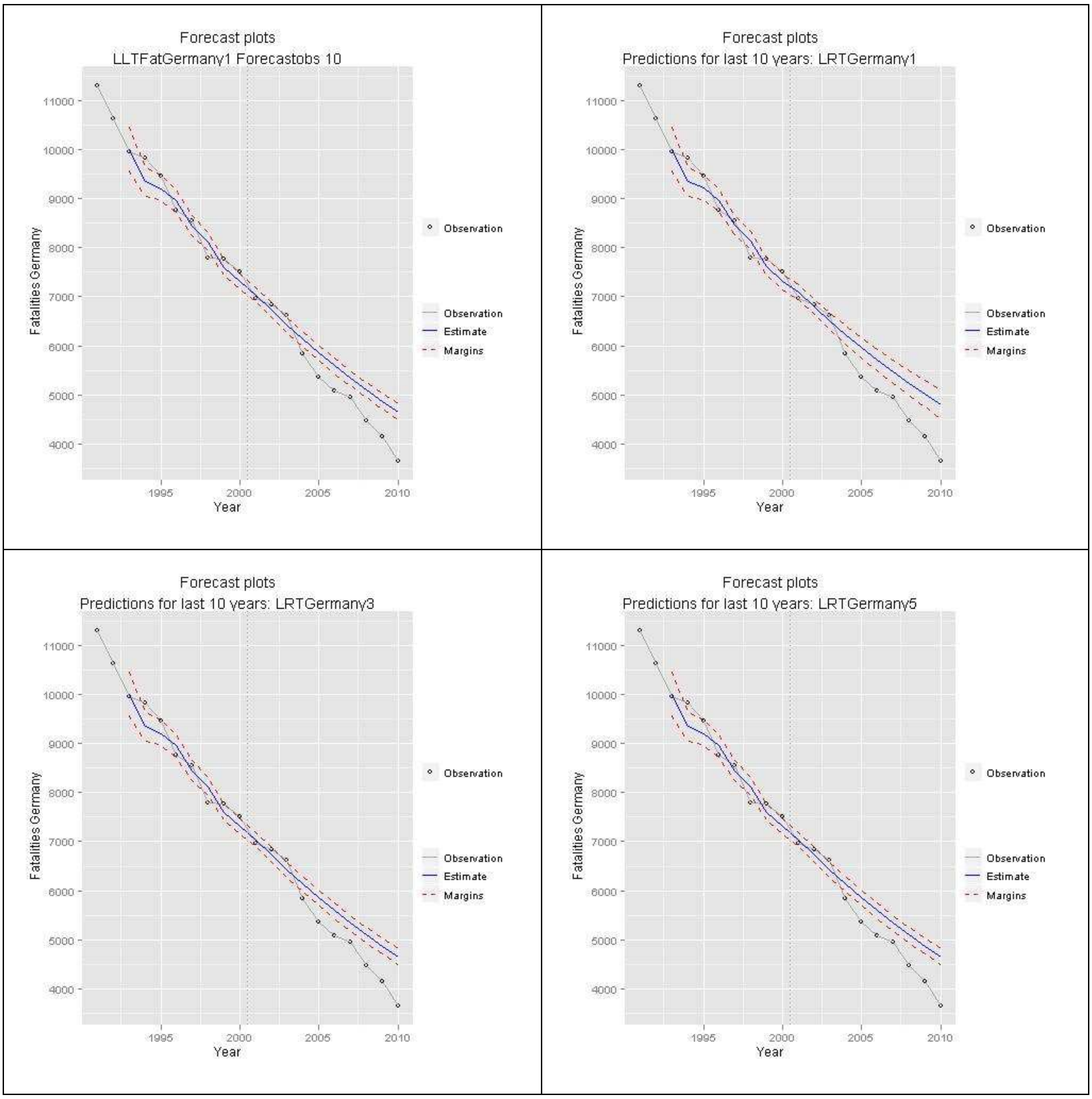


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Germany.

In Figure 5, the German fatalities are forecasted up to 2010 with the LLT model (upper left) and three different variants of the Latent Risk model using data up to the year 2000. No difference is recognizable with the bare eye and indeed as presented in Table 4, the differences in prediction quality of past observations were extremely small.

5 Forecasts 2011 - 2020

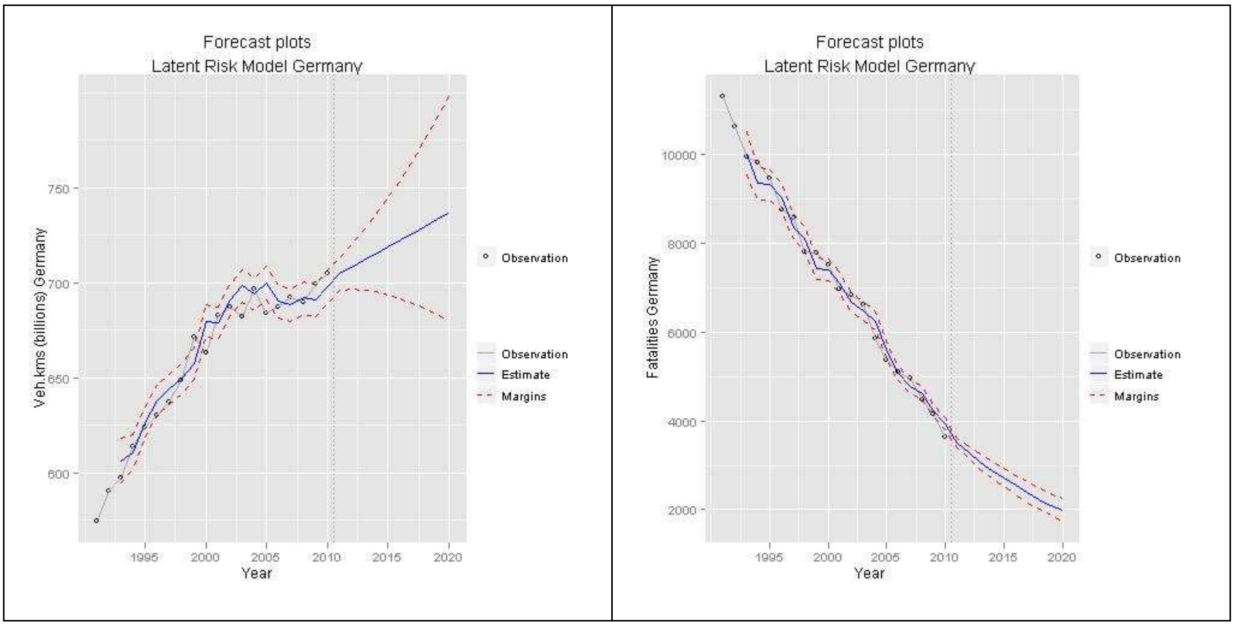


Figure 6: Plot of the vehicle kilometres (right-hand graph) and annual fatality numbers (left-hand graph) for Germany forecasted between 2011 and 2020. (Forecasting model is LRTGermany3).

The forecasts in Figure 6 and Table 4 provide an indication of the vehicle kilometres and the fatality numbers to be expected between 2011 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Vehicle kilometres (billion)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2011	**705**	688	722	**3497**	3273	3735
2012	**708**	685	732	**3281**	3004	3585
2013	**712**	682	743	**3079**	2761	3434
2014	**715**	676	756	**2889**	2539	3287
2015	**719**	670	771	**2711**	2336	3147
2016	**722**	663	787	**2544**	2148	3014
2017	**726**	656	804	**2388**	1974	2887
2018	**730**	647	822	**2240**	1814	2767
2019	**733**	639	842	**2102**	1665	2654
2020	**737**	629	863	**1973**	1528	2547

Table 4.: Forecasts of Latent Risk Model (LRT 3).

6 Scenarios

In Figure 6 it can be seen that there is some uncertainty about the development of the exposure in Germany. Given that the exposure influences the prediction of the fatalities it is interesting to demonstrate how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 7 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

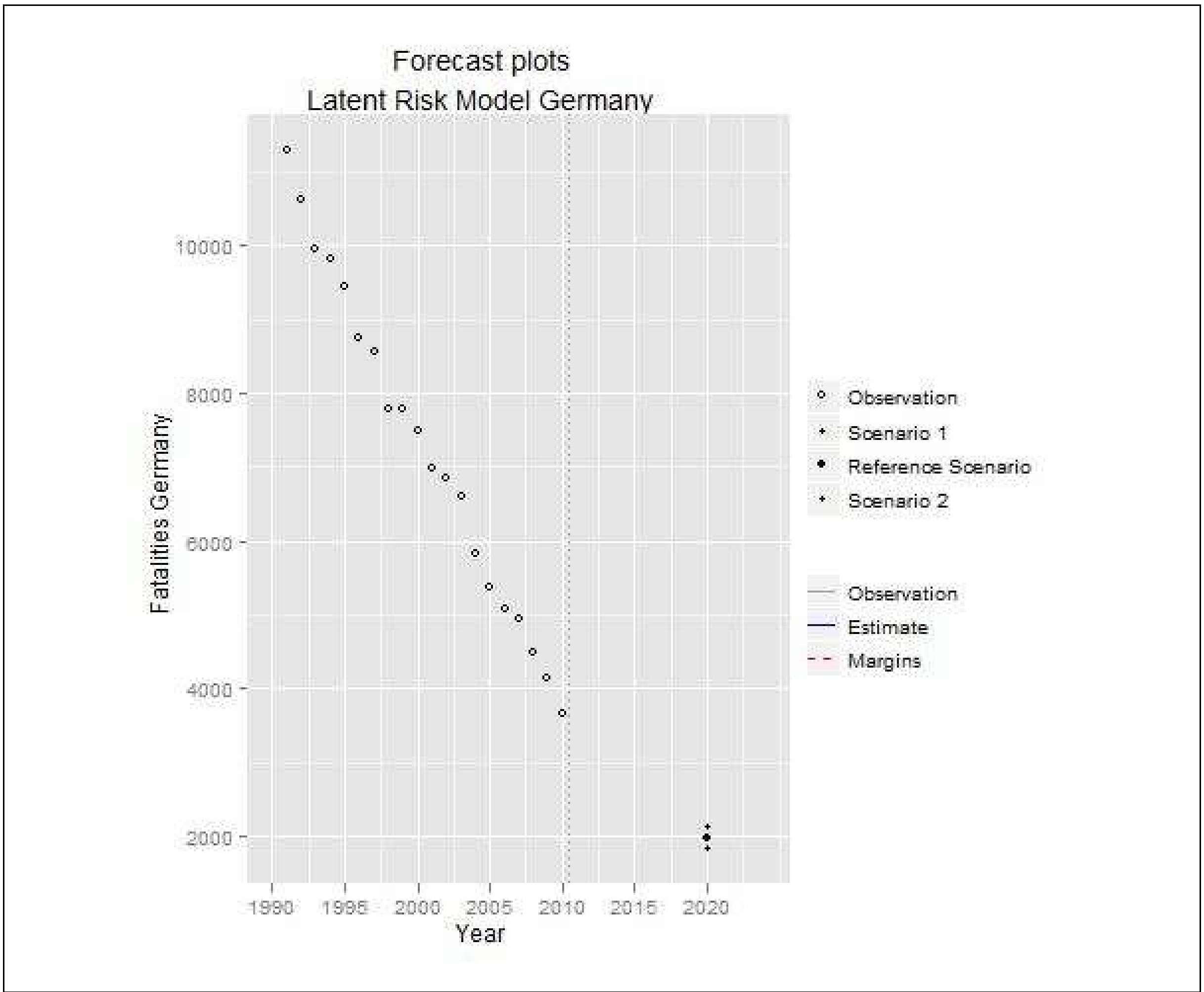


Figure 7: Fatality forecasts Germany 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the vehicle kilometres as predicted from the LRT model plus/minus one standard deviation. Assuming that these predictions are correct, and thus ignoring the uncertainty surrounding the forecasts for the exposure, what would be the consequences for the number of fatalities to be expected in 2020?

The full dot in Figure 10.6 is the expected number of fatalities given that mobility keeps developing as it has recently (prediction 692 billion veh.km per year). The circles indicate the estimated number of fatalities for an optimistic scenario for exposure (forecast plus one standard deviation: 986 billion veh.km) and for a pessimistic scenario (forecasted value minus one standard deviation[13]: 486 billion veh.km). The prediction that we achieve under these three scenarios are summarized in Table 10.5.

	Vehicle kilometres (billions)	***Road traffic fatalities***
Situation 2010:	705	3648
Prediction for 2020 according to mobility scenarios:		
Continuation of development (growth)	737	1973
Strong growth	798	2129
Decrease	680	1828

Table 5: Germany - Forecasting scenarios on the basis of the Latent Risk model (LRT 2). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation. * Fatalitiy value for 2010 based on fatalities on the spot.

[13] Note that 68% of all cases are between the estimated value +/- one standard deviation (under the assumption of a normal distribution).

GREECE

1 Raw data

1.2 Exposure

It is widely accepted that vehicle kilometer are an appropriate exposure measure. However, there are no vehicle kilometer data available for Greece and therefore the vehicle fleet is used as a proxy. The selected exposure measure are the vehicles in circulation (in thousands) per annum (see Figure 1), which are considered from 1960 onwards.

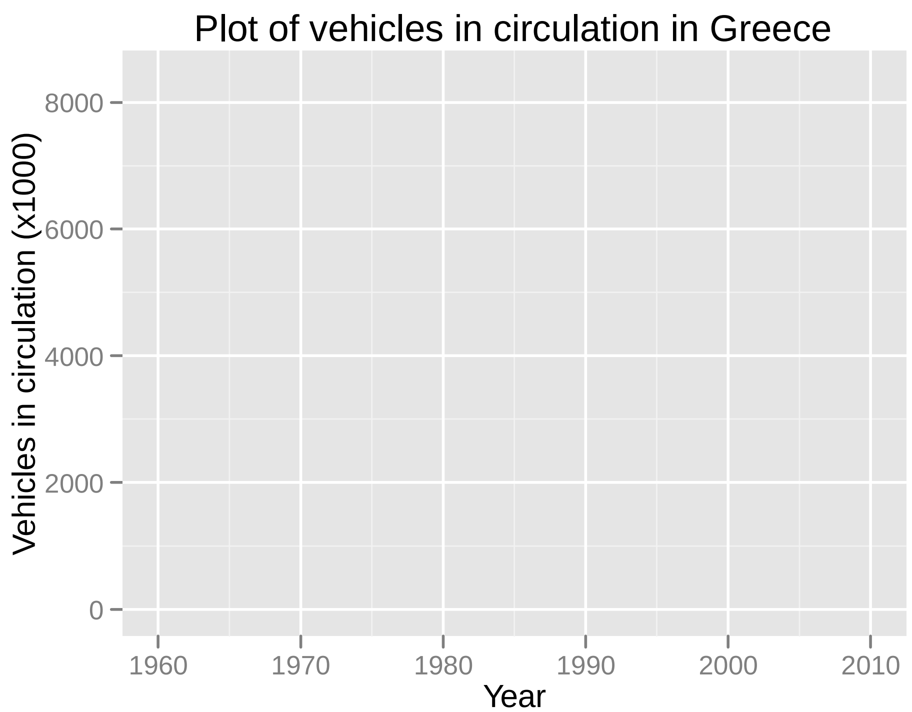


Figure 1: Plot of the annual vehicle fleet (x1000) for Greece from 1960 to 2010.

The number of vehicles in circulation shows an increasing rate of increase from 1960 to almost 2008. During the last couple of years, there appears to be a slower rate of increase, reflecting the effect of the recession. However, this effect is not as evident as it would be if a more appropriate measure of exposure, such as vehicle-kilometres, was available. If a measure such as the number of vehicle exposures was available, then the exposure measure would actually show a reduction, and not simply a reduced increase. The number of vehicles is a less volatile measure of the exposure, as (i) a reduction in the use of the vehicles does not necessarily correspond to a reduction on the number of vehicles and (ii) even when the vehicles are removed from circulation, it is not as easy to update the registry of vehicles.

1.2 Fatalities

The Greek road accident fatality figures from 1960 to 2010 are plotted in Figure 2. Before 1996 road accident fatalities in Greece were recorded based on the 24-hour definition (i.e. counting a person that has been injured in a traffic accident as a road-safety fatality, only if that person passed away within 24 hours of the occurrence of the accident), while since then the 30-day definition is used. The data presented in Figure 2 correspond to the 30-day definition for the entire period (converted via appropriate factors for the period prior to 1996).

The presented fatality data for Greece shows two distinct trends: an increasing one until approximately 1995, followed by a decreasing one thereafter. As there are only 15 data points describing the decreasing trend, it is expected that reserving a large number of observations for forecasting may affect the accuracy of the model.

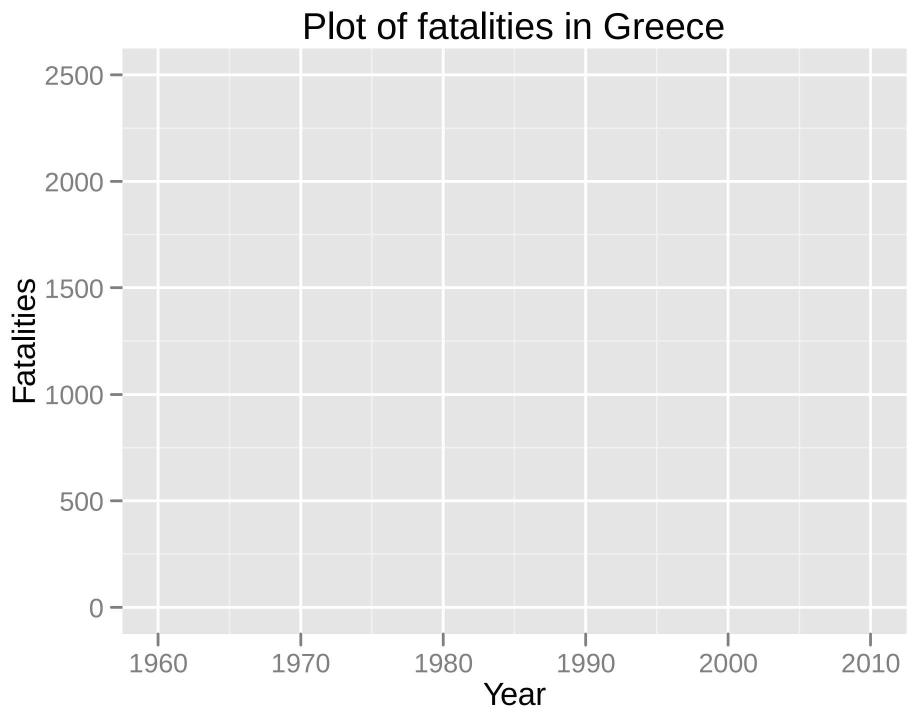


Figure 2: Plot of the annual fatality counts for Greece from 1960 to 2010.

While the exposure data seem rather smooth, the fatality data exhibit certain irregularities that could affect the model estimation results. In order to better account for these external shocks to the process, it was decided to seek possible events that could be identified and explicitly entered into the model. There are three main events that can be entered as interventions in the model for the period and data that are being analysed:

- **I1986**: in 1986 Greece encountered a financial crisis, which affected mobility and therefore exposure (note that –due to lack of the data- the exposure variable in the Greek dataset is vehicles in circulation and not direct exposure). This intervention is entered into the model as a shock in the specific time point.
- **I1991**: in 1991 Greece introduced an “old-car-exchange” scheme, under which old cars could be exchanged for a cash incentive to buy a new (safer and cleaner) car. While this did not affect the number of vehicles in circulation (one could argue that replacing older cars with newer might increase exposure), the introduction of newer, safer cars had a positive net effect in road safety. This intervention is also entered into the model as a shock in the specific time point.
- **I1996**: in 1996 the fatality recording system in Greece switched from 24-hour to 30-day. This meant that the use of the adjustment factor (from 24-hour to 30-day fatality figures) stopped at that time and real data was used from that point on. This intervention has been entered in the slope of the fatalities, as its impact is assumed to be unlike a point shock, but rather a sustained shift.

2. The SUTSE Model

2.1 Development of the state components

Figure 3 presents the varying level and slope estimation results of the SUTSE model: in particular the smoothed state plots for the exposure (top) and risk (bottom) variables. The left subfigure in each row shows the level estimate for the corresponding variable and the right subfigure shows the slope estimate. Confidence intervals are also presented in these figures. The confidence intervals on the levels are rather tight and are closely following the trends. What is perhaps more interesting is the slope of the variables. The slope of the exposure (top right subfigure) is always positive, but its magnitude is declining. The slope of the risk (bottom right subfigure) is also decreasing.

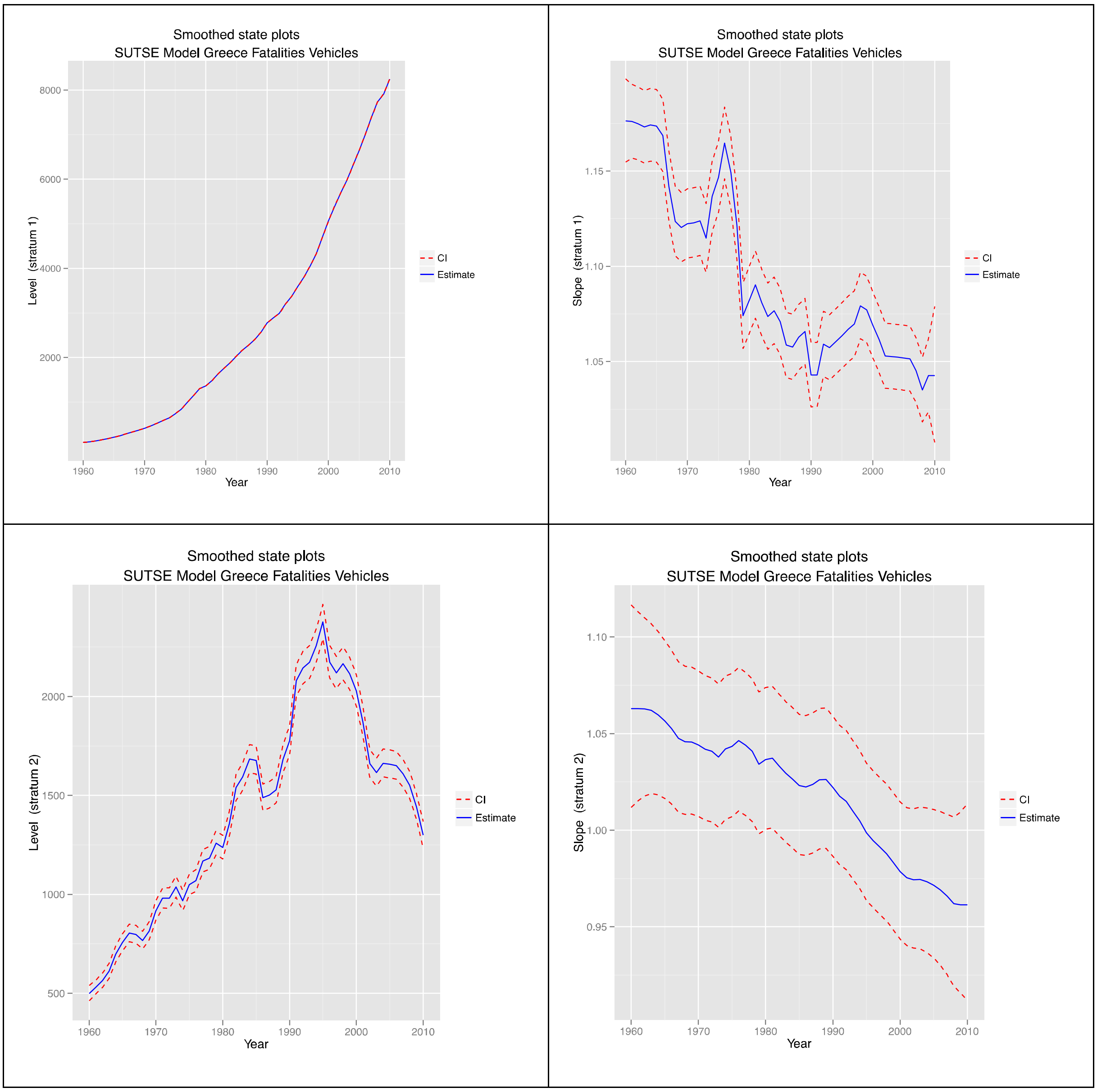


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

While the trend component is fairly smooth, the slope component varies significantly. The number of vehicles in circulation in Greece increased from less than 100K in 1960 to more than 8 million in 2010. The slope varies significantly, indicating that this increase did not take place at a constant rate. In particular, the rate of increase in the early 1960s was about 17%, while it has fallen below 5% in the recent years.

2.1.2 Fatalities

The level component varies significantly, while the slope varies less. The most important feature of the level component is a break in the trend from increasing to decreasing in 1995. The fatalities increased from about 500 in 1960 to about 2300 n 1995 and then dropped to about 1300 in 2010. In terms of the slope, the increase pretty much constantly reduced from about 5% in 1960 to zero in 1995 and then continuously decreased until about 3.5% in 2010.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

Two state components, the level of exposure and the slope of the fatalities, cannot be considered stochastic. The correlation between the two levels (p=0.33) and two slopes (p=0.77) is not significant. The value of the correlations between the two levels is 0.35 and between the two slopes is 0.24.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 6.4E-05 which is not significant (p=1).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 0.45 and is not significant (p=0.34)

Furthermore, the log-likelihood for the two models is not very similar, indicating that a possible time-varying relation between exposure and fatalities is unlikely. Therefore, it can be concluded that the fatalities and vehicle fleet series are not related and therefore further modeling can be made using the LLT model (instead of the LRT).

Model title	SUTSEGreece1	SUTSEbetaGreece1
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	237.76	237.42
AIC	-475.17	-474.53
Variance of the state components		
Level exposure	1.33E-04 nsc	1.23E-04 ns
Level risk	4.06E-03 *c	3.88E-03 *
Slope exposure	2.17E-04 *c	2.09E-04 *
Slope risk	1.09E-04 *c	7.43E-05 ns
Correlations between the state components		
level-level	0.35	1
slope-slope	0.24	1
Observation variance		
Observation variance exposure	1.014E-09 ns	5.16E-06 ns
Observation variance risk	1.689E-09 ns	9.01E-05 ns
Beta		0.45 ns

Table 1: Overview of the results for SUTSE models – Greece.

3. The LLT Model

The investigation of the SUTSE model indicates that a relation between vehicle fleet and fatalities in Greece is not present. Therefore an LLT model is fit for Greece.

3.1 Model selection

Three versions of the LLT model were run. The full model (LLT1) was run first, and all residual tests did not indicate a violation of the underlying assumptions. Furthermore, the level and slope components were significant. Therefore, a new model (LLT2) with additional interventions was estimated. While the fit of this model improved over the original model, the slope component became insignificant. Therefore, a third model (LLT3) was also run, with the interventions, but keeping the slope of the fatalities fixed.

Model title	*LLT 1*	*LLT 2*	*LLT3*
Model description	LLT for Greece – full model	LLT for Greece – with 3 interventions	LLT for Greece – with 3 interventions – fixed slope
Model Criteria			
ME4 Fatalities	-131	-61.4	-59.4
MSE4 Fatalities	28162.3	10047.9	9689.6
ME7 Fatalities	148.8	216.7	214.2
MSE7 Fatalities	26252.4	50702.2	49589.3
ME10 Fatalities	-692.5	-252.4	-251.5
MSE10 Fatalities	551769.3	71071.2	70572.97
log likelihood	85.66	65.84	65.82
AIC	-171.21	-131.56	-131.55
Model Quality			
Box-Ljung test 1 Fatalities	2.73	2.96	0.29
Box-Ljung test 2 Fatalities	3.63	4.30	2.78
Box-Ljung test 3 Fatalities	5.82	4.33	4.03
Heteroscedasticity Test Fatalities	0.79	0.75	0.76
Normality Test standard Residuals Fatalities	0.80	1.95	2.06
Normality Test output Aux Res Fatalities	1.28	1.13	1.17
Normality Test State Aux Res Level risk	1.61	1.34	1.10
Normality Test State Aux Res Slope risk	0.05	0.00	0.00
Variance of state components			
Level risk	3.91E-03 *	2.61E-03 *	2.67E-03*
Slope risk	1.25E-04 *	6.92E-06 ns	-
Observation variance			
Observation variance risk	1.00E-09 ns	1.00E-09 ns	1.00E-09ns
Intervention and explanatory variables tests			
(slope fat 1996)		-0.07 *	-0.08 *
(level fat 1986)		-0.21 *	-0.21 *
(level fat 1991)		0.15 *	0.15 *

Table 2: Overview of model results - Greece

The incorporation of the three interventions in the model LLT2 led to a considerable improvement over the model LLT1 both in terms of log-likelihood and AIC, but also in terms of the fit to fatalities when 4 and 10 observations are kept for forecasting and validation. In the case that 7 observations are kept for validation the results show a decrease in accuracy, but this is due to the variability in the last few data points. Actually, looking at the trend of the residuals when 4, 7 and 10 observations are kept for validation, one can notice that while the ME and MSE statistics increase for LLT2, ME and MSE for the case with 7 observations kept for validation for LLT1 shows lower residual values than those obtained for 4 observations.

Model LLT3 has one more degrees of freedom over LLT2 (since the slope of the fatalities is fixed) and both the log-likelihood and AIC, as well as the residual statistics ME and MSE improve. Therefore, this model is selected.

3.2 Development of the state components

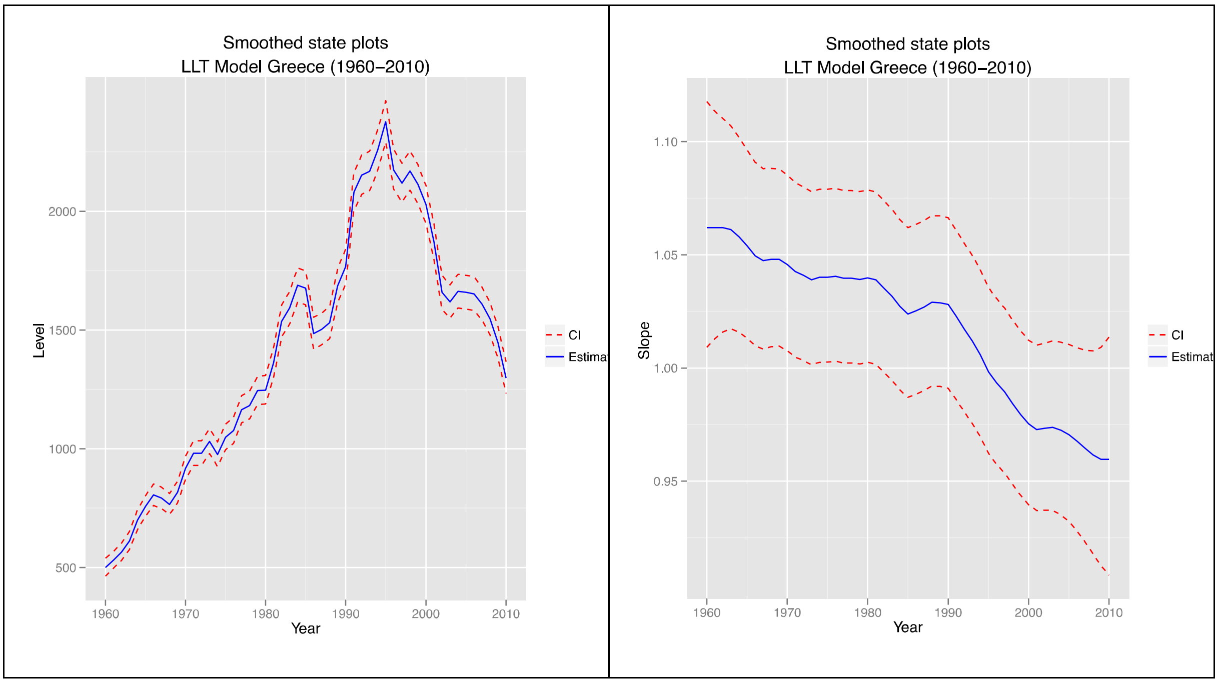


Figure 4: Developments of the state components for the fatalities, as estimated on the basis of the LLT model. The trend (level) development is represented in the right-hand graphs, the slope development in the left-hand graph.

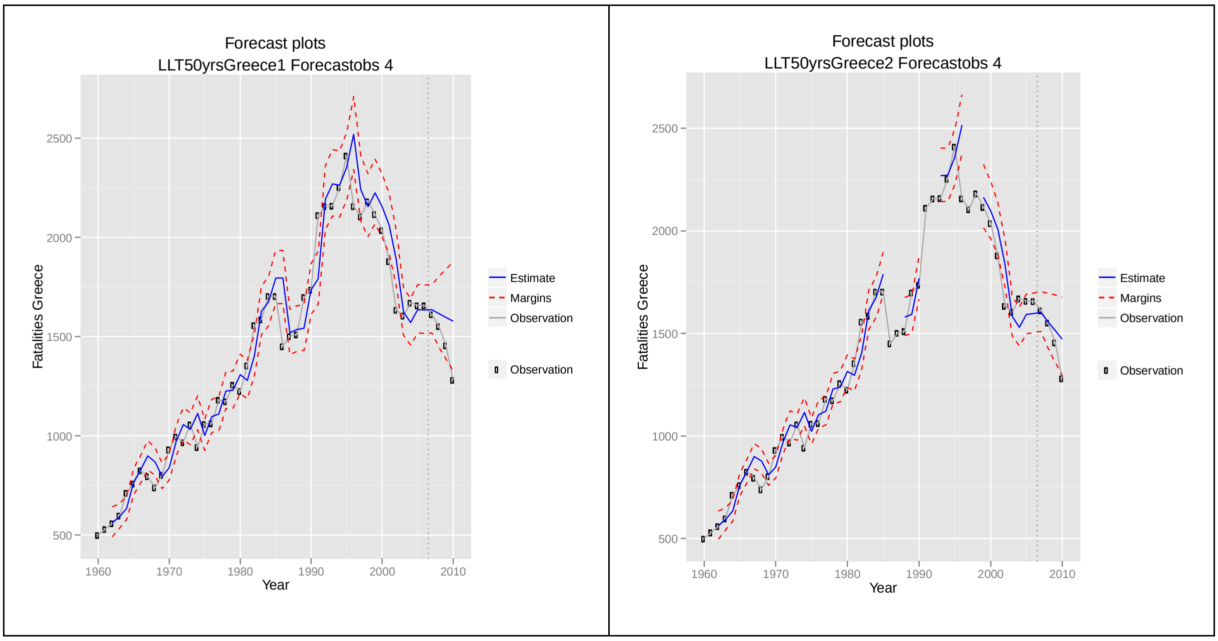
3.2.1 Fatalities

The number of fatalities has increased from about 500 in 1960 to about 2300 in 1995, at which point a decreasing trend started, reaching about 1300 fatalities in 2010. The slope of the fatalities has been reducing consistently, starting at more than 6% in 1960, reaching about 3% at 1990 and then decreasing at more rapid rate, reaching zero in 1995, when the peak in fatalities was observed. The decrease in the slope has been consistent since, reaching about -4% in 2010. The change in the slope, however, has been found to be insignificant when the interventions have been added into the model, indicating that these changes can be explained by these external factors.

4. Quality of the predictions

To evaluate how well models implemented here have done in the past, the data up to 2006 are used to forecast the fatalities between 2007 and 2010. This rather short number of observations is selected based on the nature of the last few observations and the overall nature of the fatality data (with the breakpoint in 1995). A larger number of observations reserved for validation, would leave a smaller number of observations for the model to capture the breakpoint and downward trend in the recent years). Figure 5 below shows a comparison between the predicted and actually observed values for the three estimated models. The results shown in Figure 5 indicate that the models with the interventions result in much better predictions than the model without interventions.

4.1 Fatalities



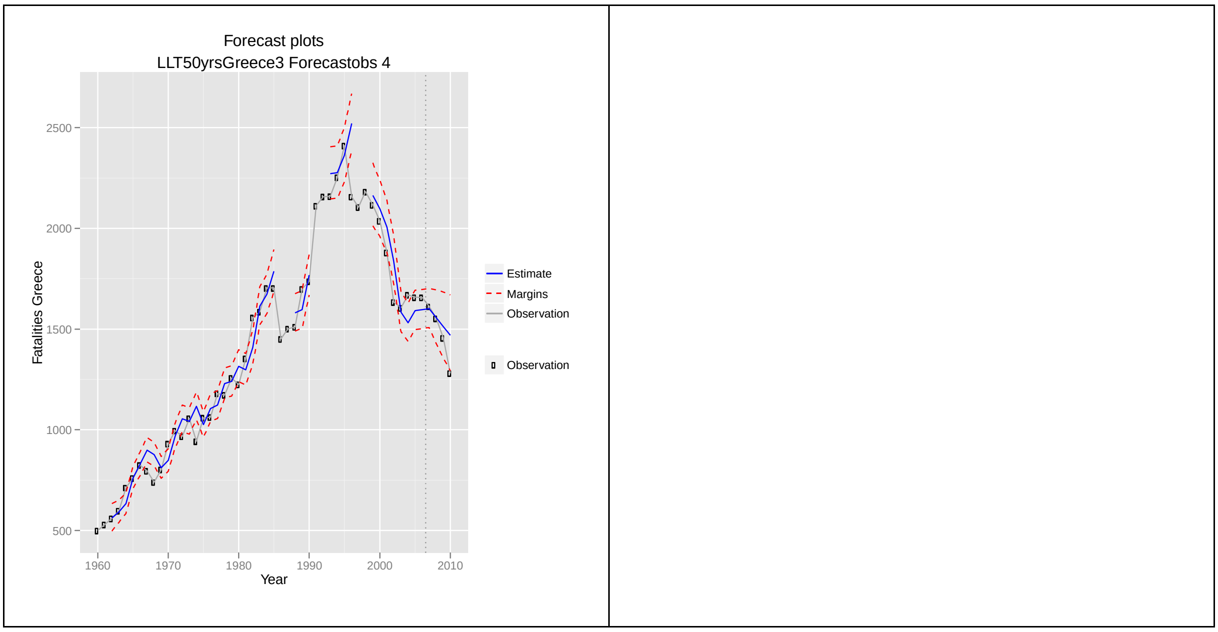


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Greece.

5 Forecasts 2011 - 2020

The forecasts in Figure 6 and Table 3 provide an indication of the fatality numbers that could be expected between 2011 and 2020 provided that the current trends keep on following throughout these years.

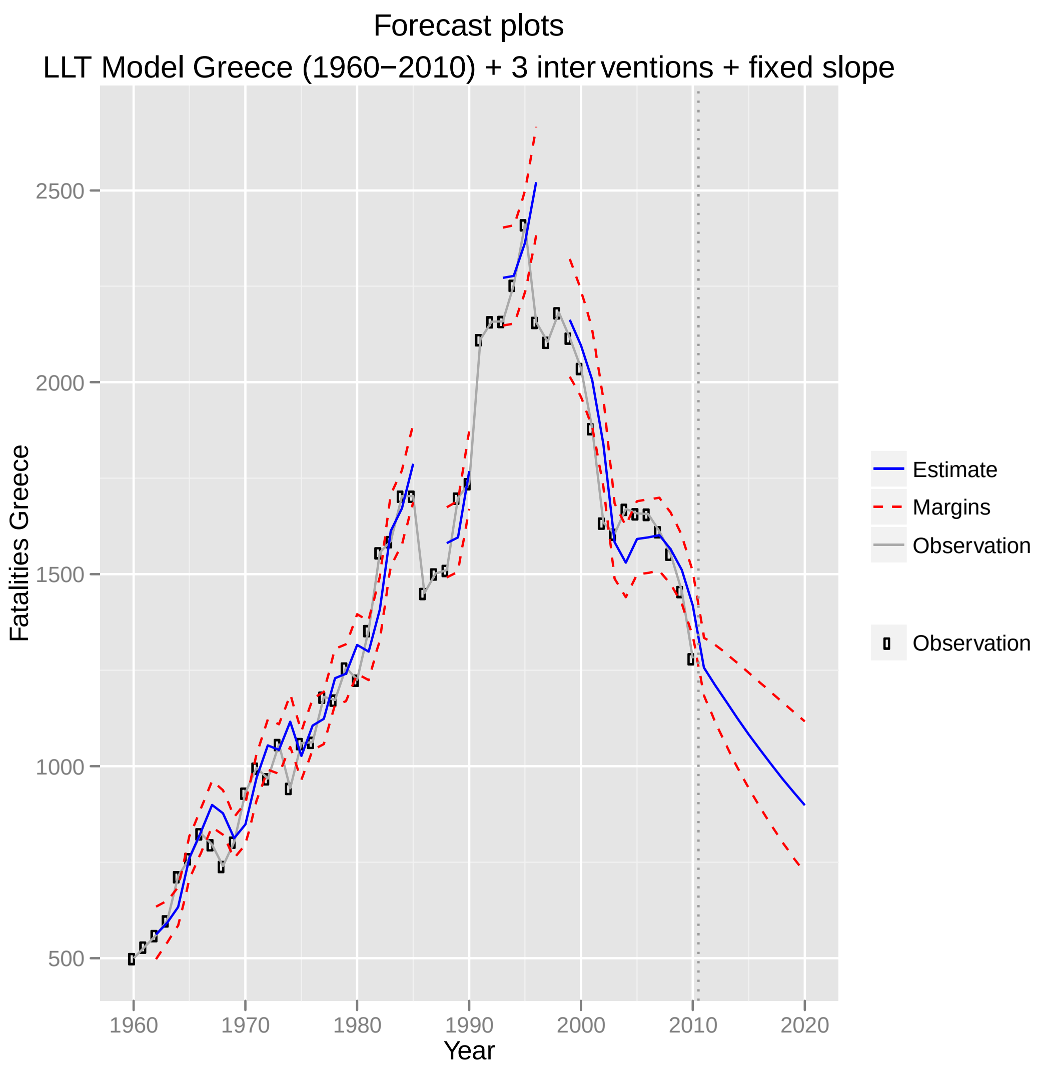


Figure 6: Forecast values for 2011-2020 for Greece based on the selected local linear trend model with interventions and fixed slope.

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**1257**	1118	1414
2012	**1211**	1029	1426
2013	**1167**	953	1429
2014	**1124**	885	1427
2015	**1083**	824	1422
2016	**1043**	769	1415
2017	**1005**	717	1407
2018	**968**	670	1398
2019	**932**	626	1389
2020	**898**	585	1379

Table 3: Forecasts of Local Linear Trend (LLT3)

HUNGARY

1 Raw data

1.1 Exposure

The available exposure measure is the person kilometres (in millions) travelled (see Figure 1), which are considered from 1970 onwards.

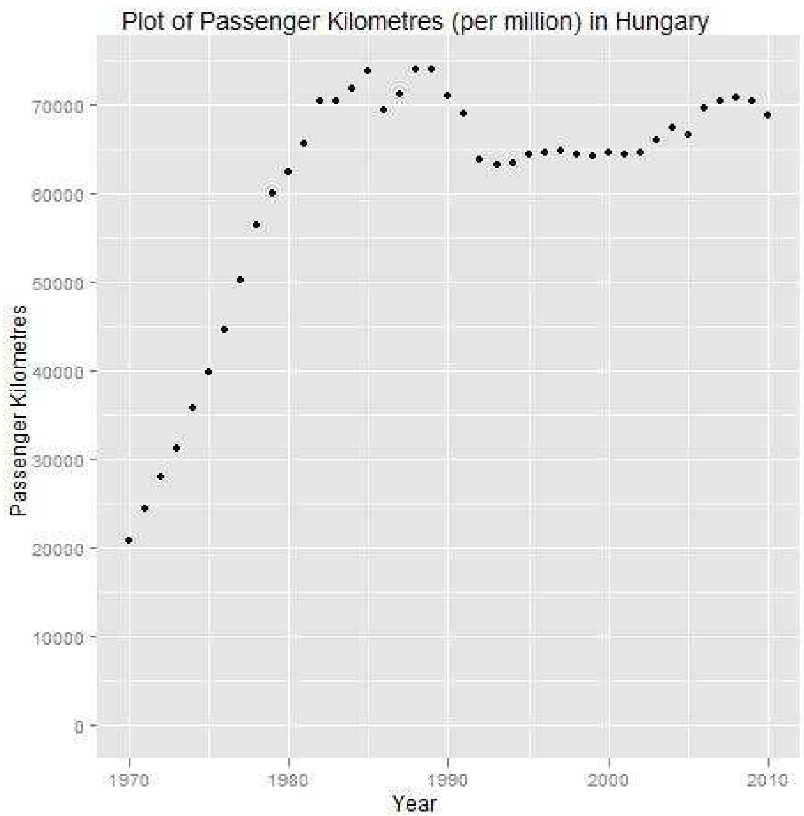


Figure 1: Plot of the annual numbers of person kilometres (in million) for Hungary from 1970 to 2010.

Between 1970 and 1989 the person kilometres in Hungary presents a sharp constantly increasing trend, interrupted by a drop on 1985. A decrease was observed between 1989-1993, followed by a flat trend until 2002. From 2002 the exposure rised again, but a decreasing trend started on 2008, reflecting the effect of global recession and possibly of other interventions at national level.

The seemingly linear increase of person-kilometres between 1970-1980 was examined more thoroughly, by differencing the series, in order to assess whether this data may be an interpolation. No constant ‘lag’ in the yearly data is involved in this part of the data and there is no indication of interpolation.

1.2 Fatalities

In Figure 2, the Hungarian road accident fatalities are plotted. The fatality figures present considerable fluctuation from 1970 to 1990, with two visible peaks in 1971 and 1978, and a striking one on 1990. From 1990 onwards, an overall decrease is observed - which appears to be more intense after 2008, despite a small decrease on 2002.

The following is known about road safety programmes or measures, changes in the data recording or other socioeconomic events in the country:

- The 30-days definition for fatalities was adopted in 1978

- A significant increase in the man-power of the Police took place in 1979

- The change of regime on 1990 may have affected mobility and road safety behaviours

- In 2002, an increase of motorway length by 19% took place.

- In 2008, a large set of road safety measures was introduced.

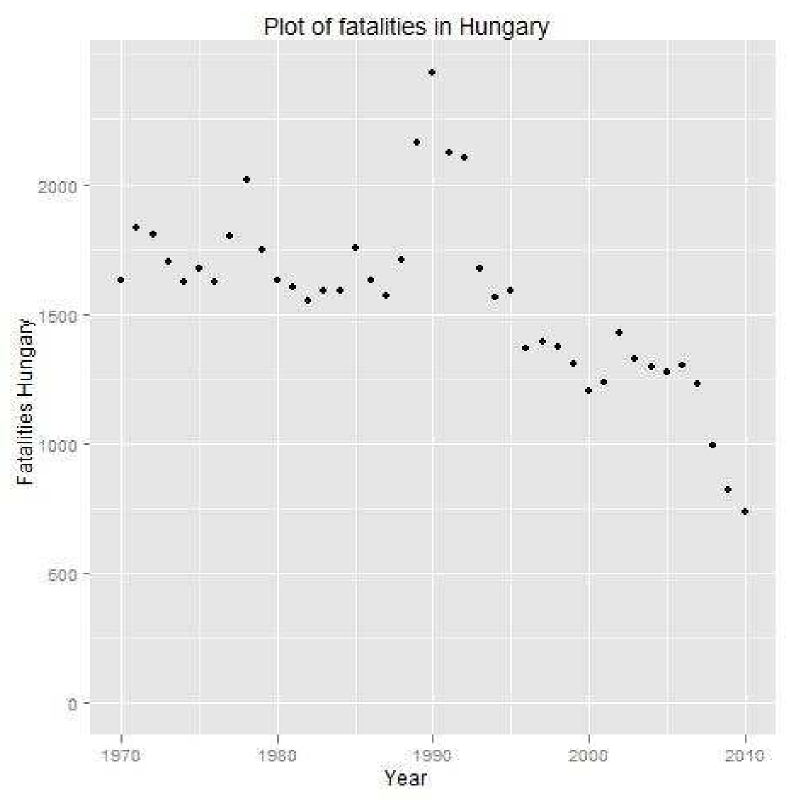


Figure 2: Plot of the annual fatality counts for Hungary from 1970 to 2010.

When examining both the exposure and fatality data in Hungary, it is observed that before 1990, although the exposure rised impressively (at a rate higher than what several Western and Northern European countries could achieve), the fatalities presented a relatively flat trend, with several bigger or smaller peaks. In fact, it appears that the development in the number of fatalities is totally unrelated to the development of exposure between 1970 - 1990. Moreover, the change of political regime in the early nineties is associated with an impressive peak in fatalities, and – rather surprisingly – a drop in exposure.

It appears that the relationship – if any – between exposure and fatalities might be very difficult to investigate through the whole series, as that relationship differs significanty in different parts of the series. This was confirmed after several attempts to model the whole series. It was therefore decided to disregard the pre-1993 parts of both series and focus on the period 1993-2010.

2 The SUTSE Model

2.1 Development of the state components

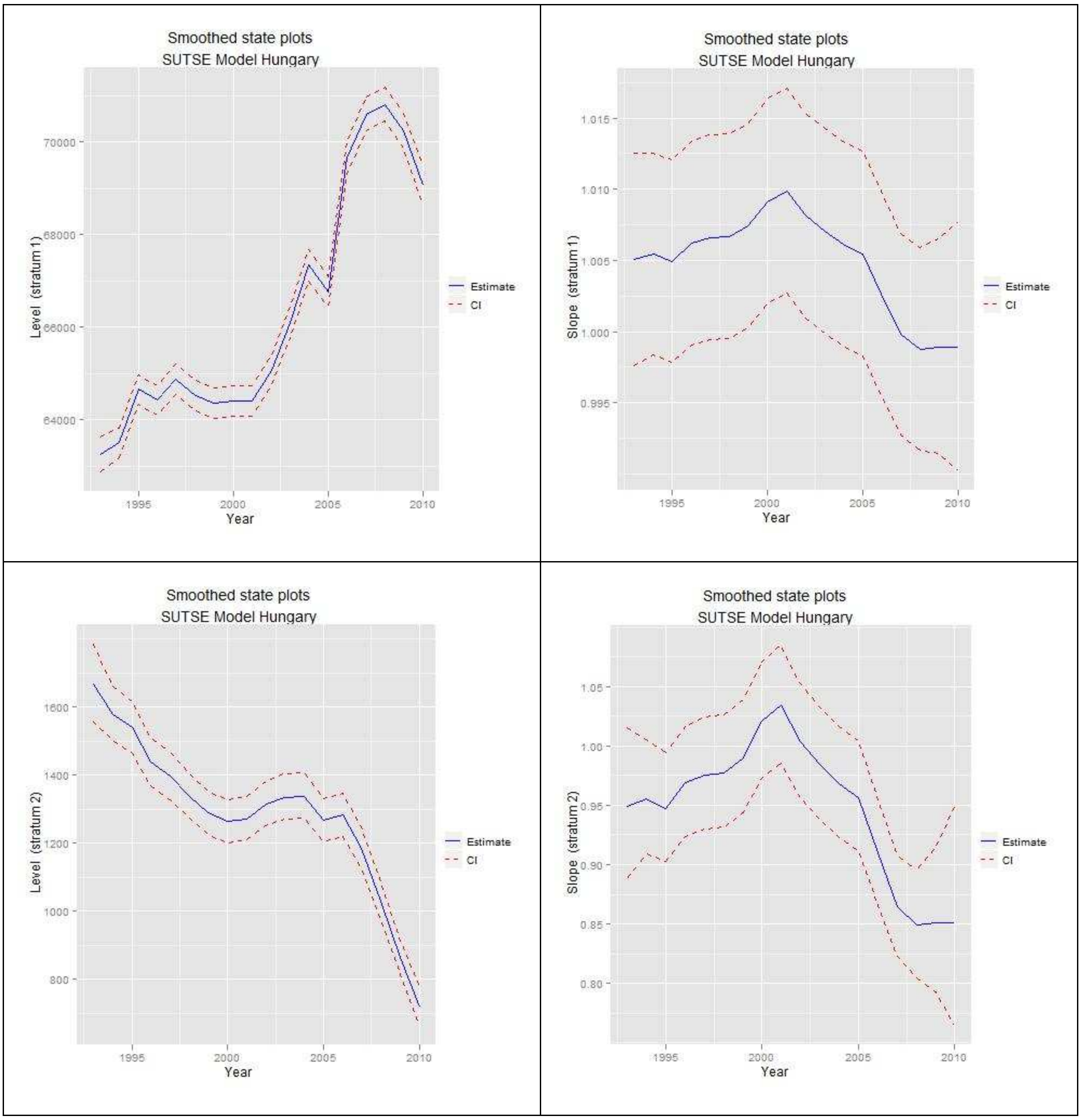


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

Only the slope component appears to vary significantly.

2.1.2 Fatalities

The slope component varies significantly, whereas the level does not. Since 1993, a constantly decreasing trend is observed in the fatality series, which is more striking from 2007 onwards.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

The level and the slope of both the fatalities and the exposure are non significant.

The variance of the exposure level is non significant at 95% (p=0.178), but is significant at 80%, and the variance of the fatalities level is non significant at 95% (p=0.500) The correlation between the two levels is 1 and non significant at 95% (p=0.711).

The variance of the fatalities slope is marginally significant (p=0.078) and the variance of the exposure slope is non significant (p=0.499). The correlation between the two slopes is equal to 1 and non significant (p=0.509).

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -0.81 which is not significant (p=0.896).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 2.965 and is not significant (p=0.328) at 95%.

The results of the restricted SUTSE/LRT model are different from those for the full SUTSE model, however its fit is not substantially improved i.e. no time-varying relationship between exposure and fatalities is indicated.

Model title	SUTSEHungary1	SUTSEbetaHungary1
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	60.56	603.43
AIC	-120.12	-119.8
Variance of the state components		
Level exposure	1.91E-04 nsc	1.74E-04 ns
Level risk	4.46E-04 nsc	6.10E-21 ns
Slope exposure	5.31E-06 nsc	4.58E-21 ns
Slope risk	1.70E-03 nsc	1.20E-03 ns
Correlations between the state components		
level-level	1	
slope-slope	1	
Observation variance		
Observation variance exposure	1.27E-05 ns	2.91E-05 ns
Observation variance risk	1.16E-03 ns	9.20E-04 ns
Beta		2.97

Table 1: Overview of the results for SUTSE models – Hungary.

On the basis of these results, it was decided not to proceed to a LRT modeling approach, and base the forecasts on LLT models instead.

3.1 Model selection

Three versions of the LLT model are presented: a full model, a restricted model (fixed level), and a restricted model with intervention variables. Finally a fourth model is presented, namely an LT (linear trend, fixed level and slope) model, which is finally selected as the best model for the Hungarian fatality data, on the basis of the LLT results.

The full LLT model (LLT 1) suggests that both the level and the slope of the fatalities are non significant. The variance of the fatalities level is non significant at 95% (p=0.256), whereas the variance of the fatalities slope is marginally significant at 95% (p=0.087).

In the restricted model, the level of fatalities was fixed, resulting in slightly improved fit of the model; in this case, the slope was indicated to be significant.

In the LLT2 model, both levels (fatalities and risk) were fixed. This model presents somewhat improved fit compared to the full model. However, the prediction errors for fatalities are increased compared to the full model.

Concerning the possible interventions, specific information was available for the specific years (1993-2010), namely an increase of approximately 20% on motorway length on 2002, and the introduction of a large set of road safety measures on 2008. These time points also correspond to changes in the data series.

These two interventions were tested in model LLT3 as regards the level of fatalities, as one intervention on 2002, and one on 2008. Both interventions were found to be highly significant (p-values<0.001). However, the slope component becomes non significant and should be thus fixed.

This case results in the deterministic linear trend model (LT), where both the level and the slope are fixed, and only the observation variance is significant. This is presented as the LT6 model.
Consequently, this model is selected as the best performing model for Hungarian fatalities

Model title	LLT 1	LLT 2	LLT 4	LLT6
Model description	full model	restricted model	restricted model with interventions	with interventions
Model Criteria				
ME10 Fatalities	196.3	196.3	196.3	196.3
MSE10 Fatalities	58253.62	58253.62	58253.62	58253.62
log likelihood	161.28	15.84	2.11	1.68
AIC	-319.24	-31.47	-4.01	-3.25
Model Quality				
Box-Ljung test 1 Fatalities	0.99	1.89	0.19	1.50
Box-Ljung test 2 Fatalities	2.87	1.9	0.21	1.89
Box-Ljung test 3 Fatalities	3.19	4.62	0.31	3.23
Heteroscedasticity Test Fatalities	2.22	2.5	1.52	2.63
Normality Test standard Residuals Fatalities	0.11	0.08	1.13	1.82
Normality Test output Aux Res Fatalities	0.99	1.02	0.56	1.18
Normality Test State Aux Res Level	0.19	0.28	0.78	0.94
Normality Test State Aux Res Slope	0.44	0.45	1.06	1.46
Variance of state components				
Level fatalities	3.49E-03 ns	-	-	-
Slope fatalities	1.30E-03 ns	1.94E-03 *	7.57E-04 ns	-
Observation variance				
Observation variance fatalities	1.00E-09 ns	1.27E-03 ns	5.72E-04 ns	1.88E-03 *
Interventions				
(2002 fatalities level)			0.18 *	0.22 *
(2008 fatalities level)			-0.17 *	-0.26 *

Table 2: Overview of the results for LLT models – Hungary.

3.2 Development of the state components:

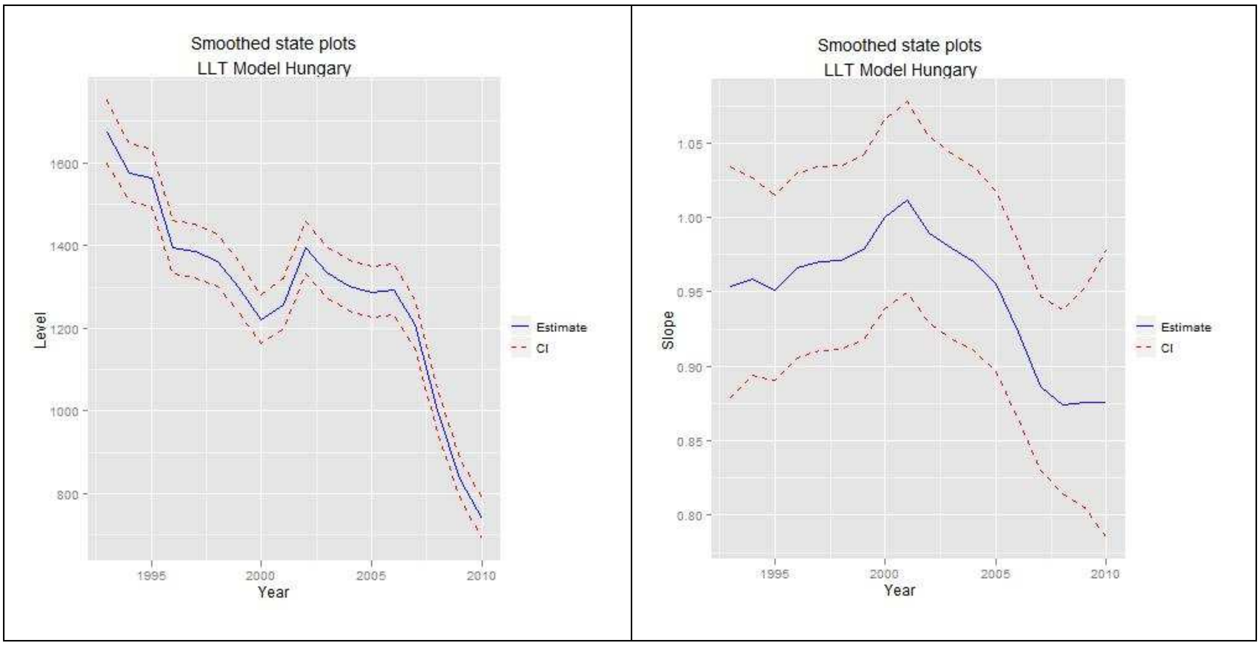


Figure 4: Developments of the state components for the fatalities, as estimated on the basis of the LLT1 model. The trend (level) developments are represented in the right-hand graph, the slope developments in the left-hand graph.

3.2.1 Fatalities:

The trend for fatalities does not appear to be stochastic, while the slope does.

The level for the fatalities has decreased from 1678 fatalities on 1993 to 740 fatalities on 2010. A visible pe on 2002, and a drop is also observed on 2008.

Overall, the fatalities have decreased on average by 4% yearly in the examined period. It may be worth r reduction of the period 1993-2001 was 3.5%, an increase of 15% took place on 2002, the average yearly was 2.8% and an average yearly reduction of 18% took place on 2008 and 2009.

The plot of the slope values over the years shows that a change of slope was involved on 2002, from incre while the opposite occurs on 2008, where reduction rate in fatalities starts to increase again.

5.1.1. Quality of the predictions:

In order to evaluate the ability of the final model (LT6) to correctly predict the fatality numbers, it has been u three different periods: 2006-2010, 2003-2010 and 1990-2010. Figure 5 below shows a plot of the pred whole series, for the second (7 observations) and third (10 observations) forecasting period. The results are quite similar to those of the second one (7 observations).

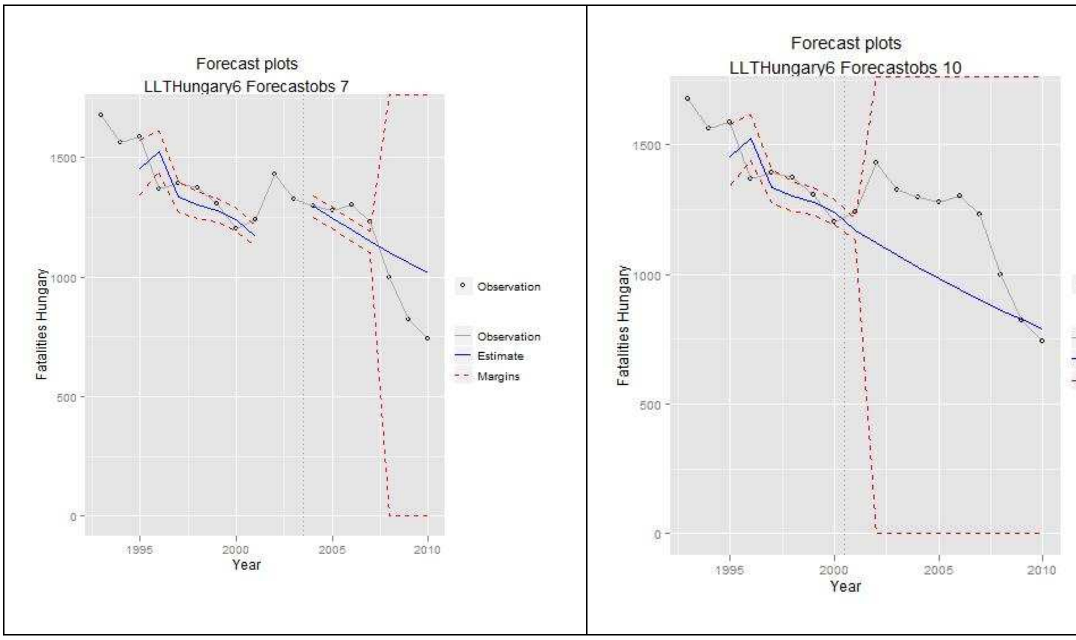


Figure 5: Plots comparing the model predictions (straight line) with the actual obs ("bullets") for the annual fatality numbers in Hungary for the LT1 model with 7 fo observations (left-hand graph) and 10 forecasting observations (right-hand graph).

It is revealed that, given the particularly steep decrease of fatalities from 2008 onwards, the first two observations) can not accurately predict the last part of the series. In case of 4 or 7 observations, the resu leak on 2002, without taking into account the 2008-2009 drop in fatalities. In case of 10 observations, successfully, but the previous values (i.e. trend between 2000 and 2010) are not at all captured.

As also shown in Table 2 with the modeling results, the prediction errors are quite large (and practically e with 10 observation, obviously due to the small series and the important developments in the last part of it. so much on prediction errors for the assessment of models for this particular country.

4 Forecasts 2010 - 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected betw throughout these years, the trends keep on following the developments that they have shown in the past.

Under this assumption, the fatality numbers for Hungary should keep on decreasing after 2010 (although a and 2010). The predicted value for 2020 is 555 fatalities, whereas 740 fatalities were recorded on 2010. values forecasted for fatalities for all years from 2010 up to 2020 (confidence levels etc.).

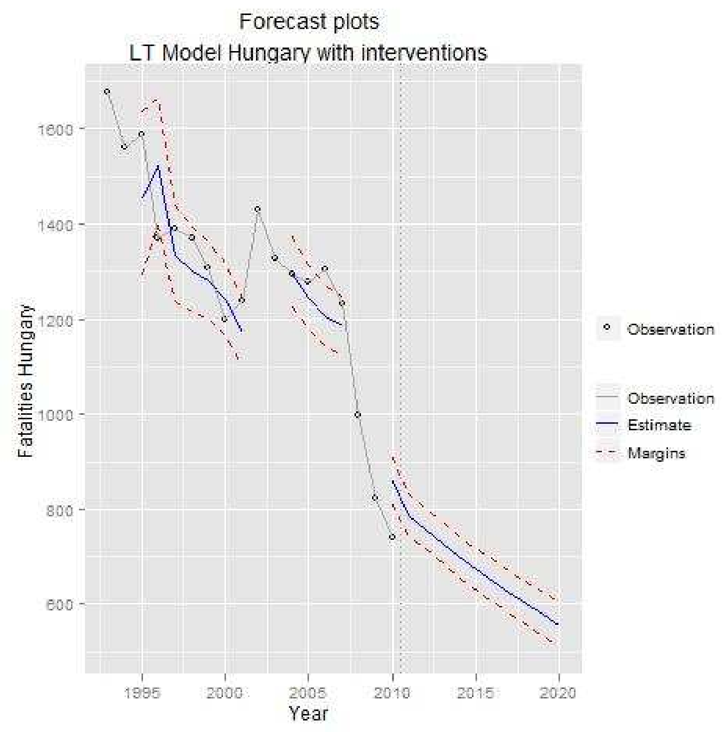


Figure 6: Plot of the annual fatality numbers for Hungary forecasted between 2010 and 2020 (LT 6).

	Fatalities Hungary		
Year	Forecast	Lower (2.50%)	Upper (97.50%)
2010	**787**	706	876
2011	**757**	677	846
2012	**728**	649	817
2013	**700**	621	789
2014	**674**	594	764
2015	**648**	568	740
2016	**624**	543	717
2017	**600**	518	695
2018	**577**	494	674
2019	**555**	472	653

Table 3: Forecasts of the Linear Trend Model (LT6)

ICELAND

1 Raw data:

1.1 Exposure:

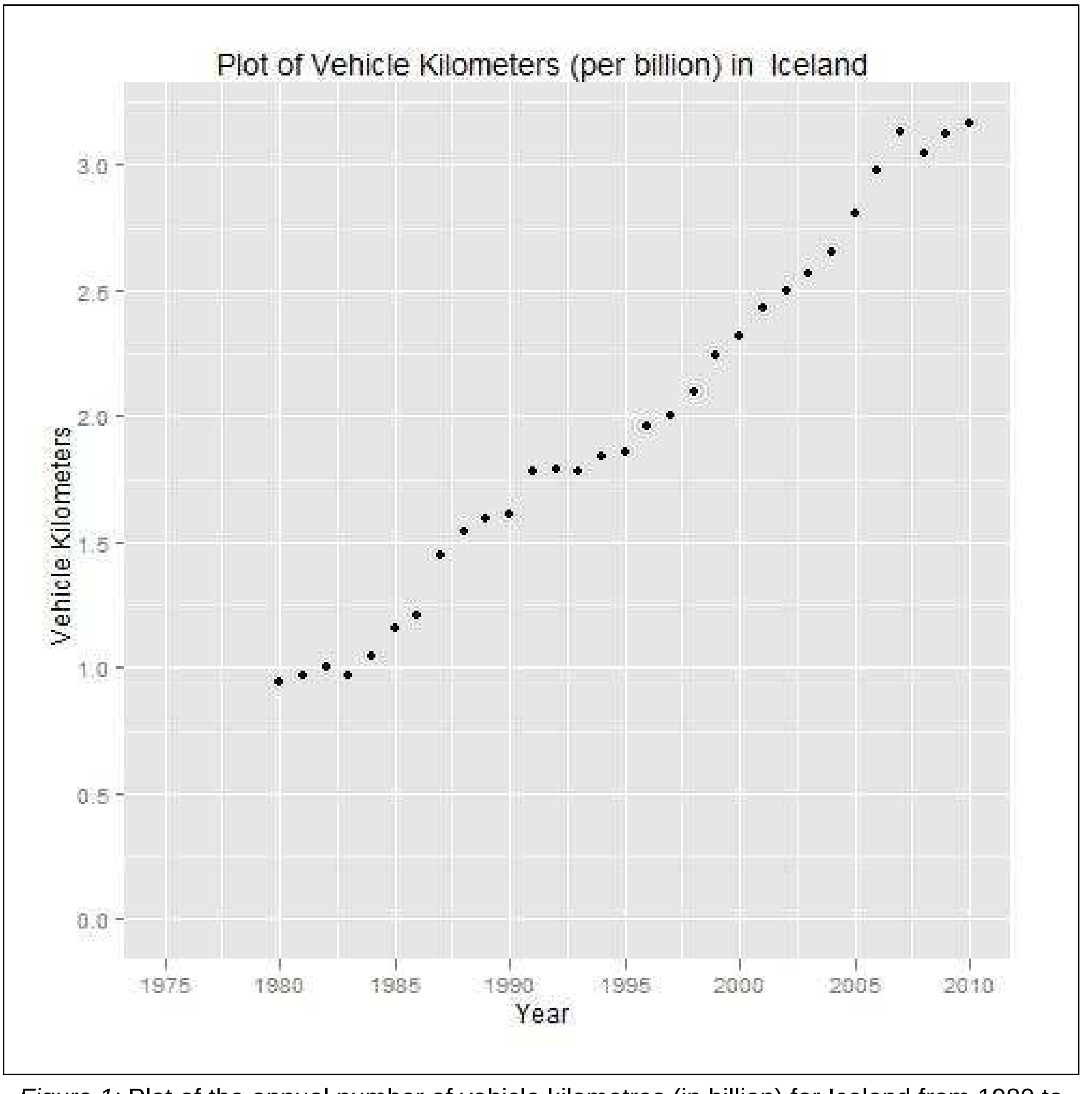


Figure 1: Plot of the annual number of vehicle kilometres (in billion) for Iceland from 1980 to 2010.

As exposure measure we consider the number of motor vehicle kilometres. Yearly data are obtained from IRTAD (2010 value from national sources) and shown for the period 1980 to 2010.

The plot shows a gradual increase over the years. In the years 1987, 1991, 1999 and 2004-2007 there was a larger increase in vehicle kilometres.

From 1980-2006, the same method was used in assessing the vehicle kilometres. The Road Administration used automatic counters (about 300 of them) on the national roads (not in urban areas) and used those numbers to assess the total amount of driven kilometres, including in urban areas. Since 2007 we have looked at the odometer in the yearly vehicle inspections to see how much is driven between inspections and used those numbers to evaluate how much is driven in a single year by the entire fleet. The sudden rise between 2005 and 2007 is due to an economic growth and the fall in 2008 is again due to the economic collapse [1].

1.2 Fatalities:

The plot below shows the number of fatalities in Iceland from 1975 to 2010. Data are from IRTAD.

There is some variation between years due to the low number of incidents; one bad accident can have a severe effect on the data. However, there has been a positive development over time. Possible explanations for the recent positive trend are [1]:

- propaganda campaigns since 2005
- increased focus on education in primary and elementary schools
- great focus on eliminating black spots, fixing roadsides and putting up side barriers along the roads where conditions demand it; in addition, focus on separating lanes with opposite driving directions with barriers and widening of roads where the traffic quantity demands it
- increased road side checking and installing speed cameras on various spots along the country.

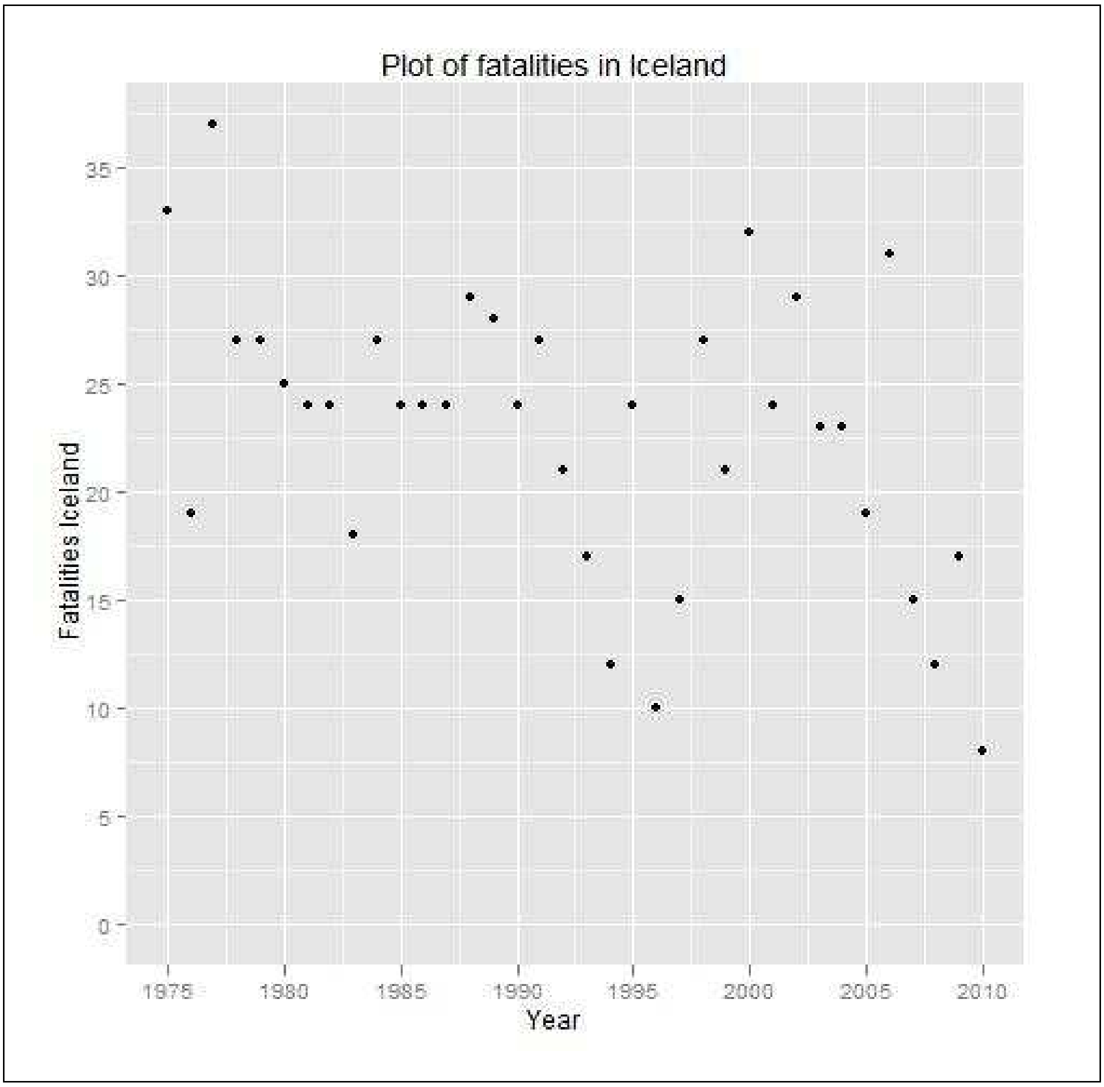


Figure 2: Plot of the annual fatality counts for Iceland from 1975 to 2010.

2 The SUTSE Model:

2.1 Development of the state components:

The figure below presents the varying level and slope estimation results of the SUTSE model: in particular the smoothed state plots for the exposure (top) and fatality (bottom) variables. The left subfigure in each row shows the level estimate for the corresponding variable and the right subfigure shows the slope estimate. Confidence intervals are also presented in these figures.

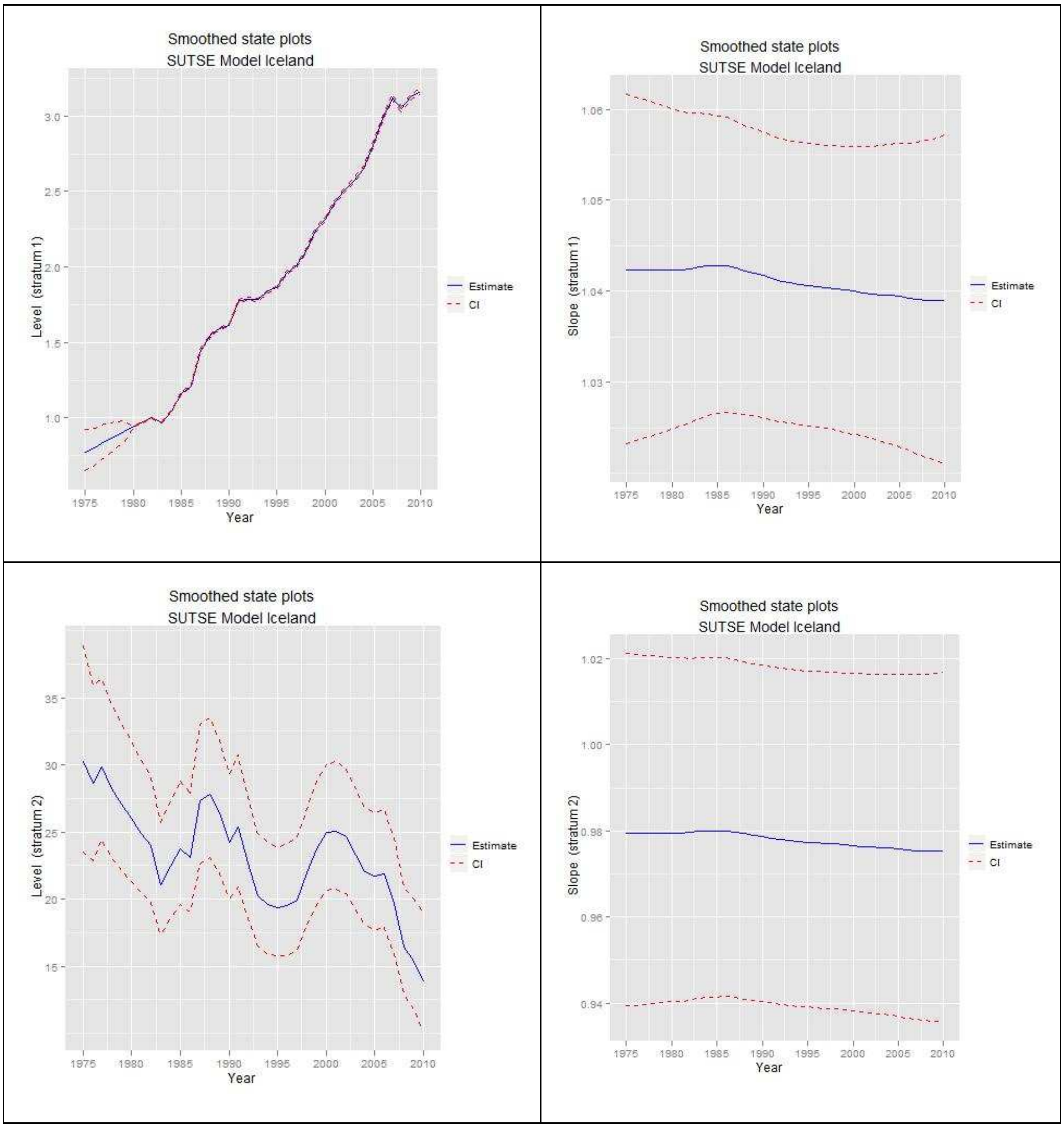


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The number of vehicle kilometres in Iceland more than tripled between 1980 and 2010. The slope of the exposure (top right subfigure in Figure 3) has been positive during the whole time period and fluctuated around 4%.

2.1.2 Fatalities

Decreasing and increasing trends have succeeded one another in the period 1975-2010. Nevertheless, in general a decrease in the annual fatality numbers took place (-2% per year).

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components

The correlation between the two levels and the two slopes is estimated as 0.55 respectively 1. The correlation between the two levels ($p=0.19$) and two slopes ($p=0.90$) is not significant.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -0.24 which is not significant ($p=0.84$).

2.2.3 Estimation of the relationship by means of a coefficient

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). The beta coefficient for the relationship between the latent developments of the two series is equal to 1.55 and is not significant ($p=0.11$).

2.2.4 Conclusion

It can be concluded that the fatalities and vehicle kilometres series are not related and therefore further modeling can be made using the LLT model (instead of the LRT).

Model title	*SUTSE Iceland1*	*SUTSEbetaIceland1*
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	72.36	72.36
AIC	-144.22	-144.27
Hyperparameters		
Level exposure	1.55E-03 nsc	1.55E-03 *
Level fatalities	1.27E-02 nsc	8.96E-03 ns
Slope exposure	2.95E-06 nsc	2.80E-06 ns
Slope fatalities	5.11E-06 nsc	4.96E-20 ns
Correlations		
level-level	0.55	
slope-slope	1	
Observation variances		
Observation variance exposure	1.06E-05 ns	1.03E-05 ns
Observation variance fatalities	1.81E-03 ns	1.79E-03 ns
Beta	/	1.55 (p= 0.11)

Table 1.: Model criteria and results for SUTSE models - Iceland

3. The LLT/LRT Model:

3.1 Model selection:

Given that no relationship could be identified between exposure and fatalities on the basis of the data at hand, a Local Linear Trend model was fit to model the fatalities.

In the full model (LLTIceland1), both level and slope appeared to be non-significant. Therefore, a second respectively third LLT model was run, i.e. LLTIceland2 with a fixed slope and LLTIceland3 with a fixed level. Given the fact that in both cases, the remaining component also appeared to be non-significant, a fourth LLT model was run (LLTIceland4) in which both the level and the slope are fixed.

For all four models, the assumption concerning the homoscedasticity of the residuals seemed to be somewhat violated. Given the smaller prediction errors (ME10 and MSE10), LLTIceland3 and LLTIceland4 are to be slightly preferred over LLTIceland1 and LLTIceland2. In the end, we select the most parsimonious model, i.e. LLTIceland4, as the forecasting model.

Model title	***LLT Iceland1***	***LLT Iceland2***	***LLT Iceland3***	***LLT Iceland4***
Model description	Full Model	Fixed slope	Fixed level	Fixed level and fixed slope
Model Criteria				
ME10	-3.95	-3.95	0.37	0.37
MSE10	58.90	58.90	41.85	41.85
log likelihood	7.69	7.69	6.91	6.60
AIC	-15.21	-15.27	-13.71	-13.14
Model Quality				
Box-Ljung test 1	1.96	1.17	0.98	0.71
Box-Ljung test 2	2.34	1.96	1.85	3.10
Box-Ljung test 3	2.71	2.34	2.17	3.86
Heteroscedasticity Test	3.70*	3.70*	3.87*	4.49*
Normality Test standard Residuals	0.49	0.49	1.75	0.31
Normality Test output Aux Res	0.03	0.03	0.04	0.33
Normality Test State Aux Res Level	0.05	0.05	0.26	0.00
Normality Test State Aux Res Slope	0.24	0.24	0.51	0.63
Variance of state components				
Level	1.21E-02 ns	1.21E-02 ns	-	-
Slope	7.17E-18 ns	-	1.49E-03 ns	-
Observation variance				
Observation variance	1.96E-03 ns	1.96E-03 ns	4.74E-03 ns	2.03E-02 ns
Interventions				

Table.2: Overview of the results for the LLT models – Iceland.

3.2 Development of the state components:

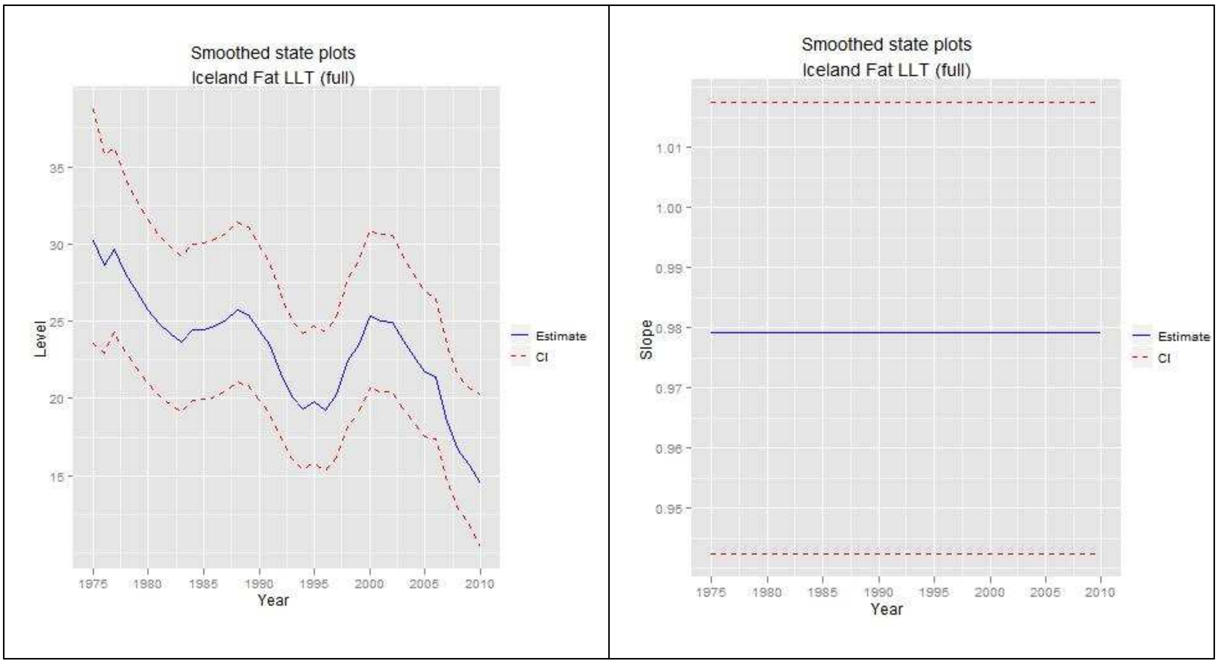


Figure 4: Developments of the state components for the fatalities, as estimated on the basis of the full LLT model.

3.2.1 Fatalities:

In general, the number of fatalities decreased during the period 1975-2010. Several consecutive years of decrease have always been followed by a period of increase in the number of fatalities (e.g. 1983-1988). Since 2000, the level has been decreasing. The slope (right-hand subfigure) shows a constant decrease of 2% per year in the number of fatalities.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series. It can be seen that, although the decreasing trend has been predicted, a number of actual values lie outside the prediction margins.

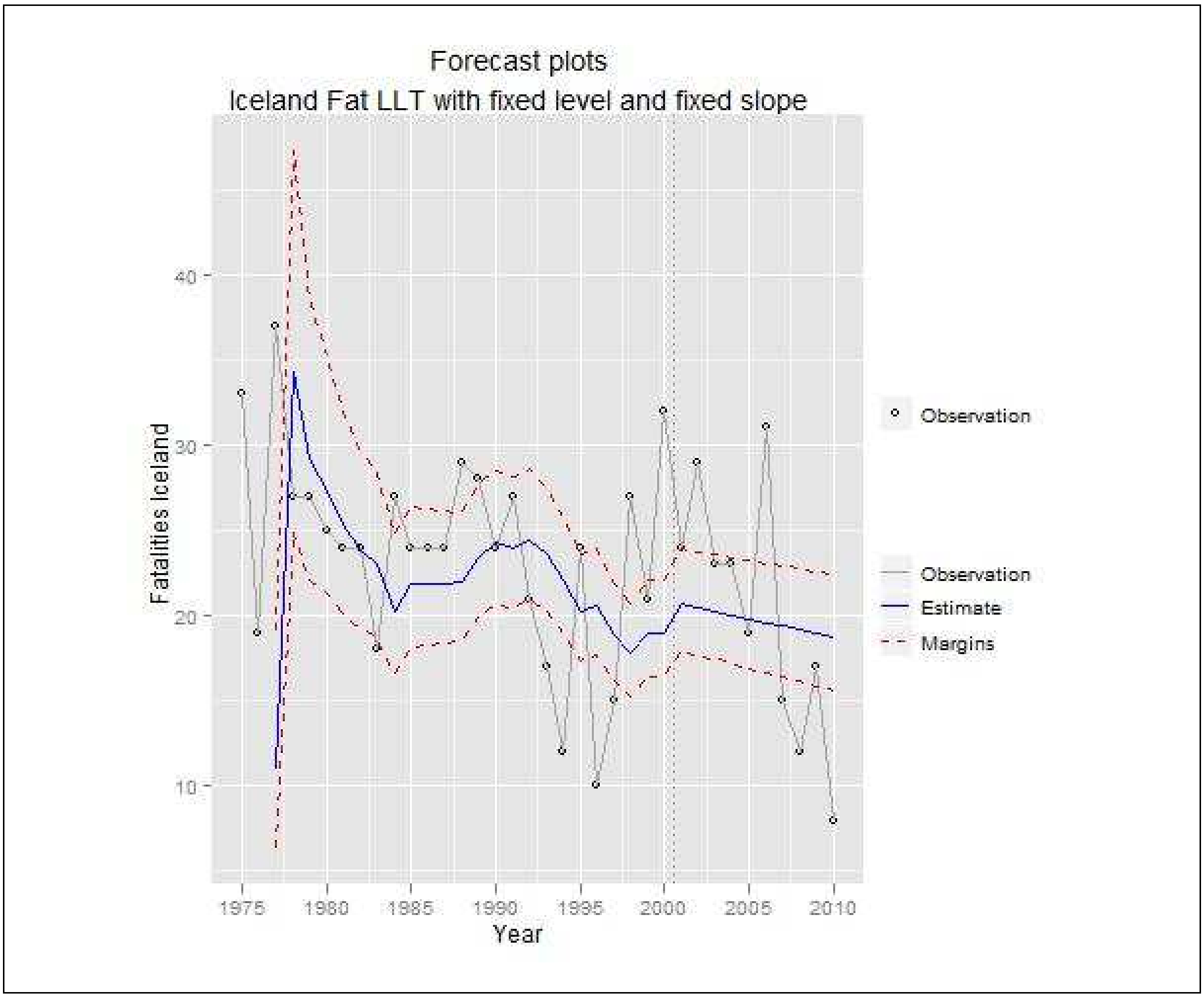


Figure 5: Plot comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Iceland for the LLTIceland4 model.

4 Forecasts 2011 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.*

In the period 2011-2020 a decrease in the annual number of fatalities is predicted. With respect to forecasting, the model takes into account the fact that in the past, consecutive years of decrease in the number of fatalities have always been followed by a period of increase. Therefore, the forecasts are less optimistic than what could be expected based on the most recent fatality numbers.

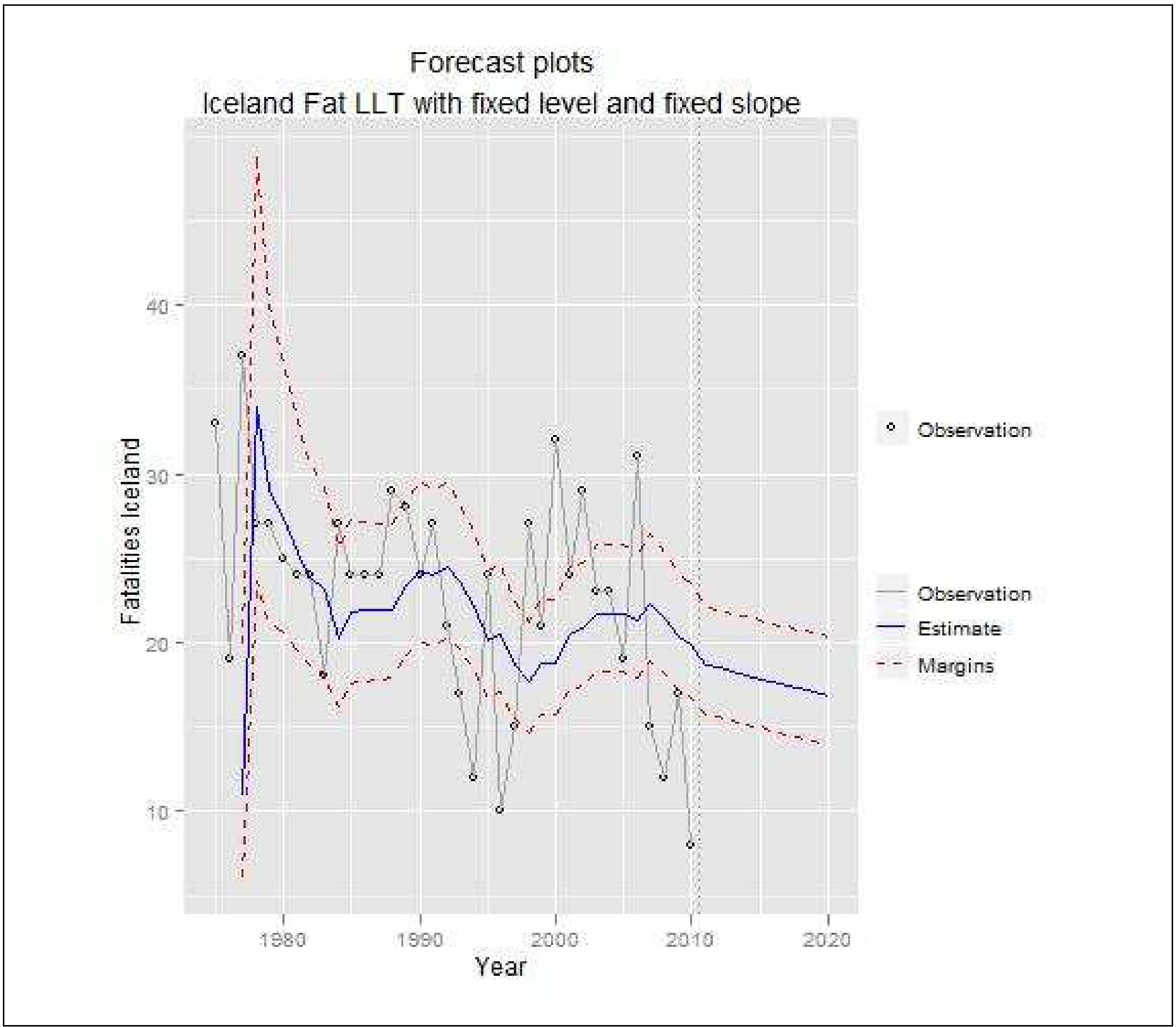


Figure 6: Plot of the annual fatality numbers for Iceland and the forecast for 2020 (based on the Local Linear Trend Model LLTIceland4).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**19**	13	26
2012	**18**	13	26
2013	**18**	13	26
2014	**18**	13	25
2015	**18**	13	25
2016	**18**	12	25
2017	**17**	12	25
2018	**17**	12	25
2019	**17**	12	25
2020	**17**	12	25

Table 3: Forecasts of the Local Linear Trend Model LLTIceland4

REFERENCES:

[1] EC National Expert for road accident statistics and road safety performance indicators.

IRELAND

1 Raw data

1.1 Exposure

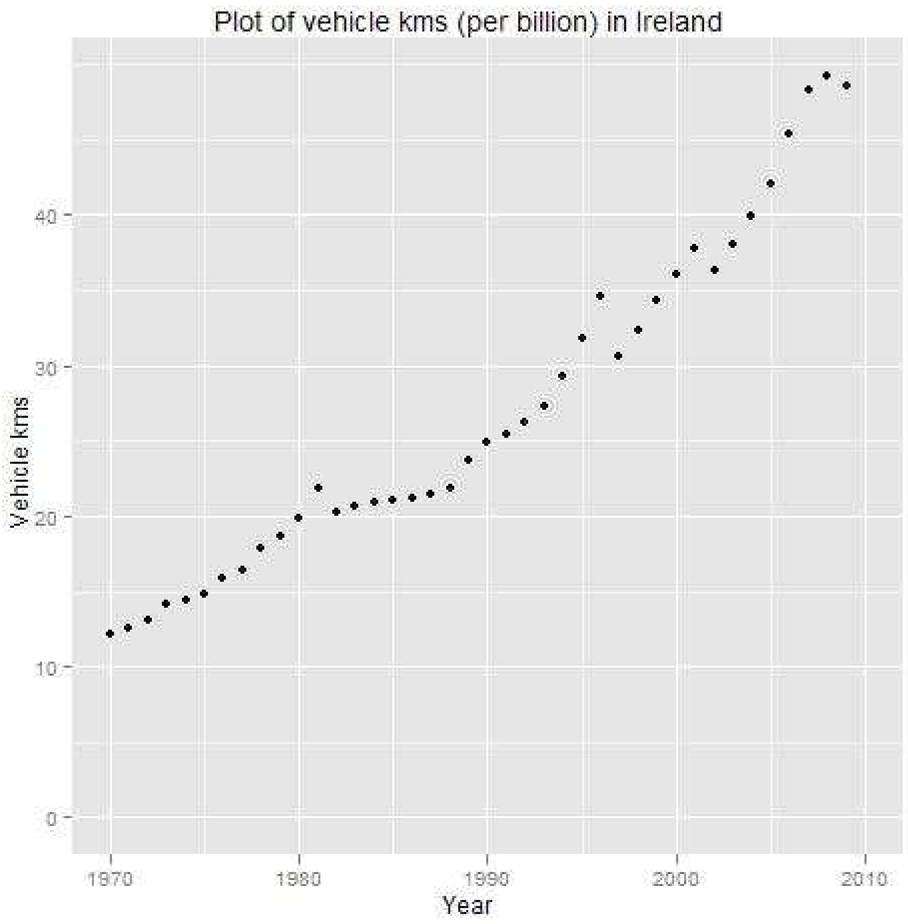


Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for Ireland from 1970 to 2009.

Annual vehicle kilometres are available for Ireland from 1970. There were four drops in the series: 1982, 1997, 2002 and 2009. The reasons for these falls are not known.

Overall, vehicle kilometres in Ireland have been increasing from 1970.

1.2 Fatalities:

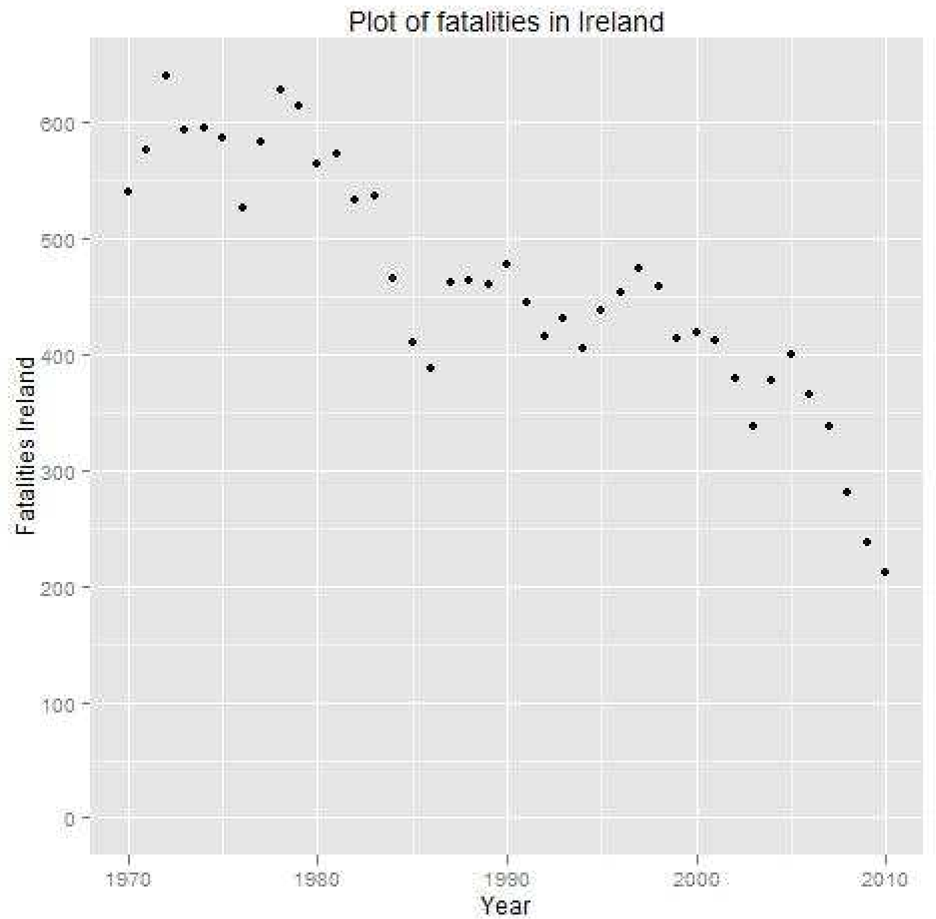


Figure 2: Plot of the annual fatality counts for Ireland from 1970 to 2010.

The raw series for the fatalities has seen two large falls one in the early 1980s and a second in 2008-2010. The latest drops may be associated with drops seen in GDP for these years. Fatalities dropped in 2003 when penalty points were introduced. Initially there were high expectations but the IT was incomplete and people realized how inefficient it was and its effect on behaviour faded away quickly. In 2005 the Road Safety authority was established which coordinated all RS efforts. It had the effect of giving road safety a higher profile and resulted in the 2007 RS strategies.

The number of fatalities observed in 2010 (212) is 2.5 times lower than in 1970 (540). The fatality series varies much more than the vehicle kilometres series.

2 The SUTSE Model:

2.1 Development of the state components:

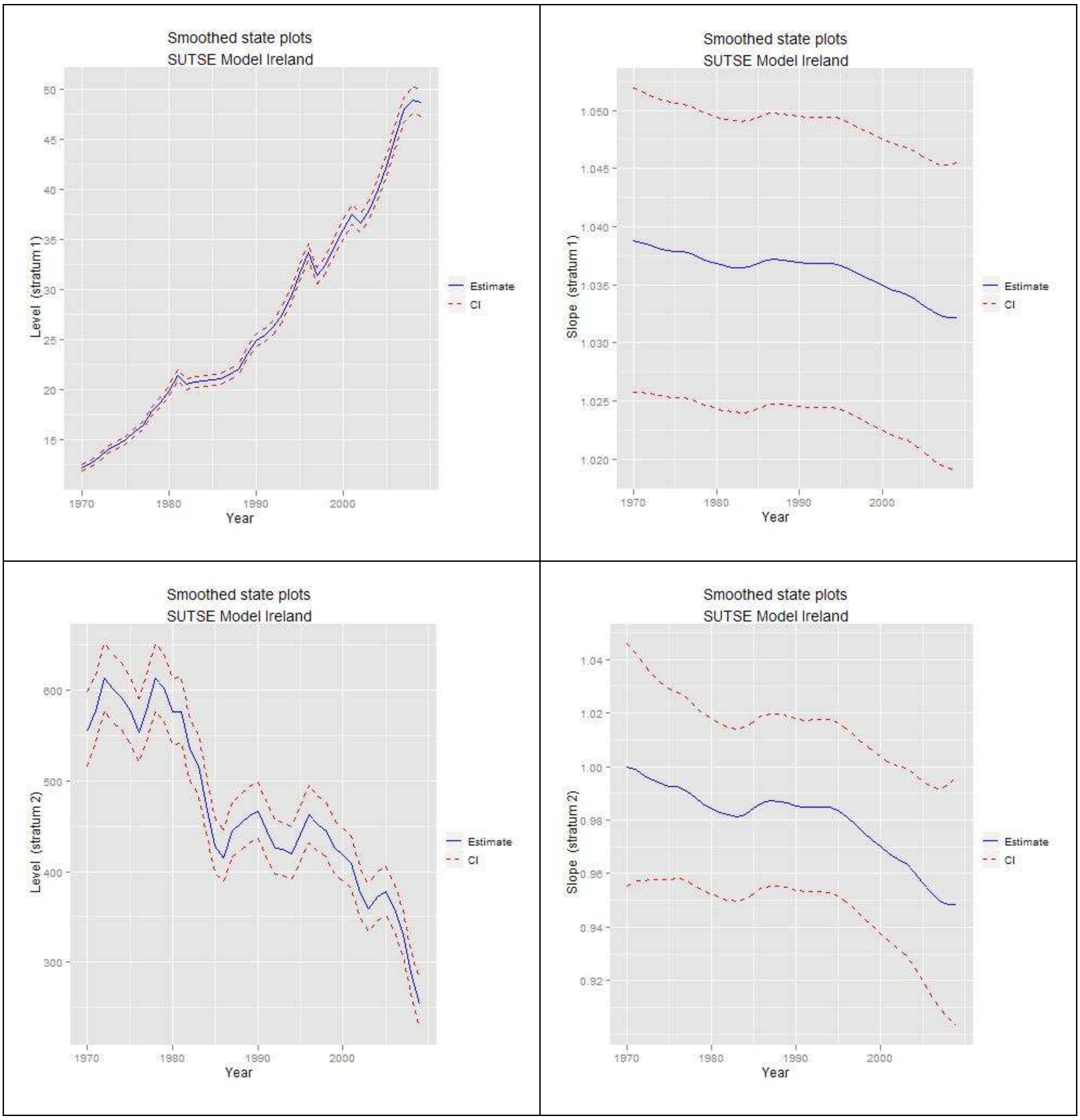


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend for exposure is estimated around 10 billion kilometres at the start of the series and around 48 billion kilometres at the end. The trend increases relatively smoothly, with three peaks (1981, 1996, and 2001).

The development of the slope is plotted in the top right of Figure 1. The slope is fairly flat showing a 3-4% increase of the number of vehicle kilometres each year between 1970 and 2009.

The two shocks in the series (1981 and 1996) were not significant when an intervention term was added.

For exposure, the level component is the only one to vary significantly over time (Table 1).

2.2.2 Risk

The risk series has a fairly flat trend between 1970 and 1981, a rapid fall between 1981 and 1986 and another rapid fall from 2005 to 2009. The trend value at the end of the series is about 250 compared with around 550 at the start.

The development of the slope for the risk is plotted in the bottom right of Figure 1. The annual fatality numbers have decreased over the whole series by around 5%.

The level and slope of the risk component do not vary significantly over time (Table 1).

2.3 Relation between the exposure and fatality series:

2.3.1 Correlation between the disturbances of the state components:

The correlation between the level disturbances of the two series is 0.33 and this correlation is not significant (p=0.29). The correlation between the slope disturbances of the two series is 1 but the covariance test for the slopes is not significant (p=0.75).

2.3.2 Correlation between the irregulars:

The measurement errors for exposure and risk are correlated at -0.23 and this correlation is not significantly different from zero (p=0.61).

2.3.3 Estimation of the relationship by means of a coefficient:

An LRT/SUTSE model was fitted where the relationship between the 2 series was estimated on the basis of a fixed regression coefficient beta (= 0.57). This coefficient is not significantly different from zero (p=0.27); i.e. implying that exposure and fatalities are not correlated.

2.3.4 Compare the log-likelihoods of SUTSE model and LRT/SUTSE model

The values are very similar (143.345 cf. 143.294).

2.3.5 Conclusion

The fatality and exposure series may be unrelated and as such a univariate local linear trend model of the fatalities should be performed. These models have been fit without any intervention terms which may cause the series to appear unrelated.

Model title		***SUTSEIreland1***	***SUTSEbetaIreland1***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	143.35	143.29
	AIC	-286.24	-286.19
Hyperparameters			
	Level exposure	1.36E-03 *c	1.36E-03 *
	Level risk	3.86E-03 nsc	3.52E-03 ns
	Slope exposure	1.14E-06 nsc	2.56E-19 ns
	Slope risk	7.73E-05 nsc	5.54E-05 ns
Correlations			
	level-level	0.33	
	slope-slope	1	
Observation variances			
	Observation variance exposure	2.47E-04 ns	2.48E-04 ns
	Observation variance risk	1.07E-04 ns	1.04E-04 ns
Beta			0.57 ns (p= 0.27)

Table 1: Model criteria and results for SUTSE models – Ireland.

3. The LLT Model:

3.1 Model selection:

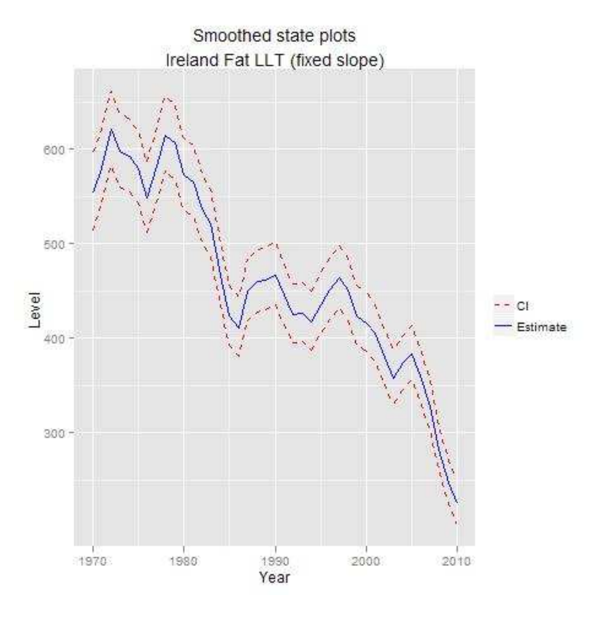
In the earlier section, no relationship could be identified between exposure and fatalities. Therefore a simple Local Linear Trend model was used to model the fatalities.

In the full LLT model the level is significant and the slope is not. Fixing the slope does not affect the AIC and log likelihood values and so this was the model used for the forecasting. A model with a fixed slope will assume the rate of change will return to the average rate of change over the whole time-span.

Model title	***LLT1***	***LLT2***
Model description	LLT model for fatalities in Ireland	LLT model for fatalities in Ireland with fixed slope
Model Criteria		
ME10 Exposure		
MSE10 Exposure		
ME10 Fatalities	-51.58	-51.58
MSE10 Fatalities	4831.79	4831.79
Log-likelihood	59.42	58.59
AIC	-118.69	-117.09
Model Quality		
Box-Ljung test 1 Exposure		
Box-Ljung test 2 Exposure		
Box-Ljung test 3 Exposure		
Box-Ljung test 1 Fatalities	4.91*	6.09*
Box-Ljung test 2 Fatalities	6.13*	6.18*
Box-Ljung test 3 Fatalities	7.20	6.68
Heteroscedasticity Test Exposure		
Heteroscedasticity Test Fatalities	1.07	1.16
Normality Test standard Residuals Exposure		
Normality Test standard Residuals Fatalities	1.60	0.91
Normality Test output Aux Res Exposure		
Normality Test output Aux Res Fatalities	1.31	1.76
Normality Test State Aux Res Level exposure		
Normality Test State Aux Res Slope exposure		
Normality Test State Aux Res Level fatalities	0.87	0.52
Normality Test State Aux Res Slope fatalities	0.02	0.00
Variance of state components		
Level exposure		
Level fatalities	3.75E-03 ns	5.29E-03 *
Slope exposure		
Slope fatalities	2.09E-04 ns	-
Correlations between state components		
level-level		
slope-slope		
Observation variance		
Observation variance exposure		
Observation variance fatalities	1.00E-09 ns	1.00E-09 ns

Table 2: Overview of the results for the LLT models - Ireland.

3.2 Development of the state components:



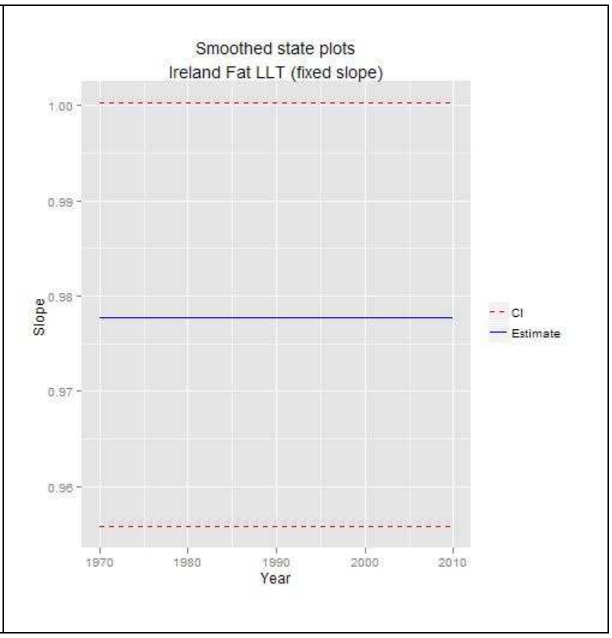


Figure 4: Developments of the state components for the fatalities, estimated using the LLT model with fixed slope. The trend (level) developments are represented in the left-hand graph, the slope developments in the right-hand graph.

3.2.1 Fatalities:

The trend for fatalities varies significantly over time. It has a fairly flat trend between 1970 and 1981, a rapid fall between 1981 and 1986 and another rapid fall from 2005 to 2010.

The slope does not vary significantly and has therefore been fixed in the model. The average rate of change is a decrease of 2% per year. All deviations from this constant decrease are attributed to random variations that have no impact on the future rate of change.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series using the LLT model with a fixed slope and the full LLT model.

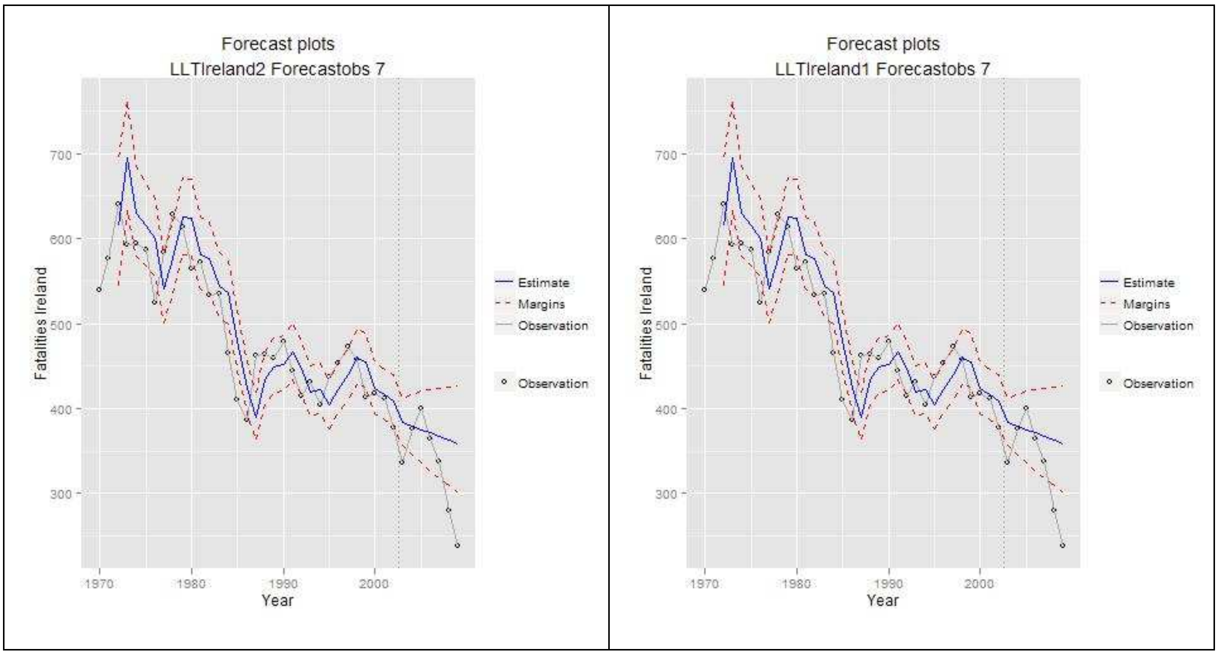


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Ireland for the full LLT model (right-hand graph) and the LLT model with fixed slope (left-hand graph).

On the basis of these plots, one can conclude that the two versions of the LLT model predict the data in a similar way but were not able to predict the large drops seen in the last couple of years. On examination of the GDP figures it may be reasonable to assume that the economic downturn has an effect on the fatalities from 2008. Finally it was decided that the LLT model with a fixed slope was to be used to produce the forecasts.

4 Forecasts 2010 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.* Under this assumption, the annual number of fatalities is predicted to be 180 in 2020.

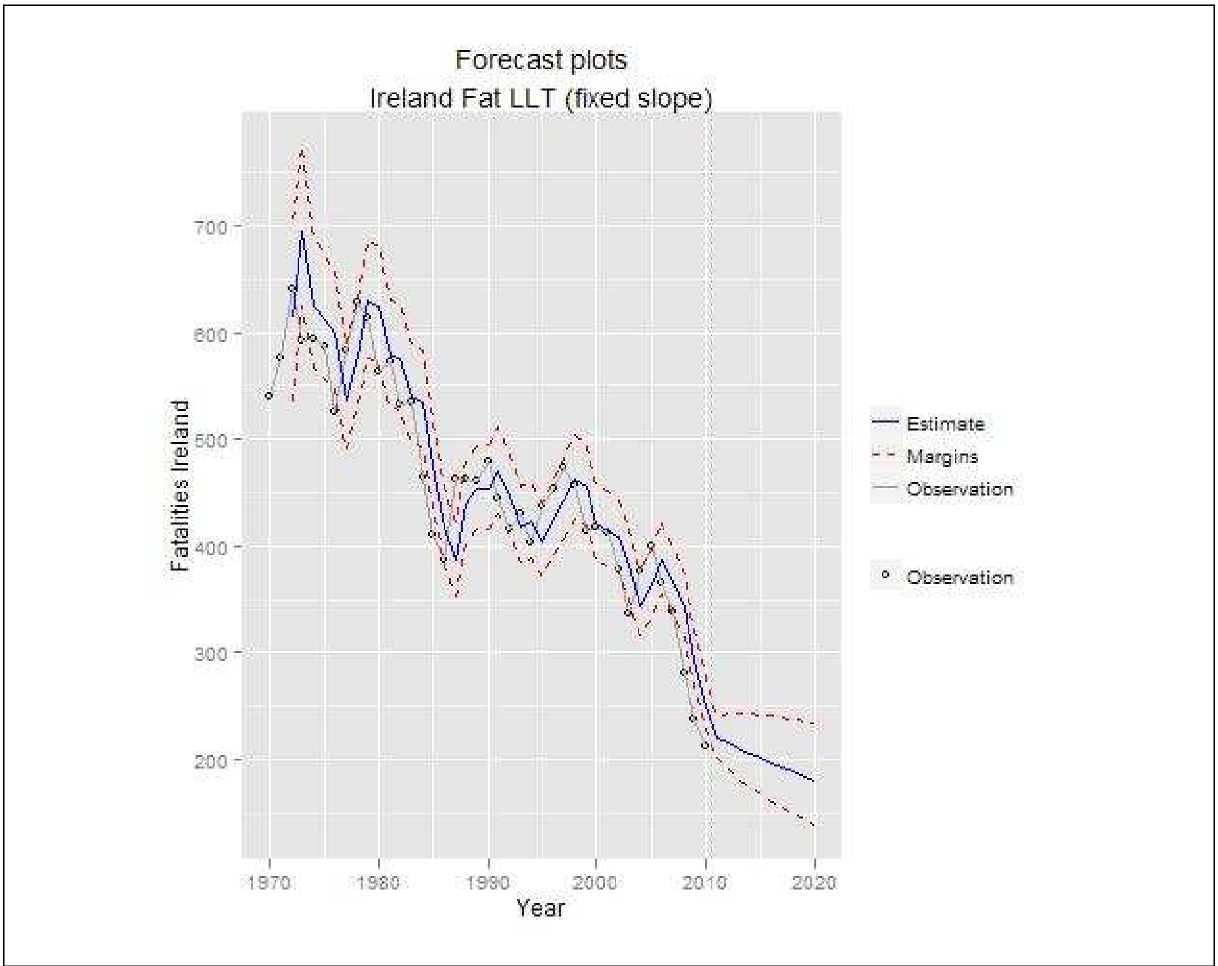


Figure 6: Plot of the annual fatality numbers for Ireland forecasted between 2011 and 2020 (LLT with fixed slope).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**220**	184	264
2012	**215**	170	273
2013	**211**	159	279
2014	**206**	149	284
2015	**201**	141	288
2016	**197**	133	292
2017	**193**	125	295
2018	**188**	119	298
2019	**184**	113	301
2020	**180**	107	303

Table 3: Forecasts of the LLT with fixed slope.

ITALY

1 Raw data

1.1 Exposure

Since no official vehicle kilometres estimate is available for Italy, the number of registered vehicles from 1980 to 2010 has been used as a measure of exposure (see Figure 1).

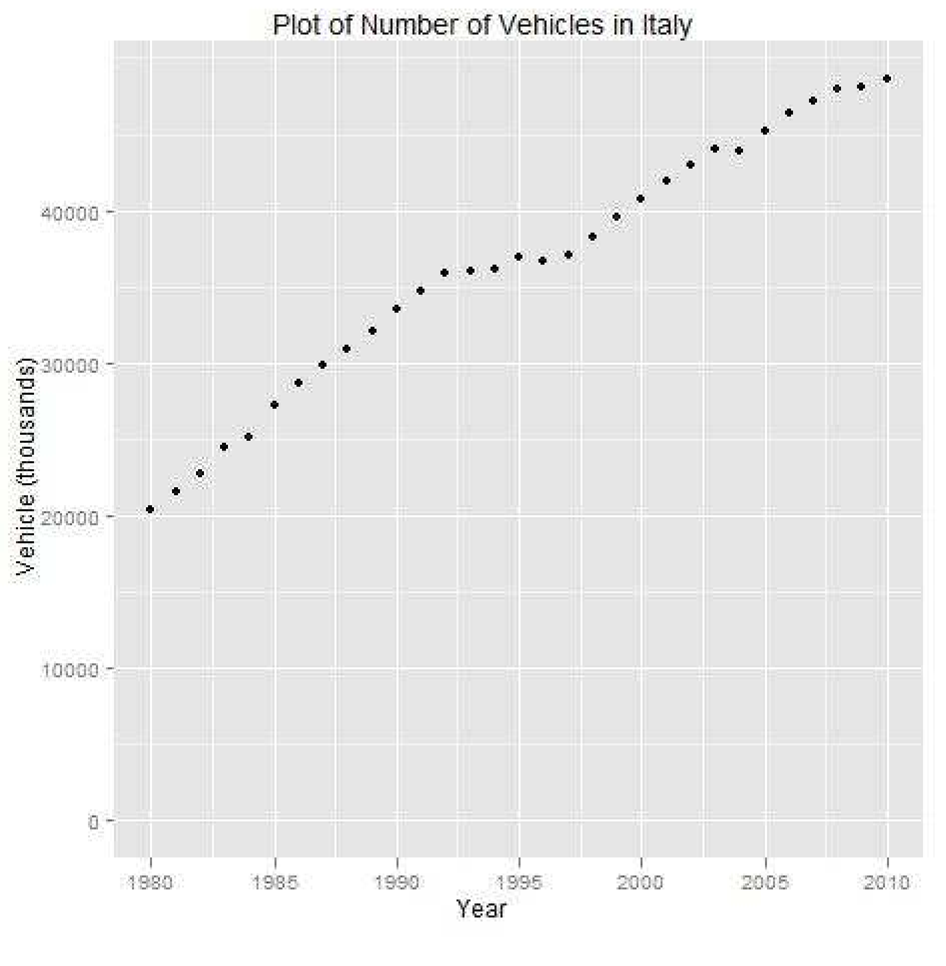


Figure 1: Plot of the annual number of vehicles for Italy from 1980 to 2010.

The number of vehicles in Italy has been increasing from 1980 to 1992. Between 1992 and 1997 a stagnation period can be observed. After 1997 the growth rate varied between 2% and 3% until 2008 with a little decrease in 2004.

From 2009 on trailers and semitrailers with weight lower than 3,5 tons have been excluded from the calculation of total vehicle fleet. This caused a little drop in the growth rate.

1.2 Fatalities

Figure 2 shows the number of road accident fatalities in Italy from 1980 to 2010. The value for 2010 is an estimation by the Italian Institute of Statistics and is not the official number yet.

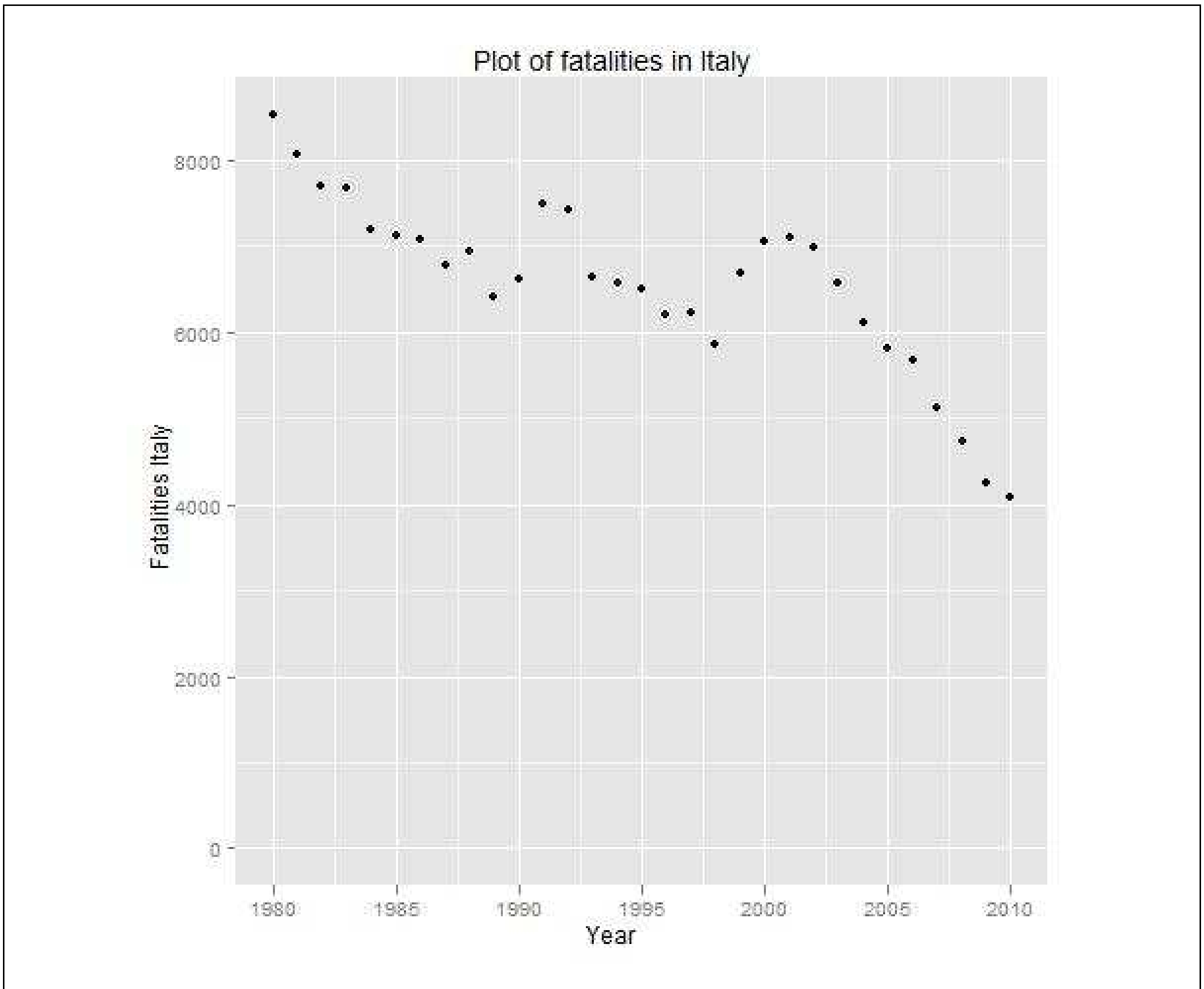


Figure 2 : Plot of the annual fatality counts for Italy from 1980 to 2010.

The number of fatalities more than halved in Italy during the period considered (1980-2010). The number of fatalities observed at the end of the series (4090) is 2.09 times lower than the starting value (8537).

The registration of road accidents in Italy is based on a form introduced by the Italian Institute of Statistic (ISTAT) in 1991. At this time, Italy adopted a new definition for road accident to take international standards into account. As a consequence, the registration procedure focused exclusively on injury accidents (before 1991 all road accidents gathered by Police forces were included in the survey). Another important date for accident data collection is

1999, when ISTAT extended the time period used for the definition of a road accident fatality from 7 to 30 days.

2 The SUTSE Model

2.1 Development of the state components

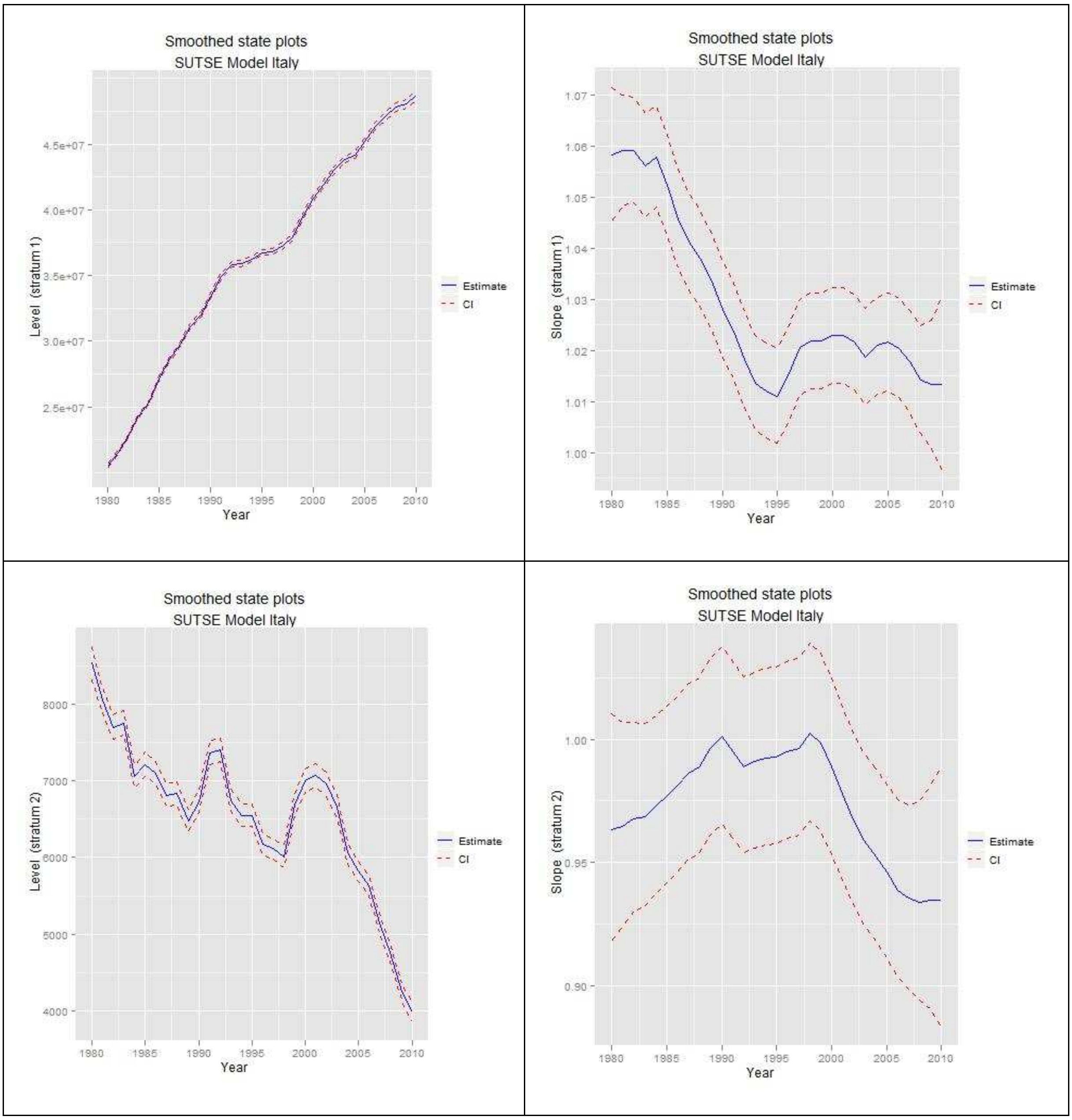


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities

(lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The slope is the only state component that varies significantly over time for the exposure series. The variation of the trend does not prove significant.

In 1980 the exposure trend is estimated around 20 million vehicles. At the end of the series, in 2010, the initial value is more than doubled, reaching 48 million vehicles.

As it can be seen in Figure 1 (upper right side), all the values of the exposure slope exceed 1. This means that every year from 1980 on there has been an increase in the number of vehicles. From 1980 to 1995, this annual increase became smaller, (from 6% to 1%). After 1995 the annual increase ranged between 1.5%-2.5%.

2.2.2 Fatalities

From 1980, the fatality trend continuously decreases with some oscillations. The trend value at the start of the series is around 8.500 fatalities and around 4.000 at the end.

There are two years in the series where the slope values are higher than 1, which means an increase in fatalities. The majority of the slope values are negative however, indicating that the number of fatalities has been decreasing for most years.

These variations in the trend and slope values cannot be considered significant, however, as indicated by the results of the SUTSE model reported in Table 1.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components:

Three state components cannot be considered stochastic, these are: the exposure level and the level and slope for the fatalities.

The two slopes are correlated to 0.2, and show a marginally significant correlation (p=0.09). The correlation between the two levels is not significant (p=0.76).

2.2.2 Correlation between the irregulars:

The measurement errors for exposure and fatalities are correlated at -0.65 which is not significant (p=0.41).

2.2.3 Estimation of the relationship by means of a coefficient:

A SUTSE model where the relationship between the two series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1).

The beta coefficient for the relationship between the latent developments of the two series is equal to 2.88 and is significantly different from 0 (p=0.04).

Model title	***SUTSEItaly1***	***SUTSEbetaItaly1***
Model description	SUTSE Model Italy	SUTSE indipendent components, beta estimated
Model Criteria		
log likelihood	149.6	149.6
AIC	-298.5	-298.5
Variance of the state components		
Level exposure	8.69E-05 nsc	8.69E-05 nsc
Level risk	2.21E-03 nsc	2.21E-03 nsc
Slope exposure	3.51E-05 *c	3.51E-05 *c
Slope risk	2.18E-04 nsc	2.18E-04 nsc
Correlations between the state components		
level-level	1.0	1.0
slope-slope	0.2	0.2
Observation variance		
Observation variance exposure	2.52E-05 *	2.52E-05 *
Observation variance risk	8.59E-05 ns	8.59E-05 ns
Beta	/	2.88 (p=0.04)

Table 1: Overview of the results for SUTSE models- Italy.

3. The LRT Model

The investigation of the SUTSE provided indications, although not strong, of a relation between exposure and fatalities in Italy. In this case an LRT model is worth being explored.

3.1 Model selection

Two versions of the LRT model were run: the full model and the model with fixed levels for exposure and risk. Looking at the residual analysis, none of the models appears to violate the necessary statistical assumptions.

Some interventions have been introduced:

1991: Change in road accident data collection introduced by ISTAT. It has been included in the model as a level break for fatalities.

1999: Change in the way of recording fatalities (from killed 7 days to killed 30 days). It has been included in the model as a level break for fatalities.

2009:.Trailers and semitrailers with weight lower than 3,5 tons have been excluded from the calculation of total vehicle fleet. It has been considered through a level break in exposure.

Model title	***LLTItaly1***	***LRTItaly1***	***LRTItaly3***
Model description		Latent Risk Model Italy (full model + 1991, 1999, 2009 interventions)	Latent Risk Model Italy (fixed level exposure and level risk)
Model Criteria			
Log-likelihood	52,7	127.0	126.84
AIC	-105,2	-253.4	-253.29
Model Quality			
Box-Ljung test 1 Exposure		0.20	0.03
Box-Ljung test 2 Exposure		0.42	0.04
Box-Ljung test 3 Exposure		1.17	0.34
Box-Ljung test 1 Fatalities	0,83	0.38	0.00
Box-Ljung test 2 Fatalities	0,89	0.40	0.61
Box-Ljung test 3 Fatalities	0,94	2.98	0.66
Heteroscedasticity Test Exposure		0.36	0.42
Heteroscedasticity Test Fatalities	0,59	1.26	1.48
Normality Test standard Residuals Exposure1		0.05	0.09
Normality Test standard Residuals Fatalities	3,91	1.13	1.27
Normality Test output Aux Res Exposure		1.69	2.24
Normality Test output Aux Res Fatalities	1,59	0.93	1.60
Normality Test State Aux Res Level exposure		0.01	0.14
Normality Test State Aux Res Slope exposure		1.11	0.84
Normality Test State Aux Res Level risk	8.10*	0.12	0.11
Normality Test State Aux Res Slope risk	1,22	1.38	1.45
Variance of state components			
Level exposure		6.89E-05 nsc	-
Level risk	2.43E-03 *	3.52E-04 nsc	-
Slope exposure		4.89E-05 *c	7.26E-05 *
Slope risk	2.27E-04 ns	1.50E-04 *c	1.98E-04 *
Correlations between state components			
level-level		1.00	
slope-slope		-0.32	0.06
Observation variance			
Observation variance exposure		2.85E-05 ns	4.76E-05 *
Observation variance risk		1.46E-04 ns	4.01E-04 *
Interventions			
1991 level exposure		-0.15 *	-0.15 *
1999 level exposure		-0.13 *	-0.13 *
2009 level risk		0.01 ns	0.01 ns

Table 2: Overview of the results for the LLT and LRT models - Italy.

The second model has a bigger AIC and is selected. The exposure and the risk follow a smooth trend model (random variation of the slope but not of the level).

3.2 Development of the state components:

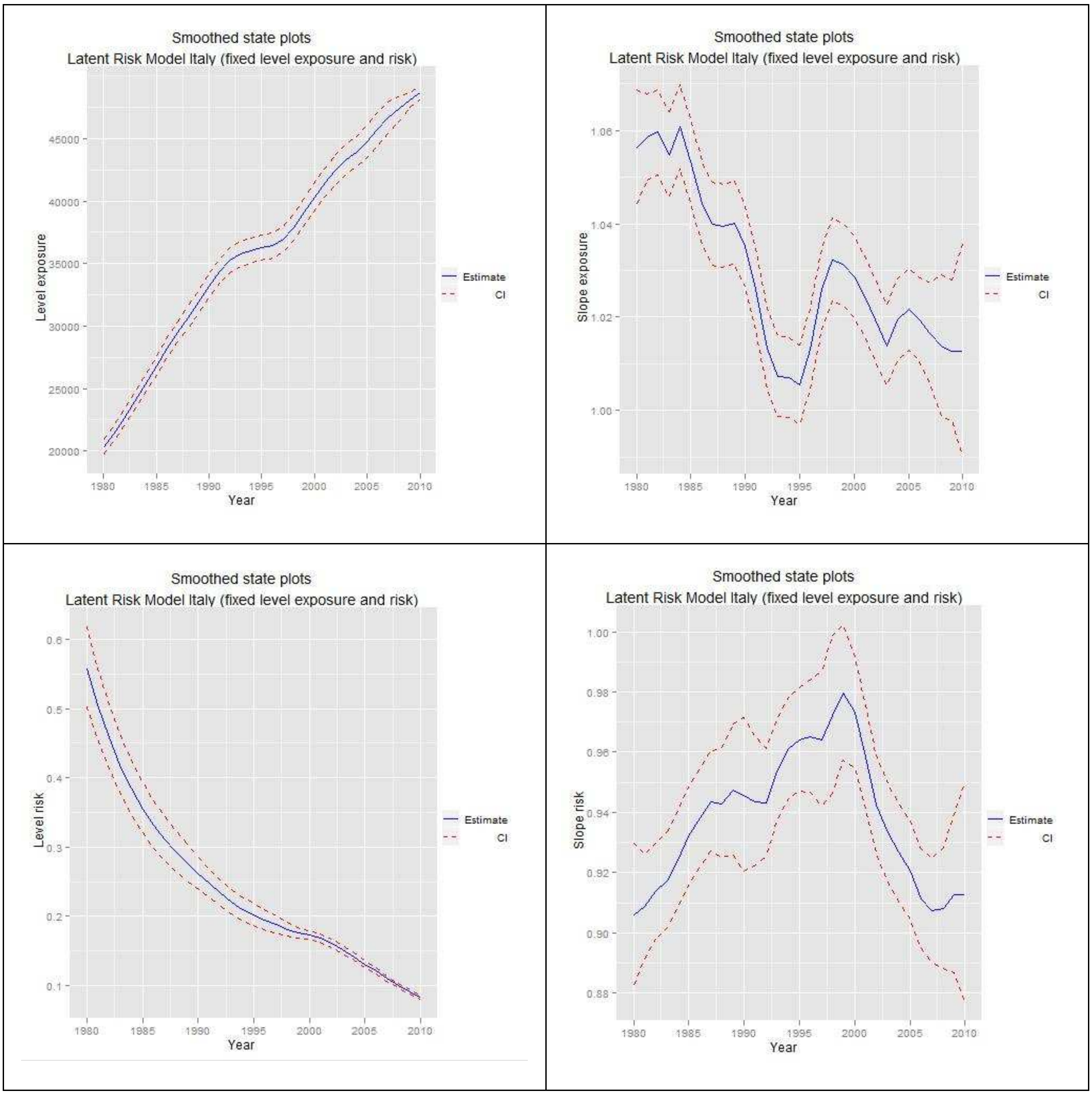


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The evolution of exposure is similar to the SUTSE model. The slope varies significantly, indicating that the rate of increase is not the same throughout the examined period. In the early eighties, the annual increase was about 5-6%. From then on, it kept on weakening, with a first sudden drop between 1992 and 1996. The increase in the number of vehicle became stronger for a short period, but it diminished again to 1% in the most recent years.

3.2.2 Risk

The risk for fatalities has reduced from 55 fatalities per 100,000 vehicles in the early 80s to less than 9 per 100,000 vehicles in the most recent years in Italy. This decrease between -2% and -10% each year is expressed in the negative slope of the risk in the lower left panel of Figure 4. On the basis of the LRT model the variation of the slope values over the years can be considered significant.

3.3 Quality of the predictions

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2004 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series.

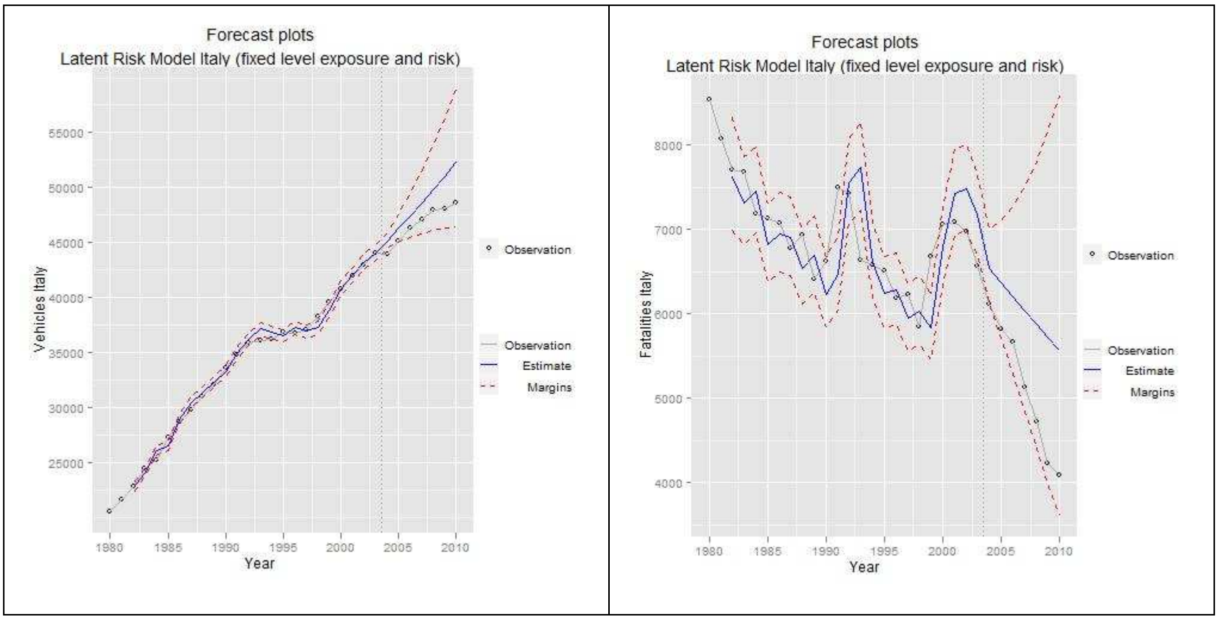


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Italy for the full LRT model (left-hand graph) and the LRT model with fixed exposure trend and risk slope.

4 Forecasts 2011 – 2020

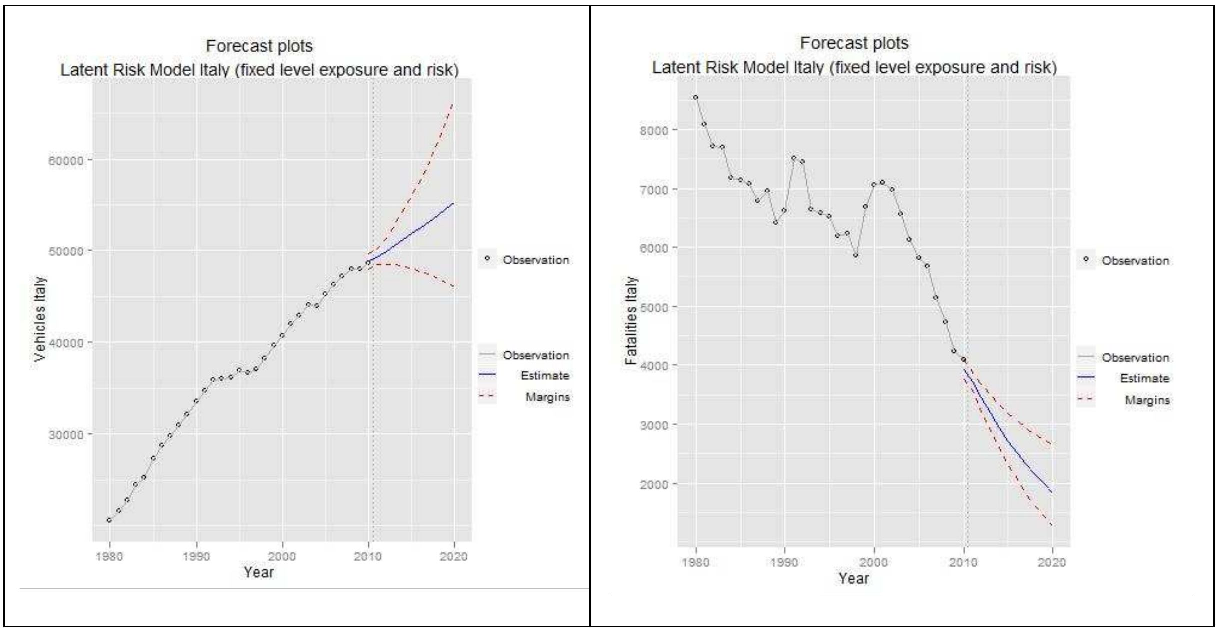


Figure 6: Plot of the annual number of vehicles (left-hand graph) and annual fatality numbers (right-hand graph) for Italy forecasted between 2011 and 2020.

	Vehicles (thousand)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2011	**49312**	47726	50951	**3725**	3426	4050
2012	**49942**	47243	52796	**3443**	3036	3906
2013	**50580**	46535	54976	**3183**	2661	3808
2014	**51226**	45665	57464	**2942**	2314	3742
2015	**51880**	44666	60259	**2720**	1998	3703
2016	**52543**	43561	63376	**2514**	1715	3687
2017	**53214**	42369	66835	**2324**	1464	3691
2018	**53894**	41106	70660	**2148**	1243	3714
2019	**54582**	39786	74881	**1986**	1050	3755
2020	**55279**	38421	79534	**1836**	884	3814

Table 3: Forecasts of the Latent Risk Model (LRT 3).

The forecasts obtained from the model provide an indication of the vehicles and fatality numbers to be expected between 2011 and 2020 provided that, throughout these years, the trends keep on following the developments that they have shown in the past. Under this assumption, the number of vehicles should increase up to 55 million in 2020 while the number of fatalities should decrease to 1836.

5 Scenarios

In Figure 6 it can be seen that there is strong uncertainty about the development of the exposure in Italy. Given that the exposure influences the prediction of the fatalities it is interesting to demonstrate how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 7 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

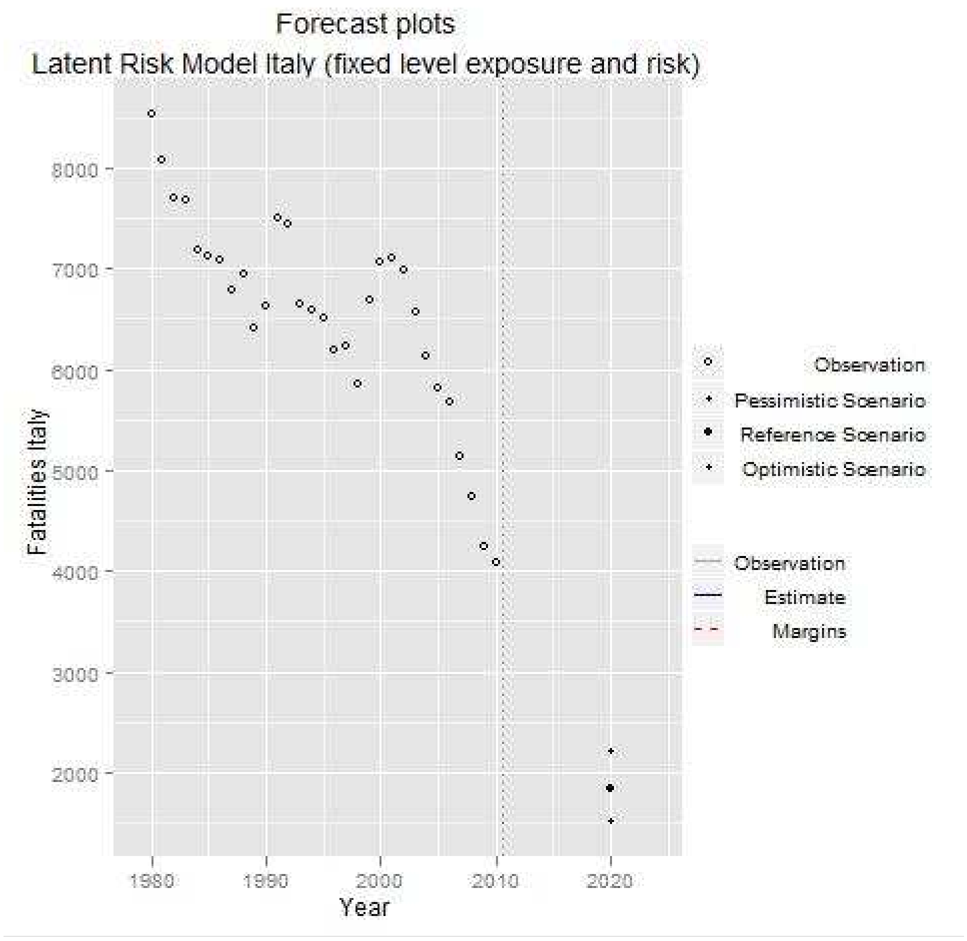


Figure 7: Fatality forecasts Italy 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT3). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the number of vehicles as predicted from the LRT model plus/minus one standard deviation. Assuming that these predictions are correct, and thus ignoring the uncertainty surrounding the forecasts for the exposure, what would be the consequences for the number of fatalities to be expected in 2020?

The predicted number of vehicles for 2020 is 55.3 million, a scenario under which one would expect 1,836 fatalities, and which is represented by a full dot in Figure 7. The circles in this figure represent the estimated fatality numbers assuming an increase (forecast plus one standard deviation: 66.5 million), or a decrease (forecast minus one standard deviation: 45.9 million) in the number of vehicles. The fatality numbers estimated for each scenario are detailed in Table 4.

	Vehicles (millions)	***Road traffic fatalities***
Situation 2010:	48.7	4090
Prediction for 2020 according to mobility scenarios:		
Continuation of development	54.6	1836
Stronger growth	66.5	2222
Lower growth	45.9	1516

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRT3). Mobility scenarios are based on predicted value +/- one standard deviation.

LATVIA

1. Raw data:

1.1 Exposure:

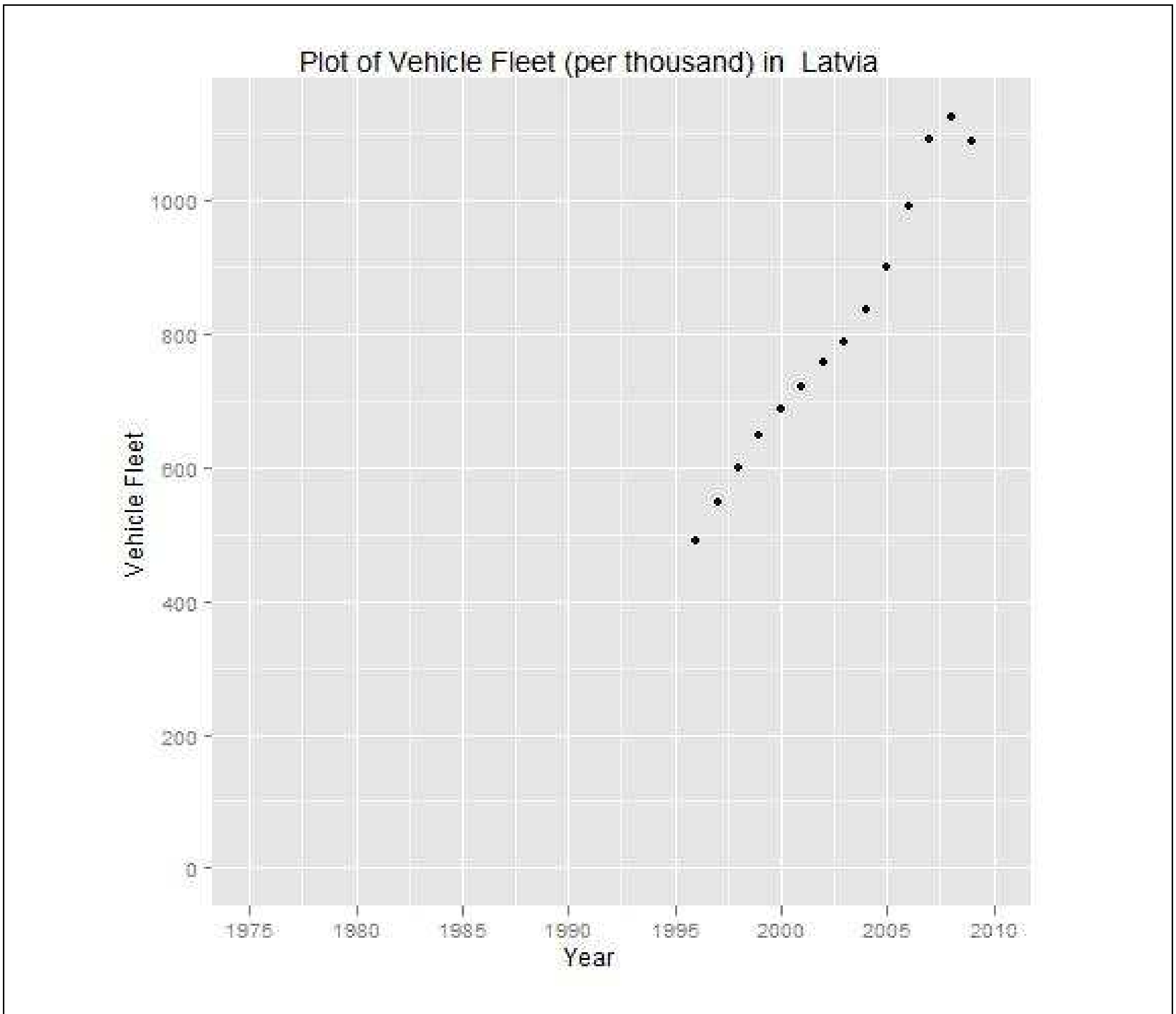


Figure 1: Plot of the annual vehicle fleet (in thousand) for Latvia from 1996 to 2009.

As exposure measure we consider the vehicle fleet (in thousand vehicles; without trailers and semi-trailers). Yearly data are obtained from national sources and available for the period 1996 to 2010. However, the very low value of 2010 is not considered in the analysis given two changes in law, affecting the vehicle's register [1]. In particular, on the one hand the increased taxes for the use of vehicles stimulated the scrapping out of vehicles and on the other hand, particular vehicles (e.g. vehicles permanently registered in a foreign country) were removed from the register of vehicles. Therefore, values up to 2009 are considered for the analyses.

The plot shows a gradual increase over the years, ending in 2008. It can be argued whether this fleet data are an adequate reflection of mobility in Latvia because the number of vehicles which passed technical inspection was approximately 60% [1].

1.2 Fatalities:

The plot below shows the number of fatalities in Latvia from 1975 to 2010. Data are from national sources (except the 2006, 2007 and 2008 values which are from CARE). The yearly values before 2004 were increased by 8% due to the formerly definition of killed within 7 days instead of killed within 30 days.

In the period 1975-1983 the number of fatalities in Latvia remained more or less constant, followed by a decrease until 1986 and an increase up to 1991. In the next years, the number of fatalities generally decreased; however, there was a peak in 1998.

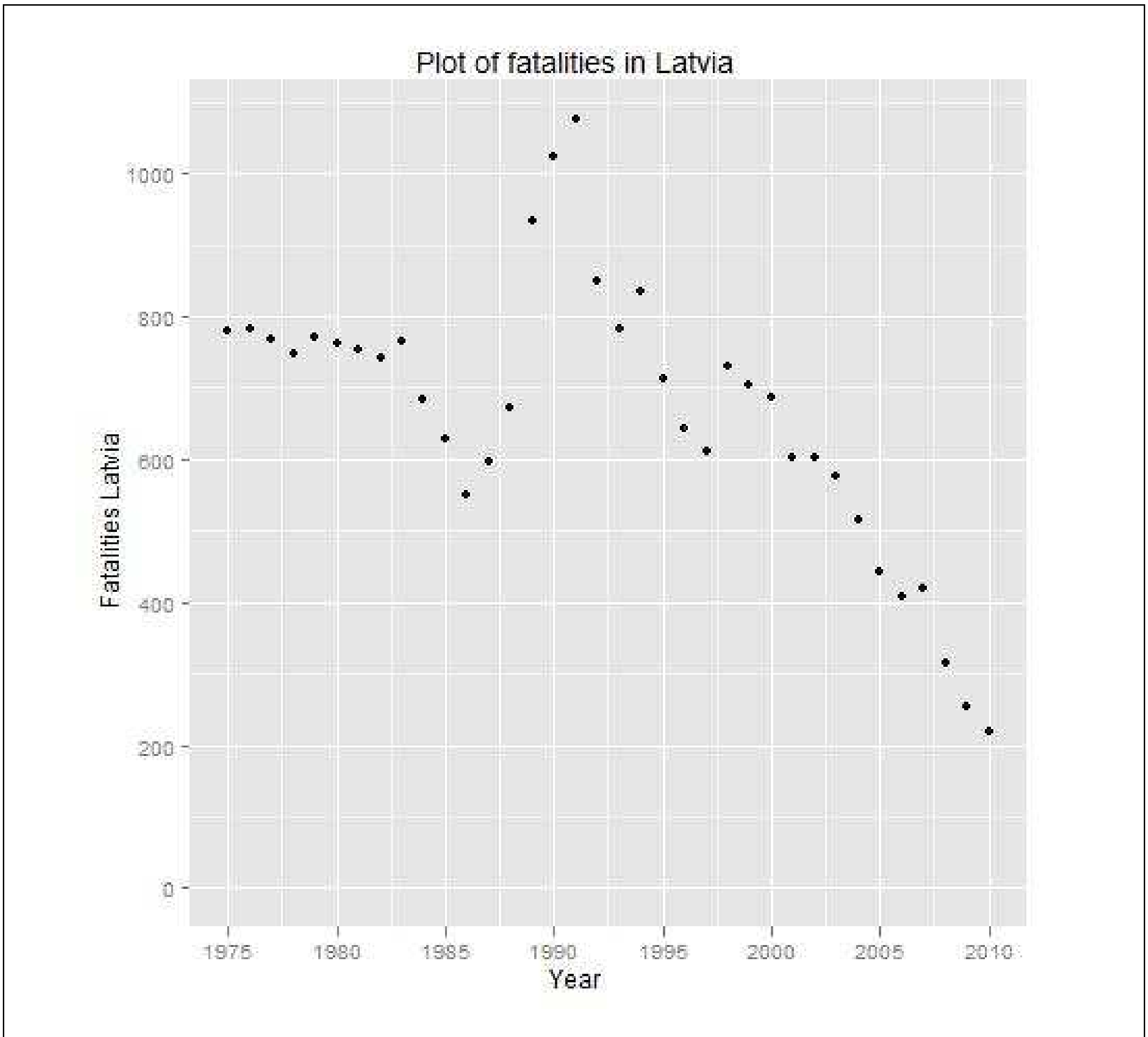


Figure 2: Plot of the annual fatality counts for Latvia from 1975 to 2010.

2 The SUTSE Model:

2.1 Development of the state components:

The figure below presents the varying level and slope estimation results of the SUTSE model: in particular the smoothed state plots for the exposure (top) and fatality (bottom) variables. The left subfigure in each row shows the level estimate for the corresponding variable and the right subfigure shows the slope estimate. Confidence intervals are also presented in these figures.

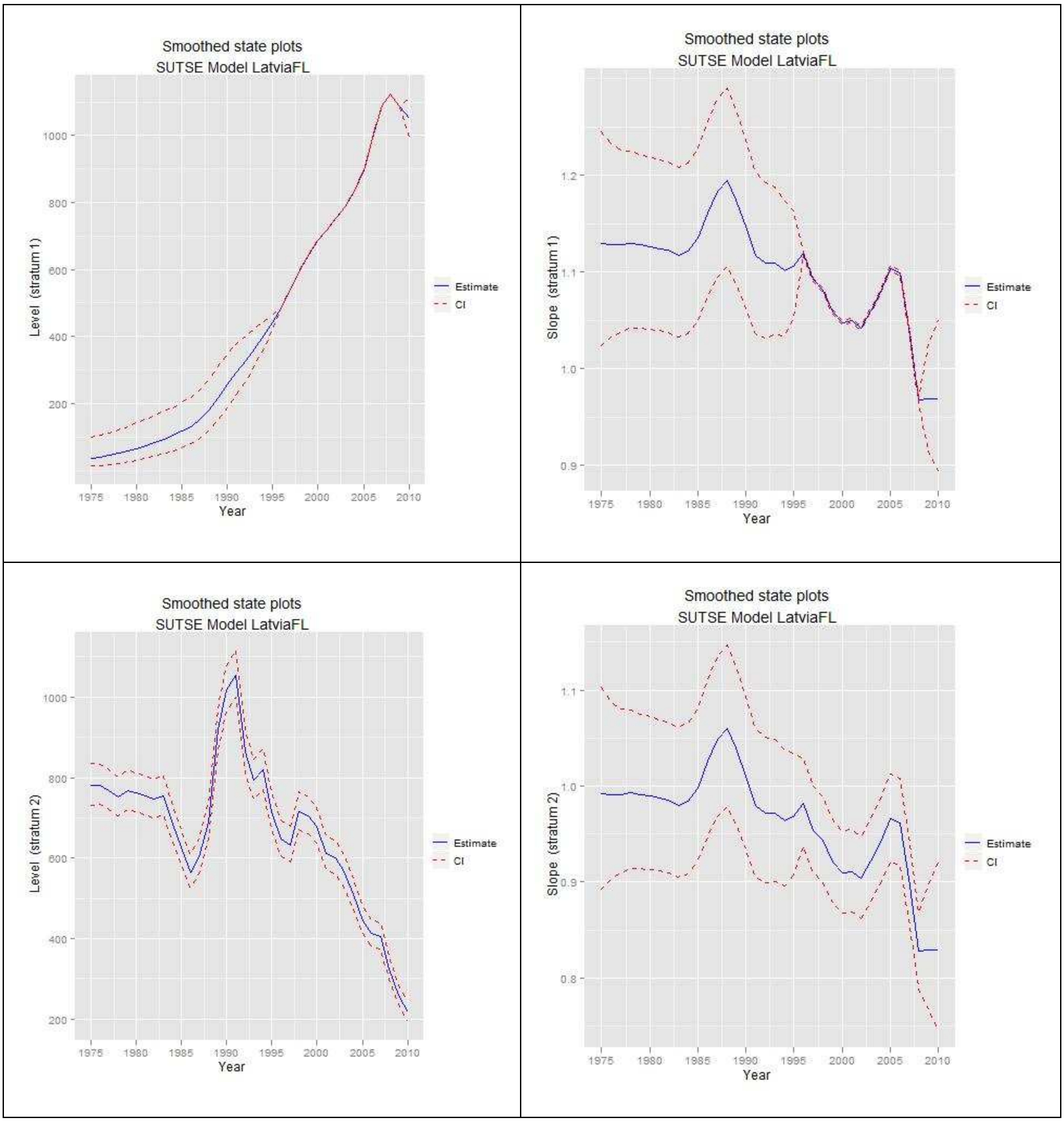


Figure 3.: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend in the number of vehicles in Latvia doubled from almost 500,000 in 1996 to more than 1 million since 2006. The slope of the exposure (top right subfigure) has been positive up to 2008 (or in other words, the vehicle fleet increased from one year to another) and generally decreasing, except in the period 2002-2005.

2.2.2 Fatalities

The level component shows a clear peak in the number of fatalities around 1991 with more than 1000 fatalities in Latvia. This number dropped during the past two decades to 220 in 2010. In general, the slope (bottom right subfigure) shows a decrease over the studied time period.

2.2 Relation between the exposure and fatality series:

2.2.1Correlation between the disturbances of the state components

Both correlations are estimated with a maximal value of 1. The correlation between the two levels (p=0.83) and two slopes (p=0.18) is not significant.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at -3.90E-04 which is not significant (p=1).

2.2.3 Estimation of the relationship by means of a coefficient

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). The beta coefficient for the relationship between the latent developments of the two series is equal to 1.28 and is not significant (p=0.11).

2.2.4 Conclusion

It can be concluded that the fatalities and vehicle fleet series are not related and therefore further modeling can be made using the LLT model (instead of the LRT).

Model title		***SUTSE Latvia1***	***SUTSEbetaLatvia1***
Model description		SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	63.29	63.26
	AIC	-126.07	-126.08
Hyperparameters			
	Level exposure	3.54E-06 nsc	1.90E-16 ns
	Level fatalities	9.13E-03 *c	8.61E-03 *
	Slope exposure	8.78E-04 *c	8.92E-04 *
	Slope fatalities	1.20E-03 *c	8.44E-13 ns
Correlations			
	level-level	1.00	
	slope-slope	1.00	
Observation variances			
	Observation variance exposure	1.00E-09 ns	1.00E-09 ns
	Observation variance fatalities	1.00E-09 ns	1.00E-09 ns
Beta		***/***	***1.28 (p= 0.11)***

Table 1: Model criteria and results for SUTSE models - Latvia

3 The LLT Model:

3.1 Model selection:

Given that no relationship could be identified between exposure and fatalities on the basis of the data at hand, a Local Linear Trend model was fit to model the fatalities.

In the full model (LLTLatvia1), the assumption concerning the independence of the residuals (see Box-Ljung test results) seemed to be violated. Therefore, a second LLT model was run (LLTLatvia2) including an intervention (in 1989 at the level of fatalities; selected based on the residual graphs). In this model, all residual assumptions were met. Moreover, both the level and slope appeared to be significant, therefore, no further LLT models (fixing a particular component) were ran.

Given the satisfactory residual test results and the smaller prediction errors (ME10 and MSE10), LLTLatvia2 is chosen as the forecasting model.

Model title	***LLT Latvia1***	***LLT Latvia2***
Model description	Full Model	Intervention 1989 (level fatalities)
Model Criteria		
ME10	-233.02	-177.88
MSE10	69620.96	41207.13
log likelihood	39.66	36.43
AIC	-79.15	-72.69
Model Quality		
Box-Ljung test 1	6.94**	2.46
Box-Ljung test 2	7.06*	2.90
Box-Ljung test 3	7.70	3.96
Heteroscedasticity Test	1.37	1.35
Normality Test standard Residuals	5.73	0.26
Normality Test output Aux Res	1.46	2.10
Normality Test State Aux Res Level	5.34	0.00
Normality Test State Aux Res Slope	0.13	0.02
Variance of state components		
Level	9.82E-03 ns	6.45E-03 *
Slope	6.91E-04 *	2.92E-04 *
Observation variance		
Observation variance	1.00E-09 ns	1.00E-09 ns
Interventions		
		fat level 1989
		0.39 *

Table 2: Overview of the results for the LLT models – Latvia.

3.2 Development of the state components:

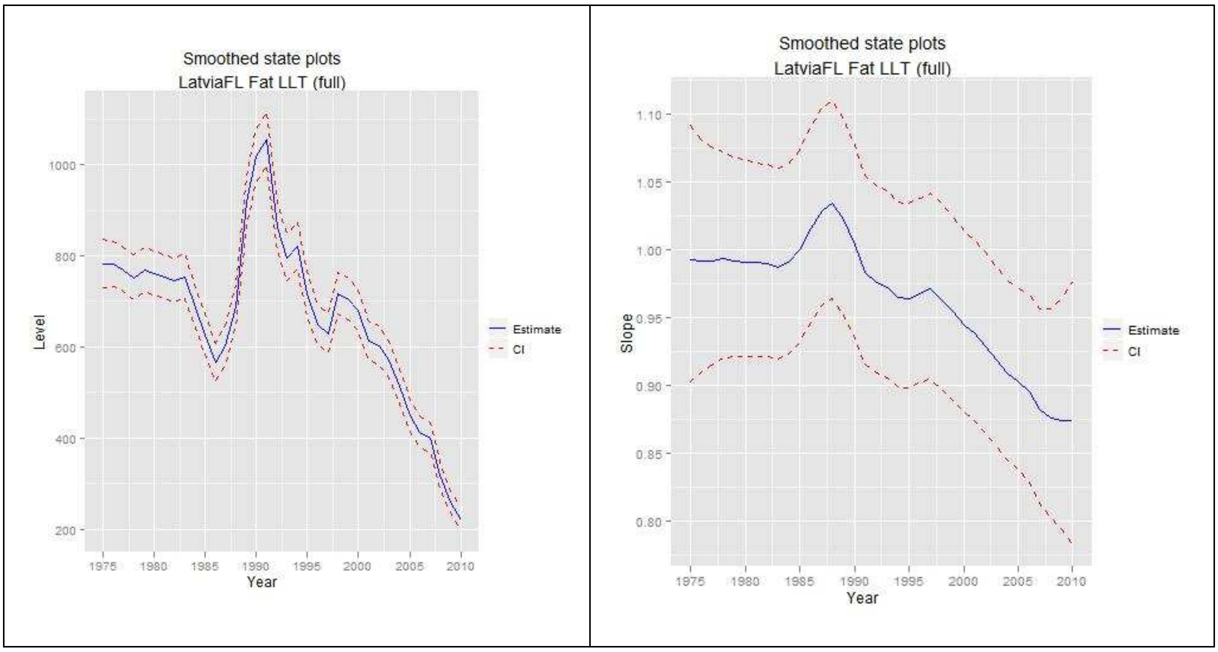


Figure 4: Developments of the state components for the fatalities, as estimated on the basis of the full LLT model.

3.2.1 Fatalities:

The trend in the number of fatalities fluctuated around 760 in the period 1975-1983. The next years, there was a decrease up to 1986 and a large increase up to 1991, at which point a decreasing trend started (until 2010). In general, the slope of the fatalities has been reducing over the time period considered; since 1997 at more rapid rate.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series.

Given the strong decrease in the number of fatalities from 2001 onwards, the model predicts larger fatality numbers than actually observed.

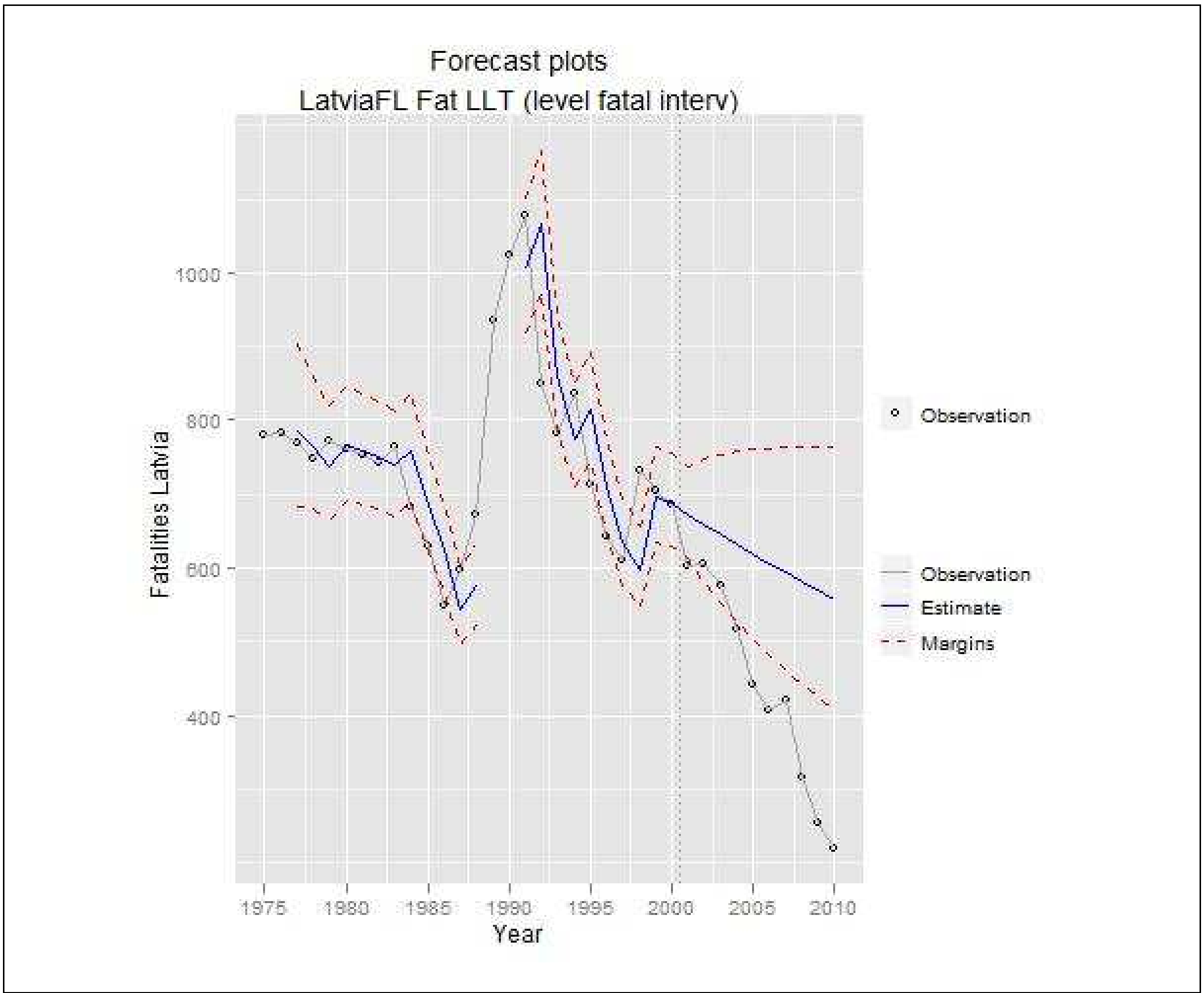


Figure 5: Plot comparing the model predictions (straight line) with the actual observations (“bullets”) for the annual fatality numbers in Latvia for the LLTLatvia2 model.

4 Forecasts 2011 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.*

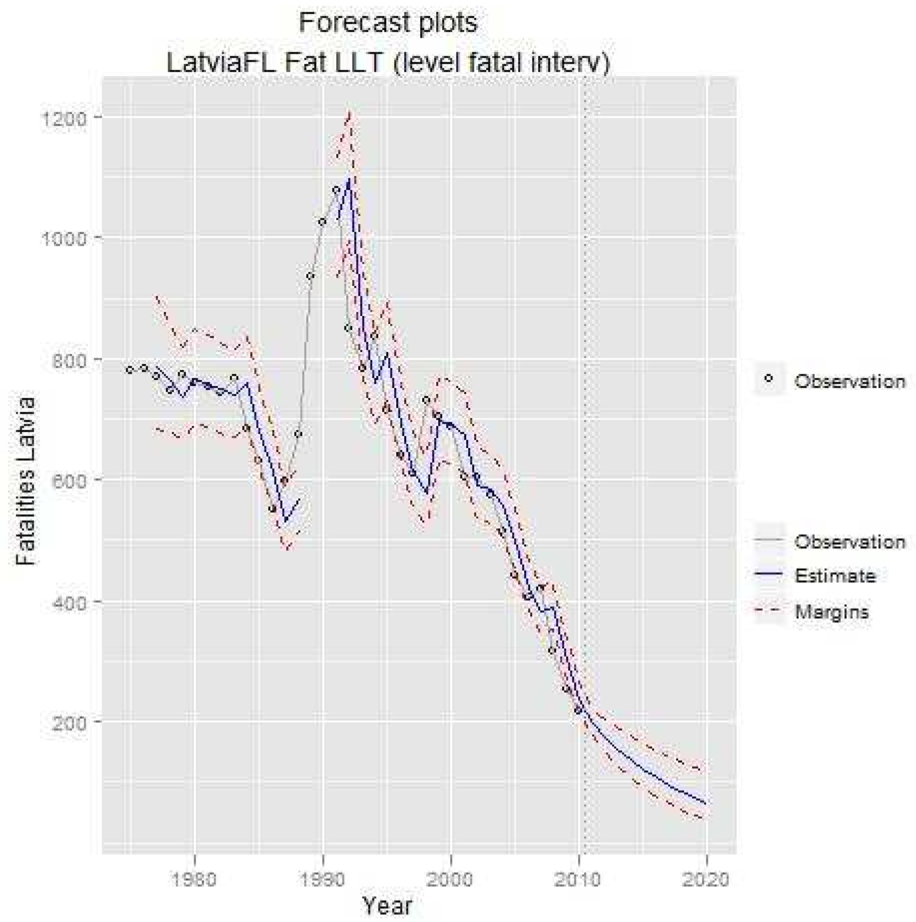


Figure 6: Plot of the annual fatality numbers for Latvia and the forecast for 2020 (based on the Local Linear Trend Model LLTLatvia2).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**198**	159	246
2012	**175**	128	239
2013	**155**	103	232
2014	**137**	84	226
2015	**122**	67	220
2016	**108**	54	215
2017	**95**	43	211
2018	**84**	34	207
2019	**75**	27	205
2020	**66**	22	203

Table 3: Forecasts of the Local Linear Trend Model LLTLatvia2

REFERENCES:

[1] EC National Expert for road accident statistics and road safety performance indicators.

LITHUANIA

1 Raw data

1.1 Fatalities

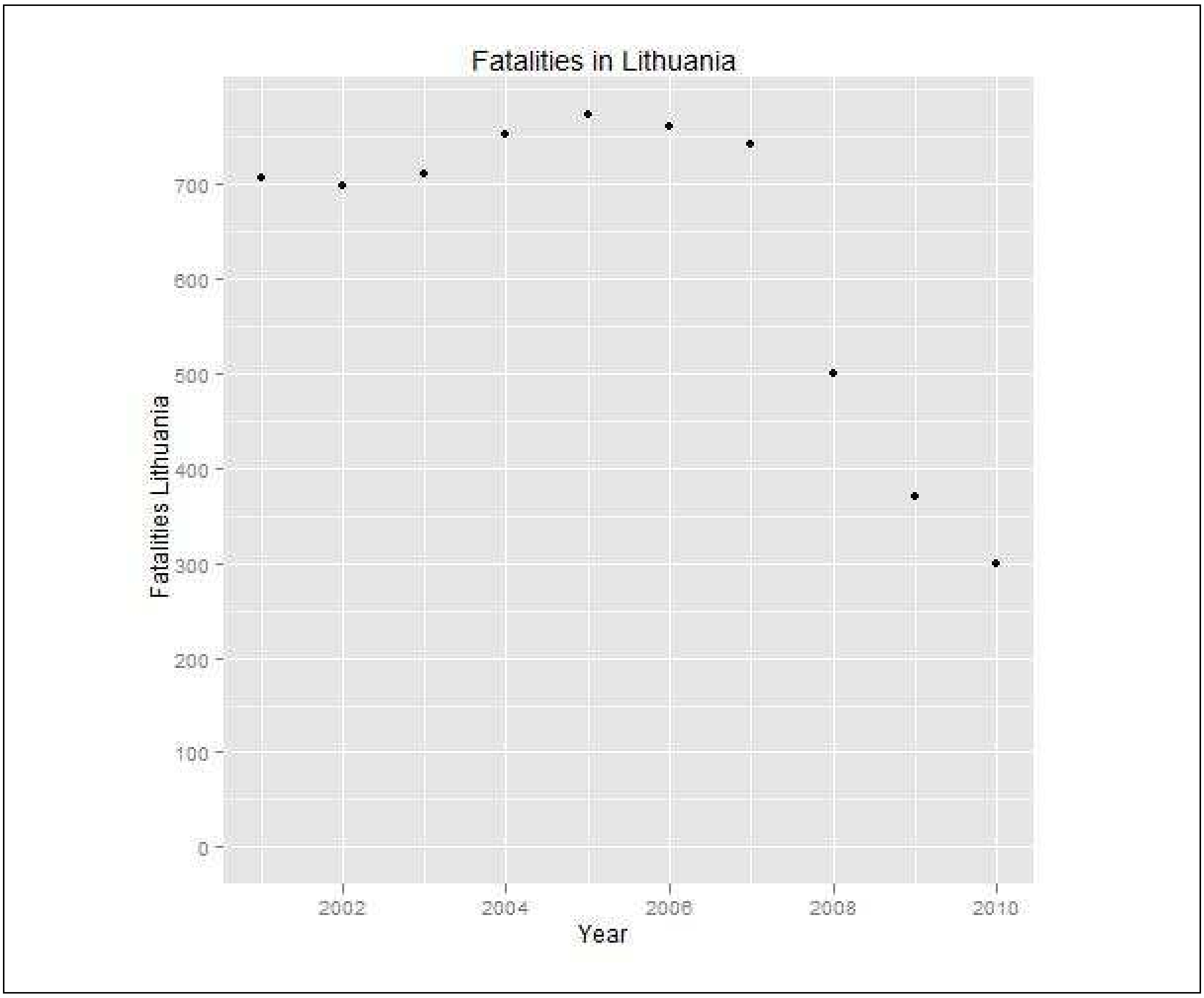


Figure 15.1.: Plot of the annual number of fatalities for Lithuania from 2001 to 2010.

The fatality series available for Lithuania covers only 10 years, and no exposure data was available for this country.

The short fatality series is stagnating (or slightly increasing) from 2001 to 2007. In 2008 a sudden and rapid decrease has been observed in the number of fatalities: the annual number dropped from about to 750 (2007) to about 500. From then on and up to 2010, the decline of the number of fatalities has been really strong. In 2010, 300 fatalities have been registered in Lithuania.

A number of road safety measures have been taken in recent years: according to [14] this reduction was reached due to a concerted effort to increase traffic safety, including awareness campaigns, infrastructure audits, lowering the legal BAC to 0.4g/l, increased speeding fines and the threat of license suspension for young drivers in the case of excessive speeding. At the same time, the economic recession showing an effect on road traffic fatalities in almost all European countries, probably also contributed to the reduction. The biggest drop does however, precede the onset of the recession (as indicated by drop in GDP), suggesting that the strong reduction in fatalities is not simply a by-effect of the economic recession.

2 The LLT Model:

2.1 Model selection:

As there is no exposure measure available, the fatalities are forecasted on the basis of a local linear trend model (LLT) on the fatalities from 2001 to 2010. It is important to note that as a general rule the minimum number of data points necessary for such an analysis would be considered 15.

[14] ETSC, 5th Road Safety PIN report, July 2011. Interverview with Eligijus Marsiulis, Lithuania Minister of Transport.

Model title	LLT1	LLT2	LLT3	LLT4	LLT5
Model description	Full LLT fatalities	slope intervention 2007	level intervention 2007	fixed level	fixed slope
Model Criteria					
ME4	-337	-337	-337	-337	-337
MSE4	148231	148231	148231	148231	148231
log likelihood	-2.18	-6.20	-10.35	-2.18	-4.74
AIC	4.96	13.01	21.30	4.76	9.88
Model Quality					
Box-Ljung test 1	0.30	5.35*	0.43	0.30	4.86*
Box-Ljung test 2	0.70	6.26*	1.02	0.30	4.89
Box-Ljung test 3	0.87	6.99	1.14	0.70	4.96
Heteroscedasticity Test	46.14*	2.38	32.89	46.14*	90.27*
Normality Test Stand. Res.	5.00	0.36	2.67	5.00	1.20
Normality Test output Aux Res	2.93	0.15	1.05	2.93	5.57
Normality State Aux Res Level	2.19	0.28	4.72	2.19	1.99
Normality State Aux Res Slope	2.07	0.00	0.55	2.07	0.00
Variance of state components					
Level	5.12E-17 ns	6.87E-17 ns	3.03E-19 ns	-	2.75E-02 *
Slope	1.32E-02 *	1.17E-03 ns	1.31E-02 *	1.32E-02 *	-
Observation variance					
Observation variance	1.00E-09 ns	1.00E-09 ns	1.00E-09 ns	1.00E-09 ns	1.00E-09 ns
Interventions					
Slope 2007		-0.31 *			
Level 2007			0.151516 ns		

Table 1: LLT model results - Lithuania

In the model quality tests for the full model (LLT1), we see that there is a strong heteroscedasticity problem in the data: the variance in the residuals in the first half of the series is smaller than at the variance in the second half. Inspection of the auxiliary residuals, suggest that the heteroscedasticity is due to the strong changes in 2007. The slope as well as the level of the series seem to be affected.

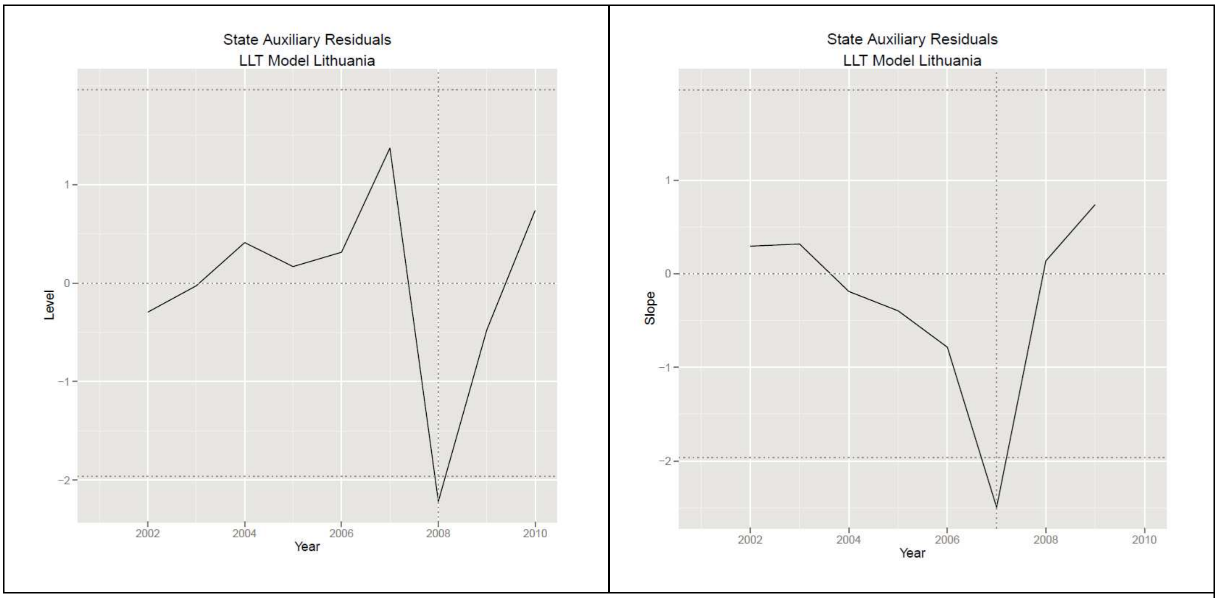


Figure 2: Auxilliary residuals for LLT1 (full model of fatalities in Lithuania, 2001 – 2007.

Moreover, the forecasts made by the full model without interventions (LLT1) seem problematic (see Table 10.2). Ranging from 0 (100% reduction) to 2500 (more than 700% increase), this model basically says that anything can happen. While this is true and reflects the fact that the observed data span only a very short series, this model is not very informative.

The very low estimated forecast indicates that purely statistical the ´best guess´ is to consider the changes in 2007 as permanent changes of direction. This best guess, however, is again based on an extremely short period. We have seen similar drops in other countries and more often than not, the decrease levelled up (or even turned into an increase again). Looking at other European countries also suggests that the period of change in Lithuania is a period of exceptional drops in almost all countries. While this knowledge by itself does not tell us yet, whether these changes are permanent or not, it at least suggests to be cautious to assume that the observed changes are the sole products of a new road safety management approach in the country in question.

To find a model with more informative forecasts and possibly with a remedy for the observed problems in the model quality criteria, several different models were run. In Table 2, 4 of those are presented. The other models, combinations of the restrictions and interventions presented here, did not offer solutions different than can be seen in the 5 models presented here.

LLT2 (slope intervention in 2007): The slope intervention defines the changes in 2007 as a change of direction that is not part of the system dynamics. The forecasts therefore exclude the possibility that a similar change could happen again. This is reflected in the low forecast (a reduction by 95% relative to 2010), but especially in the upper confidence interval (reduction by 78%), which is still a very low and seems an unlikely upper limit. Although statistically this model fits best, it is based on the assumption that the variation expected in the future is like the variation between 2001 and 2010 except for the one big change that was in fact observed in that decade.

		Forecasted reduction in 2020 as relative to 2010		
		Estimated forecast	Lower CI	Upper CI
LLT1	Full model	-92%	-100%	707%
LLT2	Slope intervention	-95%	-99%	-78%
LLT3	Level intervention	-91%	-100%	725%
LLT4	Fixed level	-92%	-100%	707%
LLT5	Fixed slope	-60%	-91%	80%

Table 2: Forecasts for 2020 - Lithuania

LLT3 (level intervention in 2007): This model differs very little from the full model without interventions. The level intervention is not significant. The model quality tests show almost the same results. The forecasts are also the same as for the full model.

LLT4 (fixed level): Fixing the level has very little effect on the model results. Again, the model quality results and the forecasts are almost the same as those for LLT1 and LLT3.

LLT5 (fixed slope): According to the model quality criteria, this model is not appropriate. The model fit (as indicated by AIC and LogLikelihood) is clearly less good than for the models in which the slope is not fixed. Moreover, the heteroscedasticity test indicates that the residuals in the first half of the period are systematically smaller than those in the second half. Nevertheless, this model -- assuming that in the past there has been one general direction (constant slope) in which deviations from the trend did not affect the direction of the next steps (level changes) -- seems to make the most informative forecasts.

The assumption of a constant general direction is a conservative one, but one that makes sense given that with only 10 data points we have no possibility to compare these changes in Lithuania to earlier periods of change.

2.2 Development of the state components:

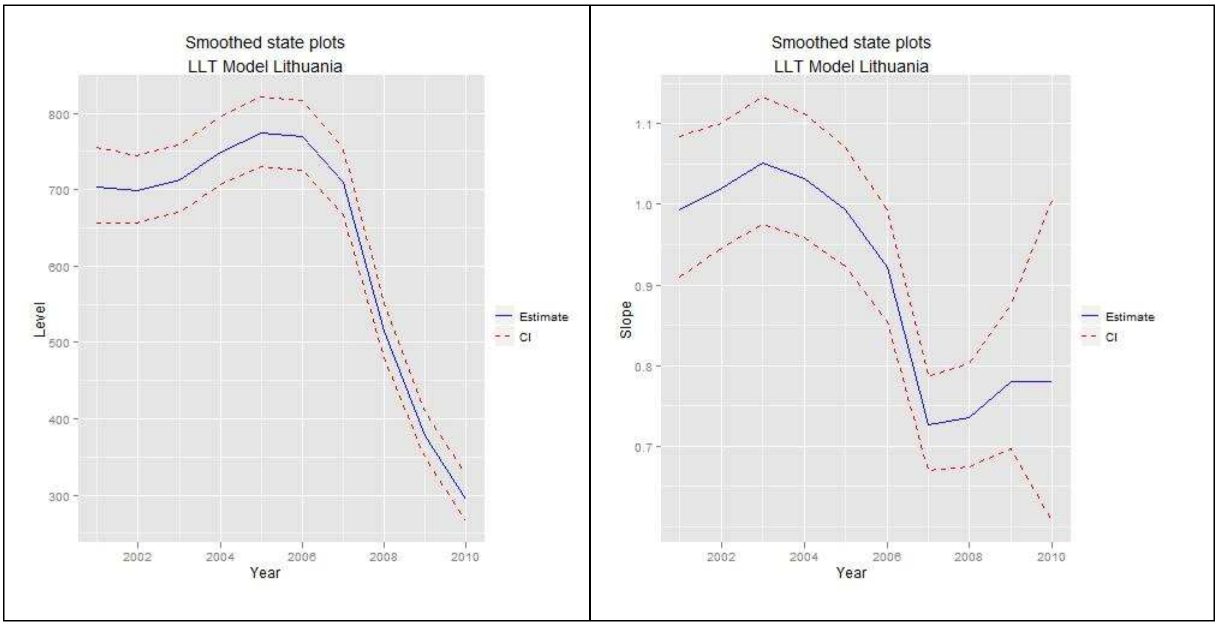


Figure 3: Developments of the state components in *Lithuania*, as estimated on the basis of the full LLT model (LLT1). The trend (level) developments are represented in the left-hand graph, the slope developments in the right-hand graph.

The fatality slope has changed from around 1 (stagnation) to less than 0.8 (annual reduction of more than 20%). Over the whole period from 2001 to 2010 this amounts to an annual reduction rate of 9%.

2.3 Quality of the predictions:

Given the short period of observed data, it is not possible to compare the models on the basis of their ability to predict past data. On the basis of data up to 2006, all models make identical predictions for the years 2007 to 2010.

4 Forecasts 2010 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2010 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.*

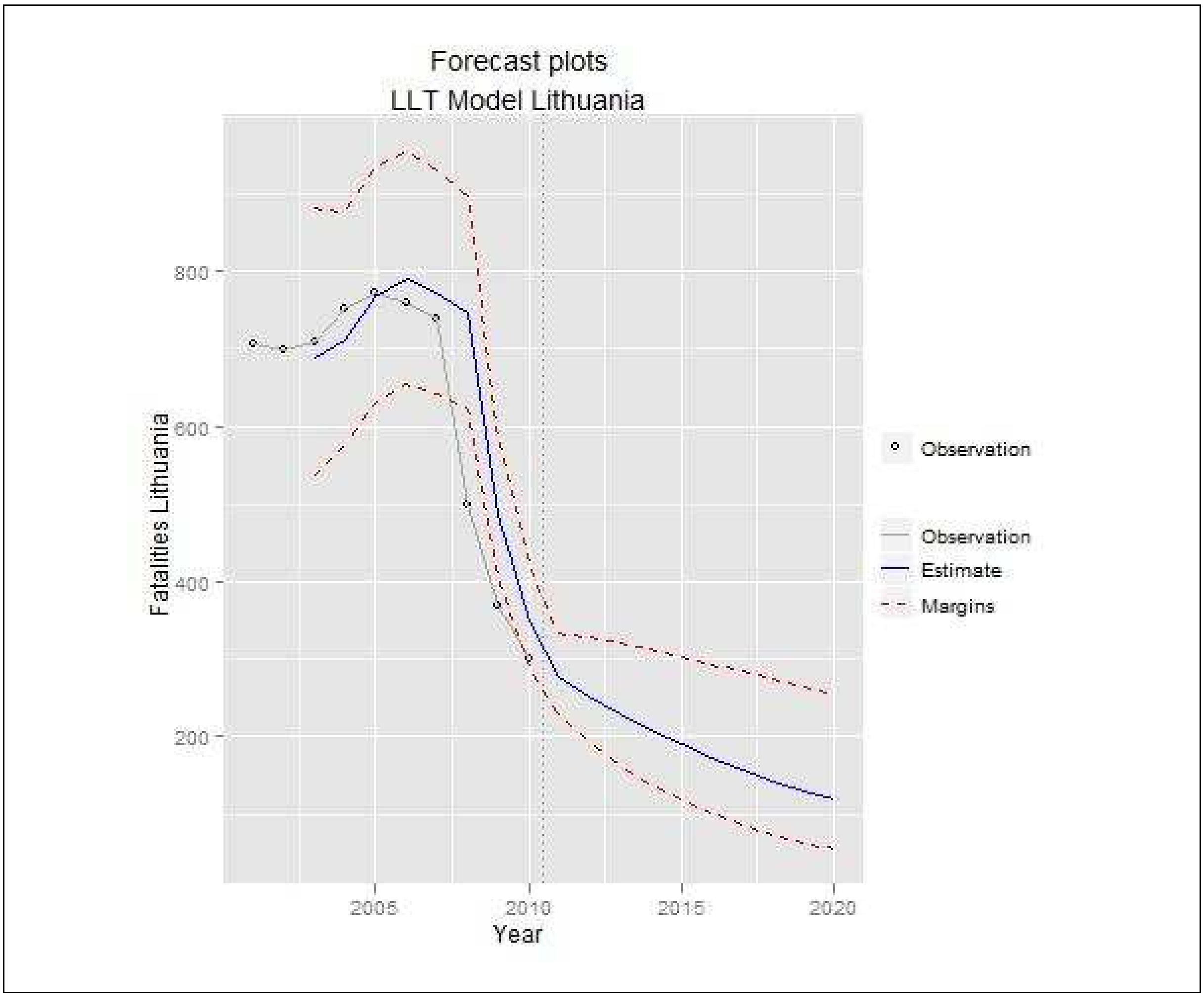


Figure 4: Plot of the annual fatality numbers for Lithuania forecasted between 2010 and 2020 on the basis of the LLT model with fixed slope (LLT5).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**277**	192	398
2012	**252**	149	426
2013	**229**	118	447
2014	**209**	94	463
2015	**190**	75	478
2016	**173**	61	492
2017	**157**	49	504
2018	**143**	40	516
2019	**130**	32	528
2020	**119**	26	539

Table 3.: Forecasts for Lithuania on the basis of the Latent Linear Trend Model with fixed slope (LLT5).

LUXEMBOURG

1 Raw data[15]

1.1 Exposure

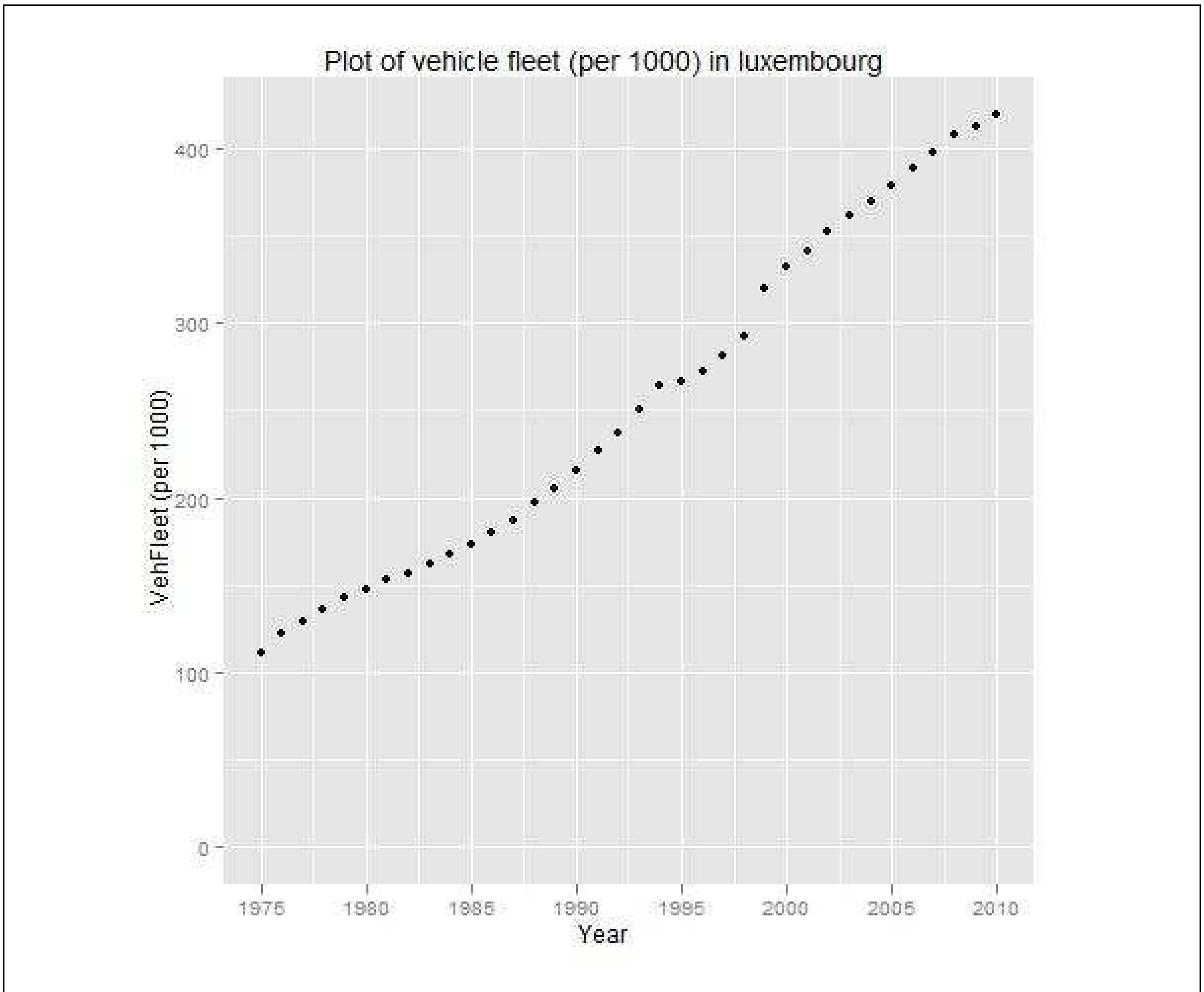


Figure 1: Plot of the annual numbers of vehicle (per thousand) in Luxemburg from 1975 to 2010.

[15] Source: M.J. Airoldi – STATEC/Unit « SOC1 » : Living conditions

Vehicle fleet data is available in Luxembourg since 1974 and up to 2011 included. However, given that the fatality series starts only in 1975 and ends in 2010, the fleet data for 1974 and 2011 will not be used in the present analysis.

Since 1975, the registration of the vehicle fleet is done by the tax administration (before, this registration was made by STATEC in collaboration with the “Société Nationale de Contrôle Technique”). Apart from some stagnation between 1994 and 1999, the fleet size has generally been increasing smoothly and regularly in Luxembourg. There is another noticeable exception to this general rule, however, as in 1999 the number of vehicles increased quite abruptly. This increase actually corresponds to a change in the registration method: Additional vehicle categories, among which mopeds and utilitarian vehicles, have been included in the calculation of the fleet totals in 1999.

The available register for vehicle fleet is known to be reliable, and to accurately reflect the number of cars registered in the country. However, the use of vehicle fleet as a reflection of road *mobility* in Luxembourg should be considered with caution. The numbers of cars circulating and the number of kilometres driven in Luxembourg does not only depend on the national vehicle fleet, but also, to a large extent, on foreign vehicles (international road transport, transit, passenger car traffic, etc.). Luxembourg has 0.5 million inhabitants, but also counts more than 150000 workers living in the surrounding countries (Belgium, France, and Germany). A large part of these foreign workers travel daily by car. There are consequently some a-priori reasons to question the fact that vehicle fleet consists of an adequate exposure indicator in the case of Luxembourg.

1.2 Fatalities:

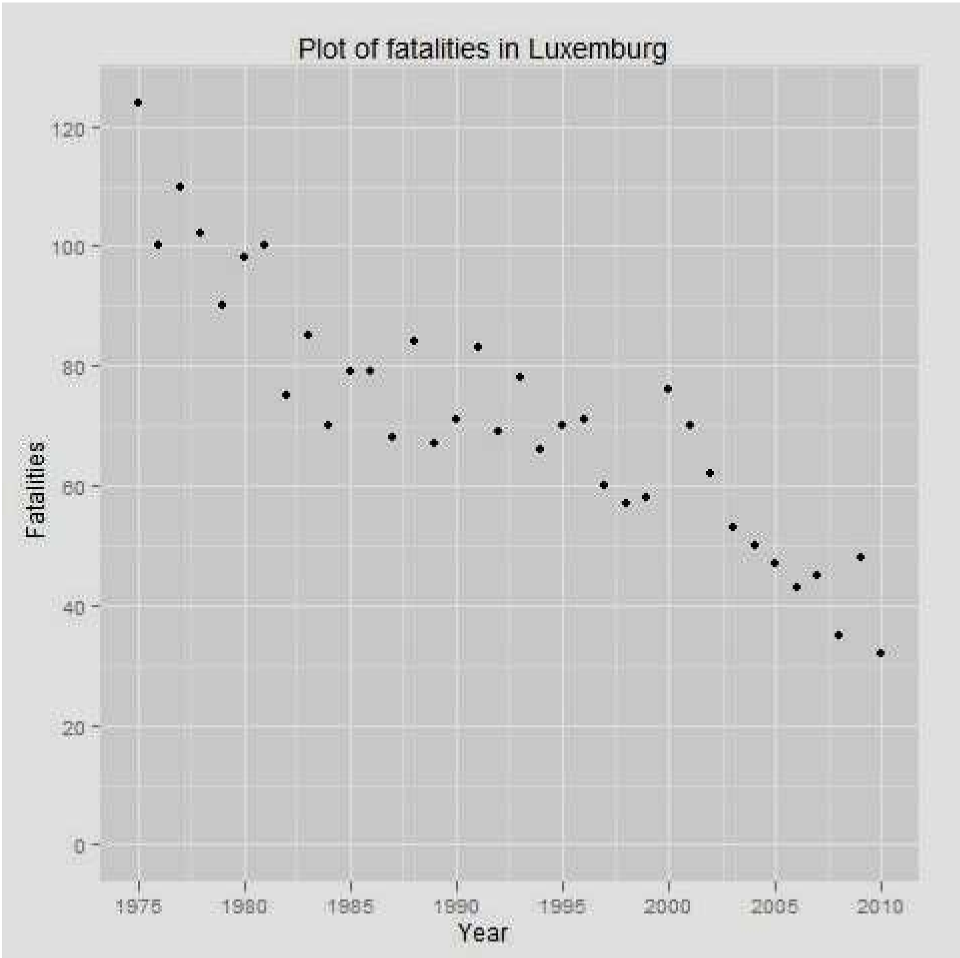


Figure 2: Plot of the annual fatality counts for Luxemburg from 1975 to 2010.

Annual fatality numbers are available in Luxembourg since 1975 onwards. According to the registration method, a fatality is defined as a death occurring within 30 days following an accident. Given that Luxembourg is a small country, the annual fatality numbers are also generally small. The low fatality numbers allow a complete registration of the fatalities in Luxembourg. But these low numbers are also characterized by important fluctuations. It is nevertheless obvious that annual fatality numbers have been decreasing steadily since 1975, although this decrease seems to have been stronger between 1975 and 1985 than in the years after.

2 The SUTSE Model:

2.1 Development of the state components:

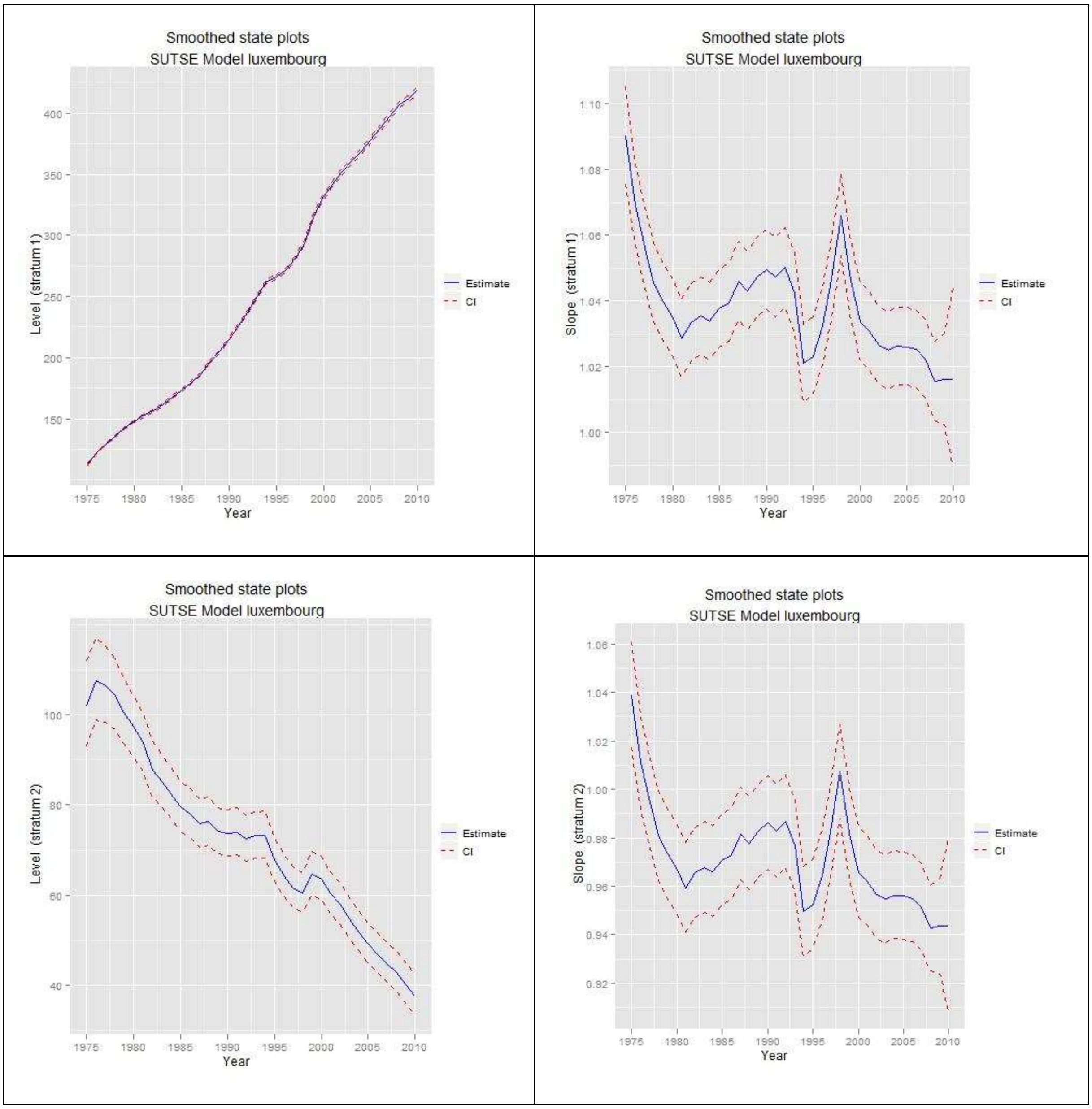


Figure 3: Luxembourg - Developments of the state components for the exposure (upper graphs) and the fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend for exposure started with a value of about 110 thousand vehicles in 1975 and grew steadily to attain 430 thousand vehicles in 2010.

The slope for exposure is the only state component to vary significantly over time. The slope values have been positive for the whole series but their values have decreased throughout the years (from a 9% increase in the number of vehicles from 1975 to 1976 to less than 2% from 2009 to 2010).

2.1.2 Fatalities

The trend value at the start of the series is estimated around 124 fatalities. It has decreased until 2010, where it is estimated around 35 fatalities.

The graph representing the evolution of the slope values over the years is almost identical to the one representing the slope development for the exposure (Figure 3). The slope values first rapidly decreased, then behaved erratically to start declining more consistently again from 2000 on.

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components:

The slope for exposure is the only state component to vary significantly over time. Given that all other components are deterministic, the correlations estimated between them can not be considered significant.

2.2.2 Correlation between the irregulars:

This correlation is equal to 0.69 and is not significant (p=0.41).

2.2.3 Estimation of the relationship by means of a coefficient:

The regression coefficient estimating the relationship between the two series equals 1.46 and is not significant (p = 0.14). This model does not fit the data better than a model in which this relation is allowed to vary over time ("SUTSE Luxembourg"), which means that the relationship between the fatalities and the number of vehicles in Luxembourg does not vary over time. Given the absence of evidence of a meaningful relation between the vehicle fleet and that of the annual fatality numbers, and given the reservations mentioned in Section 1, vehicle fleet will not be retained as a reliable exposure indicator for exposure in Luxembourg and no Latent Risk Model will be run for this country[16].

---

[16] Luxembourg proved difficult with respect to the question of the relatedness of the exposure and fatality series. We have worked with several different versions of the fleet register to come up with the present one, in which the most recently updated fleet data has been used. One version of the fleet data did - this deserves to be mentioned - yield the conclusion that the fleet and fatality data are significantly related. As a consequence, and for all certainty, we also ran several versions of an LRT model using vehicle fleet as exposure indicator. It appears clearly that the LRT does not improve the

Model title	***SUTSE Luxembourg***	***SUTSEbetaLuxembourg***
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	144.79	144.68
AIC	-289.07	-288.91
Hyperparameters		
Level exposure	4.45E-05 nsc	3.71E-05 ns
Level risk	9.56E-04 nsc	5.20E-04 ns
Slope exposure	1.36E-04 *c	1.48E-04 *
Slope risk	2.55E-04 nsc	7.58E-21 ns
Correlations		
level-level	1.00	
slope-slope	1.00	
Observation variances		
Observation variance exposure	1.66E-05 ns	1.66E-05 ns
Observation variance risk	8.61E-04 ns	6.83E-04 ns
Beta	/	1.46 (p = 0.14).

Table 1: Model criteria and results for SUTSE models- Luxembourg.

prediction of the observed annual fatality numbers. The LLT and LRT models also produce identical forecasts of the fatality numbers up to 2020. Finally, calculating alternative forecasts, based on different scenarios for the development of the vehicle fleet is associated to minor differences in the forecasted numbers, further confirming that vehicle fleet does not really contribute to the prediction of the fatality numbers. The choice to stick to the simpler LLT model is based on all these considerations.

3 The LLT Model:

3.1 Model selection:

The examination of the results of the SUTSE model suggests that the indicator chosen for exposure – vehicle fleet – is not correlated with the annual fatality numbers. As a consequence, we chose to limit our model for Luxembourg to the fatality series and to run a Local Linear Trend model. Given that the results of the full LLT model indicated that none of the two model components could be considered stochastic, we fixed the slope in a second version of the model. Although this yield no improvement in terms of the model fit (AIC, log-likelihood), the prediction of the observations for the last 10 years is considerably improved once the slope is fixed. This model is thus selected for the remaining of the analyses.

Model title	***LLT Lux.***	***LLT Lux.2***
Model description	LLT model for fatalities in Luxembourg	LLT model for fatalities with slope fixed
Model Criteria		
ME10 Fatalities	-12.01	-6.67
MSE10 Fatalities	228.88	104.22
Log-likelihood	35.82	35.56
AIC	-71.48	-71.02
Model Quality		
Box-Ljung test 1 Fatalities	0.64	1.02
Box-Ljung test 2 Fatalities	1.36	1.31
Box-Ljung test 3 Fatalities	2.79	1.60
Heteroscedasticity Test Fatalities	1.39	1.41
Normality Test standard Residuals Fatalities	2.10	1.17
Normality Test output Aux Res Fatalities	2.09	1.46
Normality Test State Aux Res Level fatalities	0.32	0.52
Normality Test State Aux Res Slope fatalities	0.30	0.33
Variance of state components		
Level risk	1.97E-18 ns	1.62E-03 *
Slope risk	9.50E-05 ns	-
Observation variance		
Observation variance risk	1.00E-09 ns	1.06E-03 ns

Table 2: Overview of the results for the LLT models - Luxembourg.

3.2Development of the state components:

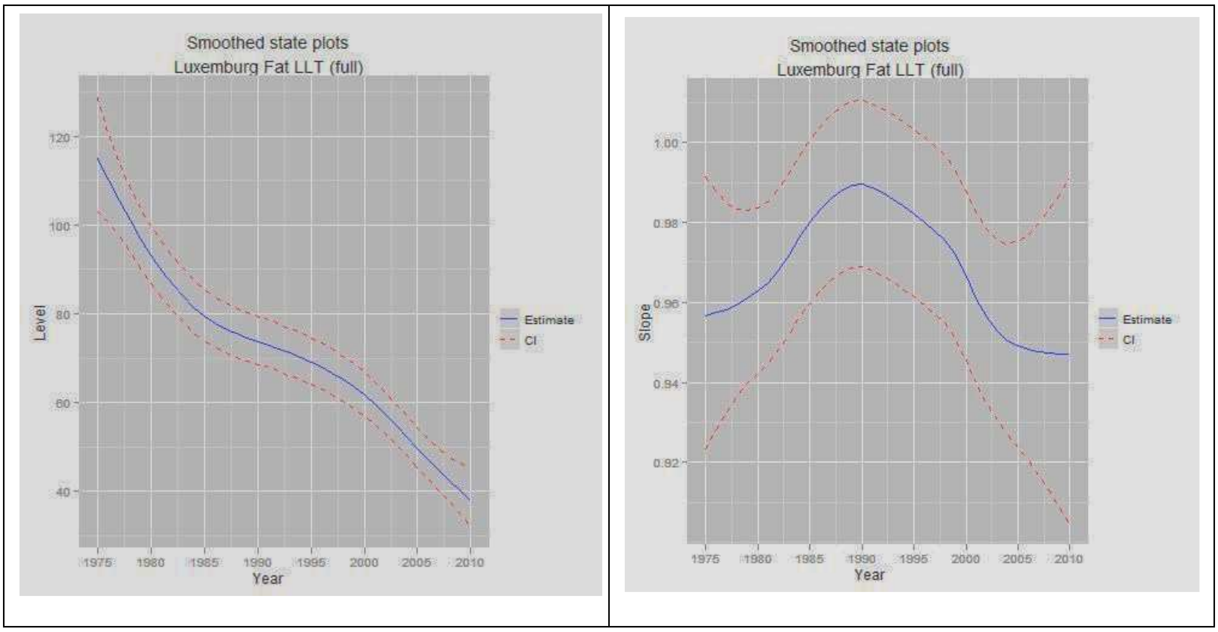


Figure 4: Luxembourg - Developments of the state components for the fatalities, as estimated on the basis of the full Local Linear Trend model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Fatalities

The trend started around 117 fatalities in 1975 to attain 40 fatalities in 2010. The number of fatalities is thus about 3,5 times lower in 2010 than in 1975.

The slope value is now estimated to vary between 0.95 and 0.99 throughout the series. When the slope is fixed its value is estimated at 0.97, which means a fixed decrease of about 3% from one year to the other between 1975 and 2010.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. This allows comparing the actual and the forecasted values. Figure 5 below shows a plot of the predicted and observed values for the whole series. The predictions of the last ten years of the series are based on past observations only, and hence allow evaluating how well the structure of the series, as it is modelled, accounts for the actual observations. Inspection of Figure 5 reveals that – whatever the slope is fixed or not – information from past observations does not allow the model to predict the drop in the fatality numbers that occurred in 2003. From this year on, all observations fall beyond the lowest boundary of the confidence interval surrounding the predictions. Fixing the slope, however, improves the predictive quality of the model: the overestimation of the post-2003 observations is reduced.

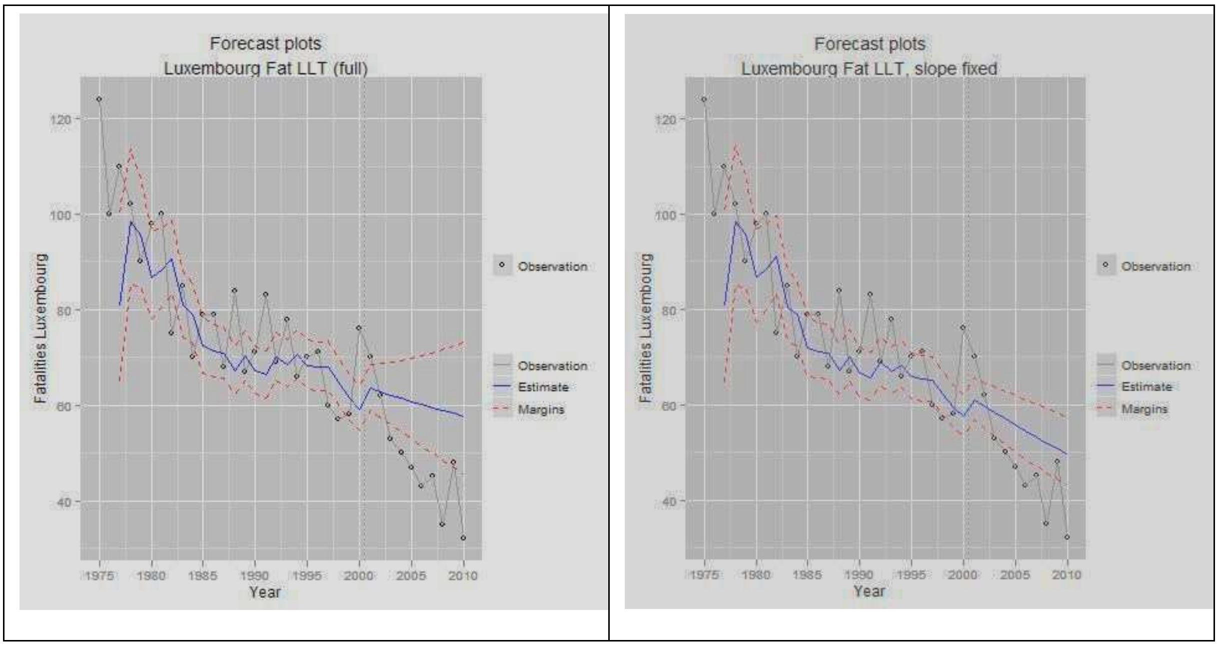


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Luxembourg for the full LLT model (left-hand graph) and the LLT model with fixed risk slope.

4 Forecasts 2010 – 2020:

The forecasts obtained from the model provide an indication of the vehicle kilometres and fatality numbers to be expected between 2008 and 2020 *provided that, throughout these years, the trend keeps on following the developments that it has shown in the past.*

Under this assumption, the LLT model with fixed slope would predict the annual fatality number to come down to 30 in 2020. One should bear in mind, however, (1) that we have not been able to take the evolution of the mobility into account, and (2) that we have indications that the predictive quality of the model is limited, as indicated by the wideness of the confidence interval around this forecast (lower bound: 21 fatalities and upper bound 42 fatalities for 2020).

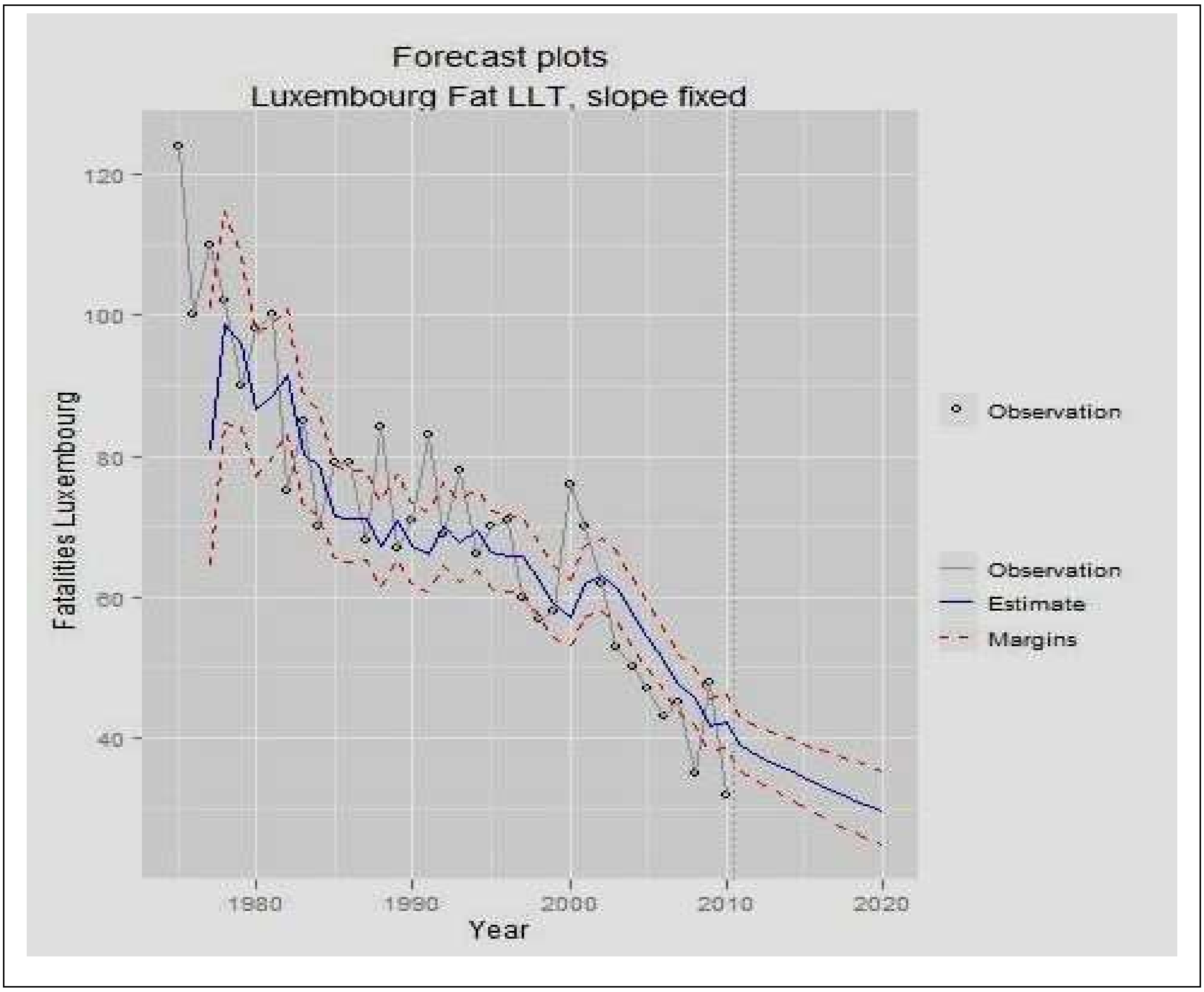


Figure 6: Plot of the annual fatality numbers forecasted between 2010 and 2020 for Luxembourg on the basis of the LLT model with fixed slope.

Still assuming that past developments will extend into the future, the fatality numbers for Luxembourg should keep on decreasing after 2010. The predicted value for 2020 is 30 fatalities. Table 3 provides the details of the values 2010 up to 2020.

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**39**	32	46
2012	**38**	31	46
2013	**37**	29	46
2014	**35**	28	45
2015	**34**	26	45
2016	**33**	25	44
2017	**32**	24	44
2018	**31**	23	43
2019	**31**	22	43
2020	**30**	21	42

Table 3: Forecasts of the Local Linear Trend model (LLT Lux2).

MALTA

1. Raw data

1.1 Exposure

Annual vehicle kilometres and vehicle fleet data are not available for Malta, although population data is available and is plotted in figure 1. There is a large jump in the series from 1994 to 1995.

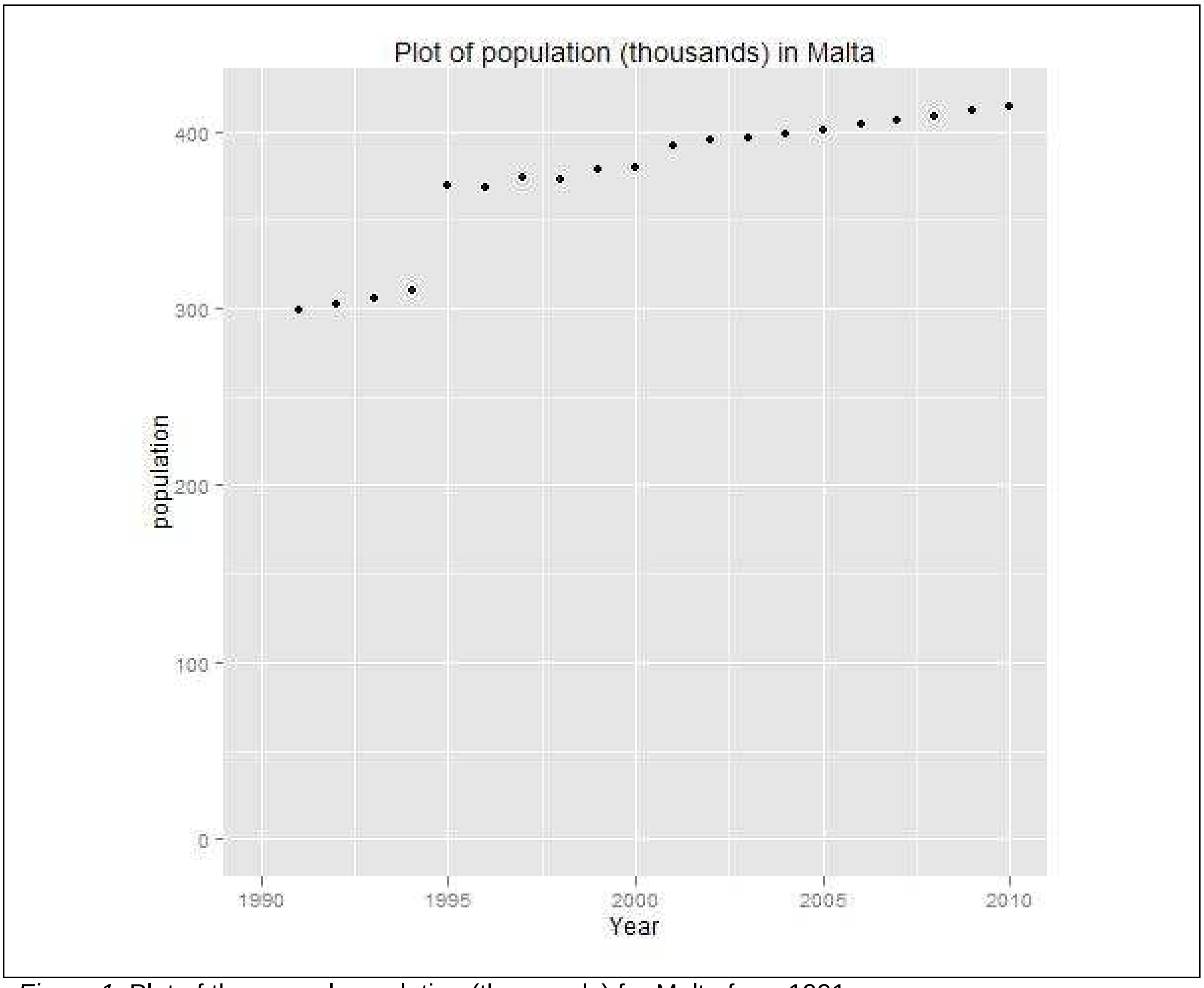


Figure 1: Plot of the annual population (thousands) for Malta from 1991.

1.2 Fatalities:

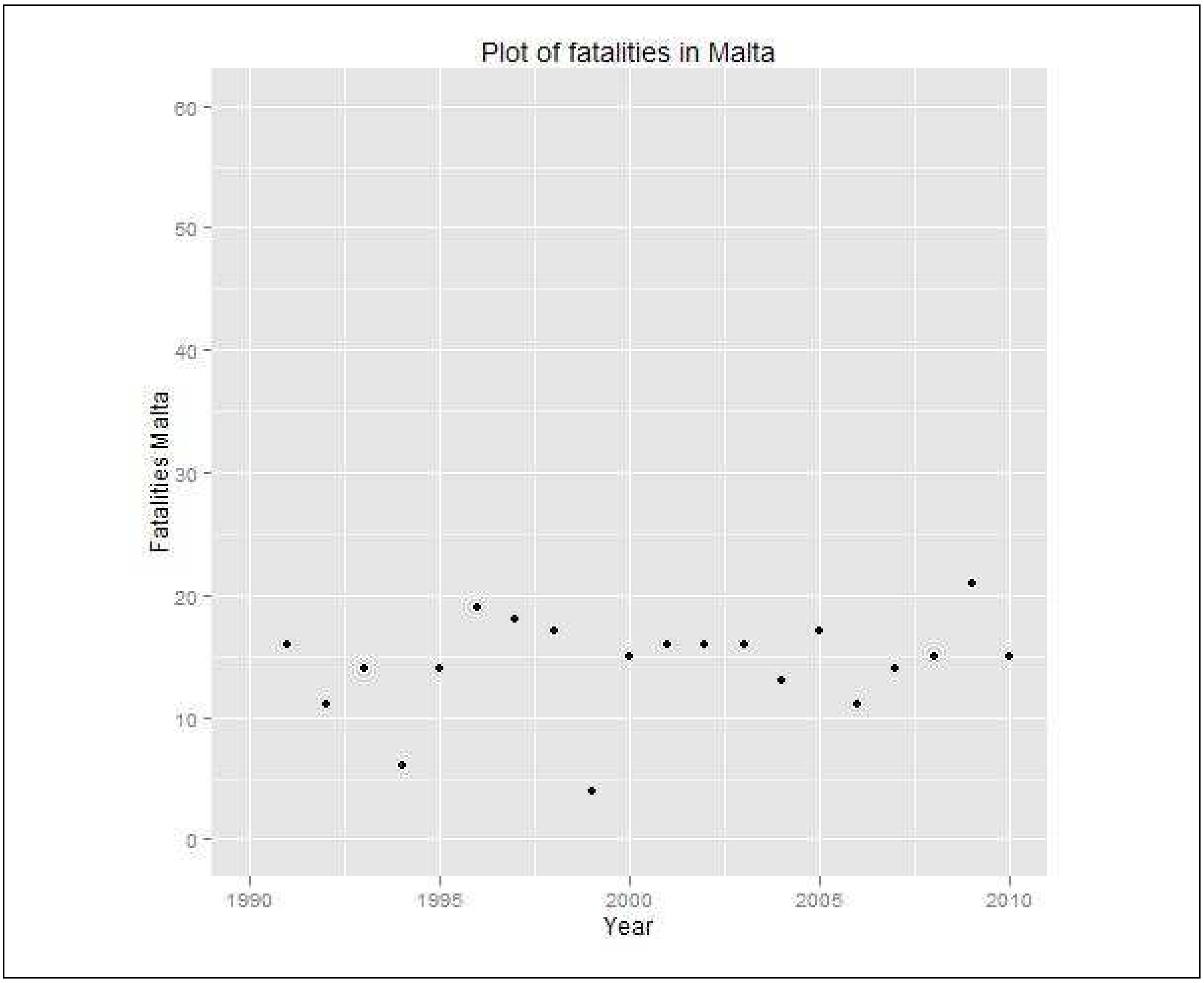


Figure 2: Plot of the annual fatality counts for Malta from 1991.

The raw series for the fatalities is shown in figure 2. The data is fairly flat and displays the variation expected with small numbers.

2 The LLT Model:

2.1 Model selection:

There is no exposure data that can be usefully used in the Latent Risk Model. Therefore a simple Local Linear Trend model was used to model the fatalities with a fixed level and fixed slope.

Model title	***LLT1***	***LLT 2***
Model description	LLT model for Malta	LLT fixed level and fixed slope
Model Criteria		
ME7Fatalities		0.22
MSE7Fatalities		7.84
Log-likelihood	-10.58	-10.58
AIC	21.46	21.26
Model Quality		
Box-Ljung test 1 Fatalities	2.16	0.11
Box-Ljung test 2 Fatalities	3.00	0.48
Box-Ljung test 3 Fatalities	5.73	2.16
Heteroscedasticity Test Fatalities	0.10*	0.10*
Normality Test standard Residuals Fatalities	17.2***	17.2***
Normality Test output Aux Res Fatalities	21.4***	21.4***
Normality Test State Aux Res Level fatalities	1.66	1.66
Normality Test State Aux Res Slope fatalities	0.00	0.00
Variance of state components		
Level fatalities	2.65E-18 ns	-
Slope fatalities	3.41E-19 ns	-
Observation variance		
Observation variance fatalities	0.15 *	0.15*
Interventions		

Table 2: Overview of the results for the LLT model.

2.2 Development of the state components:

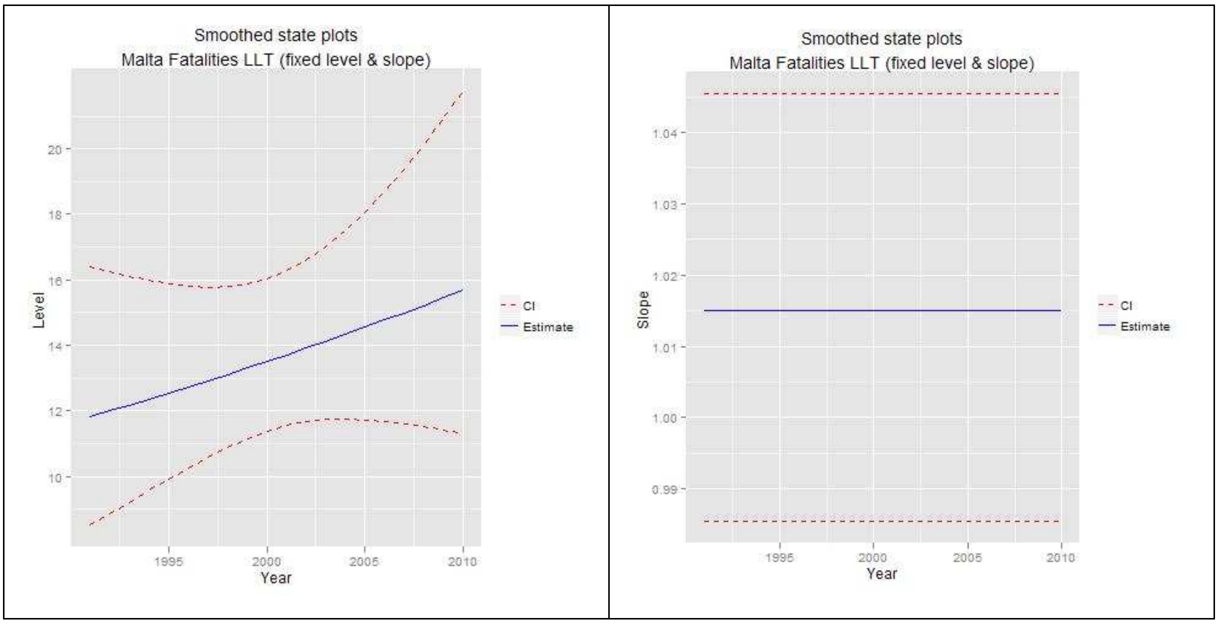


Figure 3: Developments of the state components for the fatality series, estimated using the LLT model (with fixed level and fixed slope). The trend (level) developments are represented in the left-hand graph, the slope developments in the right-hand graph.

The trend for fatalities has a fixed level and slope. The slope corresponds to a general annual increase of 1.5%.

2.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2004 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series.

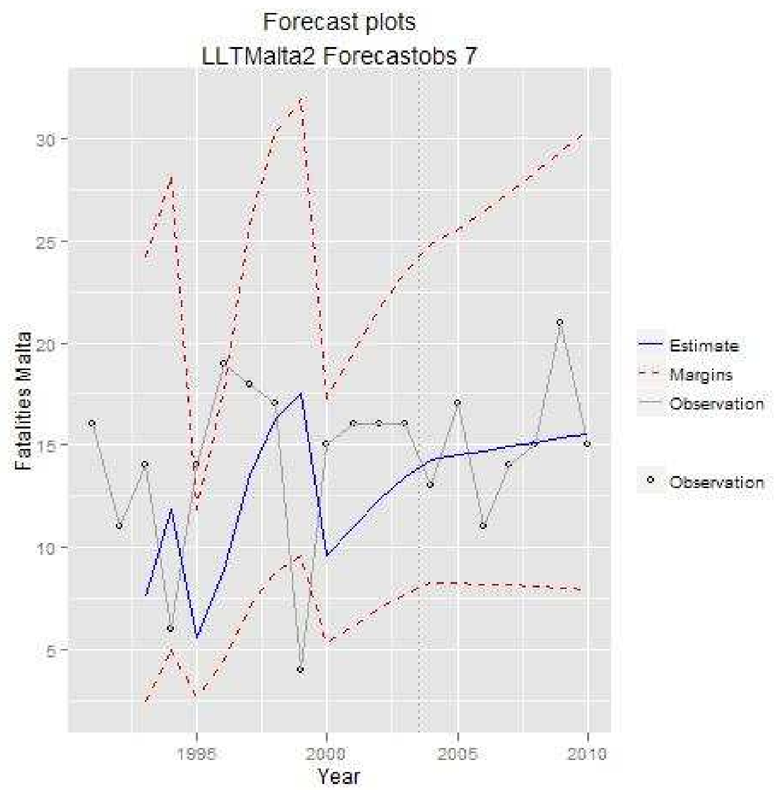


Figure 4: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Malta for the LLT model with fixed level and slope.

3 Forecasts 2011 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.* Under this assumption, the annual number of fatalities is predicted to be.

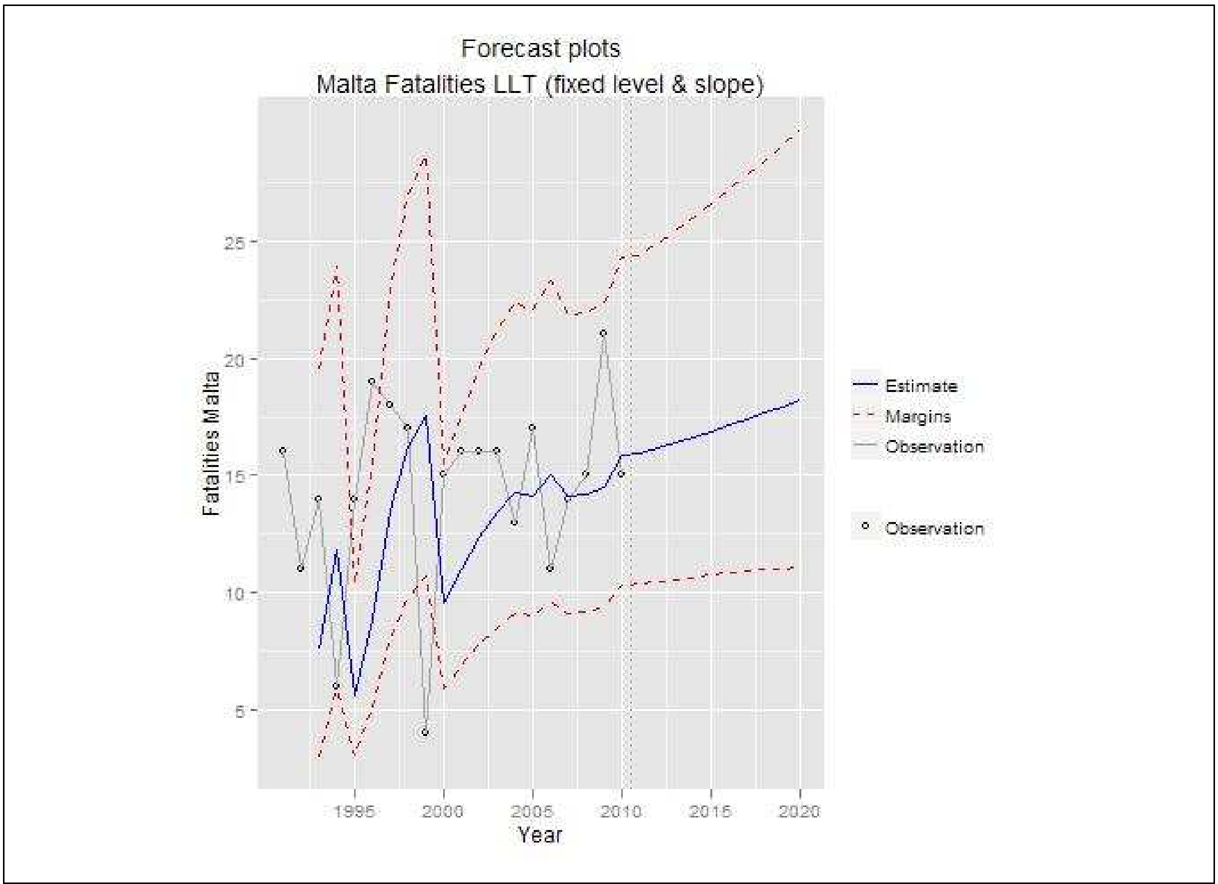

Forecast plots
Malta Fatalities LLT (fixed level & slope)
Fatalities Malta
Year
5
10
15
20
25
1995
2000
2005
2010
2015
2020
Estimate
Margins
Observation
Observation

Figure 5: Plot of the annual fatality numbers for Malta forecasted between 2011 and 2020 (LLT with fixed level and slope.

	Predicted fatalities		
Year	Predicted	Confidence Interval	
2011	**16**	7	37
2012	**16**	7	38
2013	**16**	7	39
2014	**17**	7	40
2015	**17**	7	41
2016	**17**	7	42
2017	**17**	7	44
2018	**18**	7	45
2019	**18**	7	47
2020	**18**	7	48

Table 3: Forecasts of the LLT with fixed level and slope.

THE NETHERLANDS

1 Raw data

1.1 Exposure

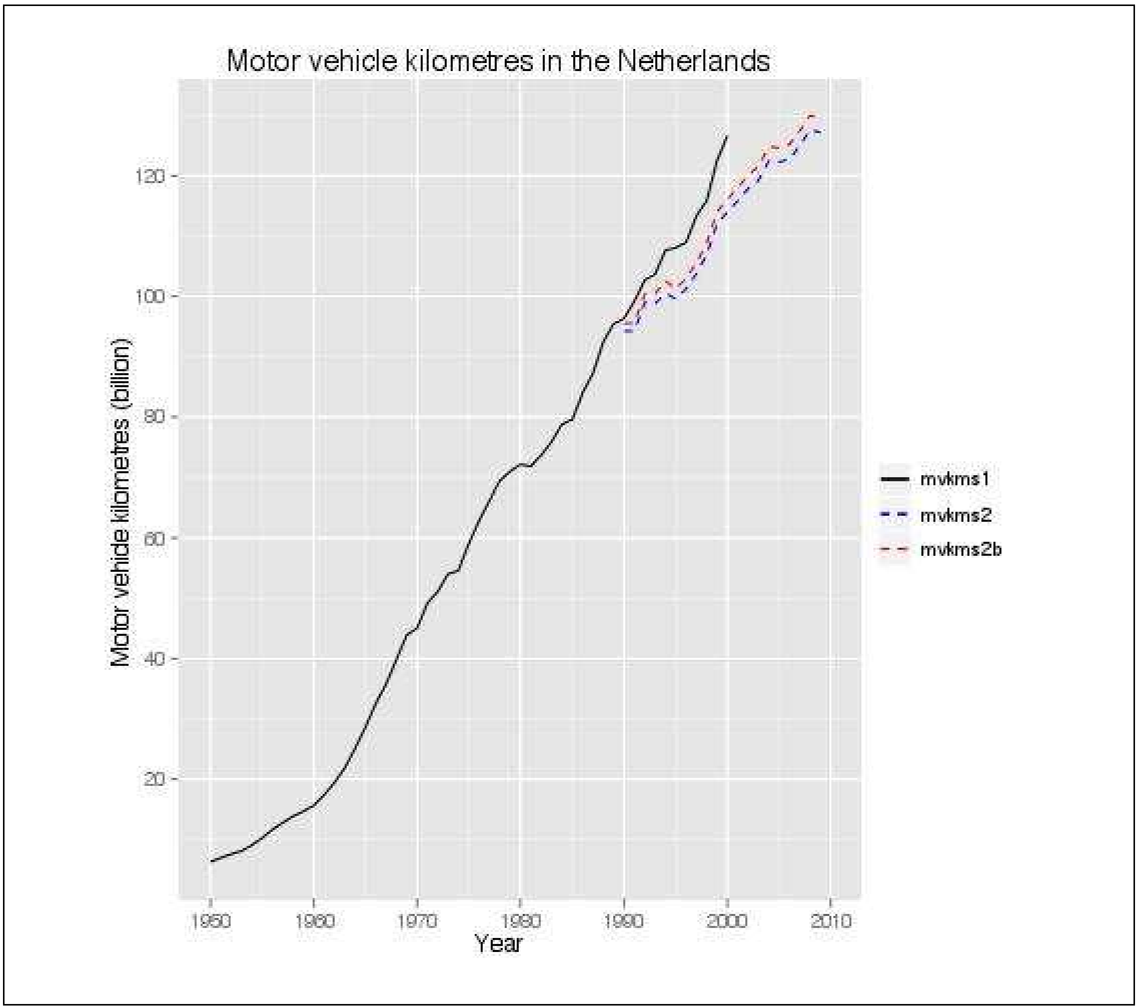


Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for In the Netherlands from 1950 to 2009. Three series are plotted: 1) "mvkms1" the 'original' series. This series is discontinued in 2000. 2) "mvkms2" The new series based, starting in 1990, which excludes "special" vehicles and motorcycles. 3) "mvkms2b" is "mvkms2" augmented with an estimate of traffic volume by motorcycles and special vehicles.

Annual vehicle kilometres are available for the Netherlands from 1950 to 2009. The original series was halted after 2000 when it became clear that certain assumptions were no longer met. To replace that series, a new approach was developed (in part) based on odometer readings taken from a large sample of vehicles under mandatory inspection, in addition to (amongst others) survey information regarding foreign vehicles. It is noted that this series is smoothed, in part due to the averaging effect of the odometer readings.

In modeling, the traffic volume data is treated as two separate series measuring exposure. One series (the old) started in 1950 and ended in 1989, the other starts in 1990. It is foreseen that a break in the measurement of traffic volume may occur.

1.2 Fatalities:

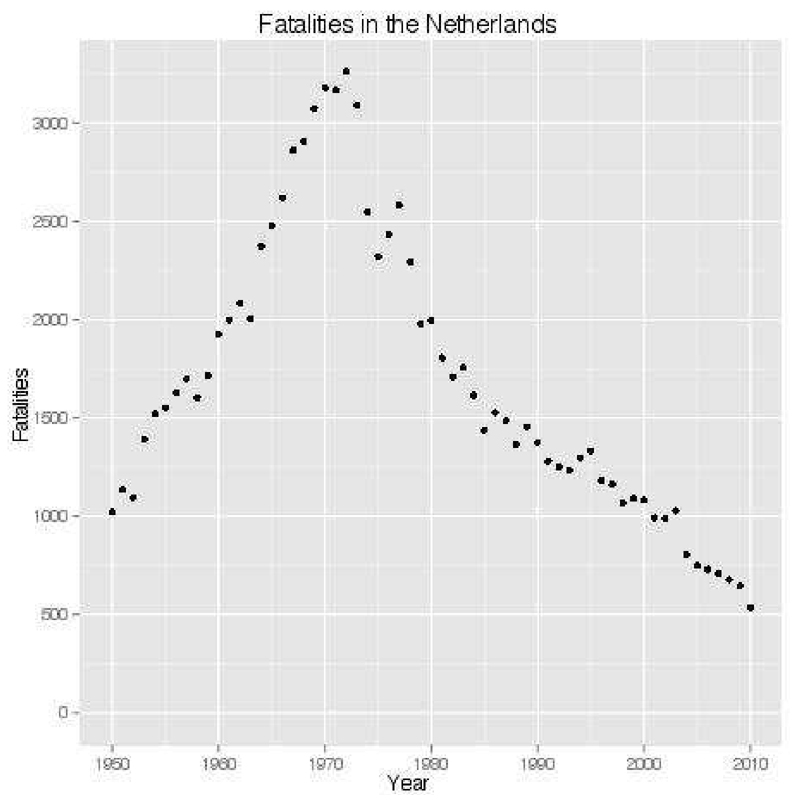


Figure 2 : Plot of the annual police-registered fatality counts for the Netherlands from 1950 to 2010.

The raw series for the fatalities starts increasing until the early 1970's, with a peak in 1972. After that, it more or less continuously decreased up to 2010. The number of fatalities observed at the peak of the series (3264) is 6 times the value observed at the end of the series (537). One can note that the year-to-year variation of the fatality counts larger than that of the vehicle kilometres, although this does not appear to be the case in the last few years.

2 The SUTSE Model:

2.1 Development of the state components:

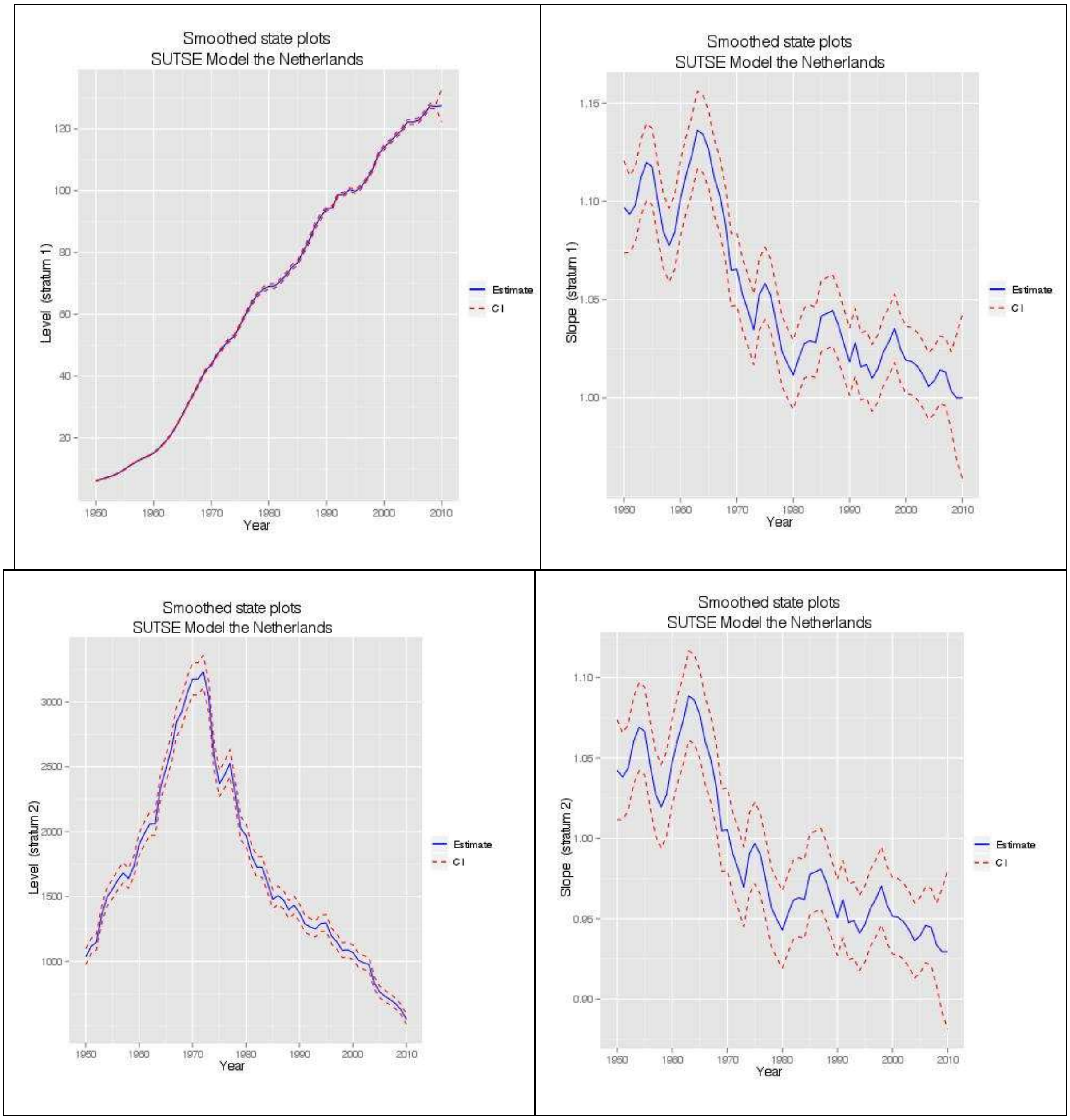


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs. Please note the similarity between the slope components.

2.1.1 Exposure

The trend for exposure is estimated around 6.3 billion kilometres at the start of the series and around 127 billion kilometres at the end. The trend increases smoothly, were some effect of (probably) economic developments may be visible.

The various values taken by the slope over the series are plotted in the upper right part of Figure 1. Each slope value indicates the percent change in the vehicle kilometres that took place from one year to the other. All these values exceed 1, which means that the number of vehicle kilometres has systematically increased from one year to the other. The “size” of these annual increases, however, varies over the years: It became smaller between 1970 and 1980, and appears to have dropped to (almost) zero near the end of the series.

For exposure, the slope component is the only one to change significantly over time.

2.1.2 Fatalities

Just as the raw fatality series, the trend peaks around 1972 to exceed 3000 fatalities. From then on, it steadily decreases (although with some ups and downs). The trend value at the end of the series is about 550. Overall, the inspection of the trend for the fatalities leads to very similar conclusions than that of the raw series.

The graphs for the state developments presented in Figure 1 also reveal that the development of the slope for the fatalities resembles much that of exposure. The later (largest) part of the slope values are smaller than 1, which indicates a decrease of the annual fatality numbers over most the series. There are visible ups and downs in the values taken by the slope over the series. The development of the slope stabilized clearly in the period from 1970 to 1980 - indicating that the decrease in the fatality counts became stronger over the years until about 1980 – then the decrease stabilized after 1980. The decrease between the fatality numbers observed from 2000 to 2010 is 50.

The variance of the slope values (more precise, its disturbances) over the years appears significant. There is no evidence of a significant variance for the trend (level) state component of the exposure series. Correlation between the slope disturbances is significant too, and the slope components appear to be common.

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components:

The disturbances of the exposure and fatality slope and that of the fatality level can be considered stochastic. The correlation between the slope components of the fatalities and exposure is significant as well. In fact there is no evidence against a hypothesis that the disturbances of both slope components are common.

2.2.2 Correlation between the irregulars:

The exposure series is split in 1999. Consequently, the correlation with the irregular for the fatalities is estimated separately for each part of the exposure series. None of these correlations are significant, but the small number of observations on which these tests are based raises doubts about their power and reliability.

2.2.3 Estimation of the relationship by means of a coefficient:

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). The beta coefficient for the relationship between the latent developments of the two series is equal to 1.18199 and is significant (p=0.00478046) at a reasonable level. As a consequence, the two series are assumed to be related.

Description	*SUTSE Model the Netherlands*	*SUTSE beta Model the Netherlands*
Model criteria		
log likelihood	***283.884***	***283.565***
AIC	***-567.342***	***-566.738***
Hyper parameters		
Dynamic variance		
Level exposure	***1.67E-04 nsc***	***2.00E-05 ns***
Level fatalities	***3.15E-03 *c***	***3.44E-03 ****
Slope exposure	***1.86E-04 *c***	***2.51E-04 ****
Slope fatalities	***2.86E-04 *c***	***4.73E-21 ns***
Transition Correlations		
Level exposure with level fatalities	***-0.12***	
Slope exposure with slope fatalities	***1***	
Observation variances		
Observation variance mv. kms	***1.28E-05 ns***	***4.83E-05 ns***
Observation variance fatalities	***1.92E-04 ns***	***1.21E-04 ns***
Observation variance old mv. kms	***4.56E-05 ns***	***8.49E-05 ****

Table 1: Model criteria and results for SUTSE models- the Netherlands

3 The LRT Model:

3.1 Model selection:

Given that some evidence of a relationship between the development of traffic volume and the development of the number of fatalities in the Netherlands could be established, traffic volume data can be included in the model for the Netherlands. After fitting a basic LRT model (also visible in the SUTSE model) a few potential structural breaks appear in the development of the level and slope of traffic volume and the level of risk. Unfortunately some evidence appears for potential structural breaks in the level of the risk near the end of the series. Because of that the last few observations need not be predictable without assumptions regarding these breaks. This fact rules out the natural usefulness of in-sample forecasts that include the period in which these breaks may appear. Therefore such tests are omitted.

The structural breaks considered included an intervention in the level of level exposure in 1974, at the same time an intervention in the level of the risk in 1974, and two more in 1994 and 2004. One exposure datum appeared an outlier, and one fatality count appeared likewise, but no explanation for these outliers was found.

Index	LRT1	LRT7	LRT9	LRT11
Model name	Latent risk model	Latent risk model	Latent risk model	Latent risk model
log likelihood	283.884	226.04	225.241	223.76
AIC	-567.342	-451.599	-450.149	-447.298
Model Quality				
Box-Ljung test 1 Veh.kms	3.00601	2.0424	1.92947	1.99597
Box-Ljung test 2 Veh.kms	3.04228	2.04826	2.67664	2.82345
Box-Ljung test 3 Veh.kms	3.75437	2.43228	2.67856	2.82349
Box-Ljung test 1 Fatalities	3.92712*	2.85887	2.98409	1.59755
Box-Ljung test 2 Fatalities	3.95256	2.97444	3.14424	1.82673
Box-Ljung test 3 Fatalities	4.39384	3.08585	3.3145	2.82788
Box-Ljung test 1 oldmvkms	3.11804	2.02954	0.412617	0.463981
Box-Ljung test 2 oldmvkms	3.259	2.11694	1.8815	1.98606
Box-Ljung test 3 oldmvkms	6.43862	3.21977	1.95026	2.10919
Heteroscedasticity Test Veh.kms	0.1167*	0.20448	0.203151	0.223219
Heteroscedasticity Test Fatalities	0.846473	0.594382	0.503357	0.496647
Heteroscedasticity Test oldmvkms	0.532012	1.14886	1.10196	1.06773
Normality stand. Res. Veh.kms	0.400089	0.588366	0.609572	0.690499
Normality stand. Res. Fatalities	0.58195	3.16454	2.70916	0.744138
Normality stand. Res. oldmvkms	0.561413	0.44972	0.500634	0.555026
Normality output Aux Res Veh.kms	0.150973	0.0219382	0.0188859	0.00726174
Normality output Aux Res Fatalities	0.600313	0.348825	0.797861	0.340461
Normality output Aux Res oldmvkms	3.41259	0.563093	0.562621	0.877815
Normality Aux Res Level exposure	2.03295	0.528326	0.561102	1.1397
Normality Res Slope exposure	1.40504	1.24097	0.881351	0.880689
Normality Aux Res Level risk	2.14801	4.45214	2.50202	0.313899
Normality Aux Res Slope risk	0.173098	0.41184	0.254737	0.298953

Index	LRT1	LRT7	LRT9	LRT11
Model name	Latent risk model	Latent risk model	Latent risk model	Latent risk model
Model Q-matrix tests				
Level exposure	1.67E-04 nsc	5.54E-05 nsc	-	-
Level risk	3.50E-03 *c	6.72E-04 nsc	8.82E-04 *	9.03E-04 *
Slope exposure	1.86E-04 *c	2.06E-04 *c	2.29E-04 *	2.27E-04 *
Slope risk	1.06E-05 nsc	4.23E-06 nsc	-	-
Transition Correlations				
Level exposure with Level risk	-0.34	-1		
Slope exposure with Slope risk	1	1		
Model H-matrix tests				
Veh.kms (billions) the Netherlands	1.28E-05 ns	3.97E-05 ns	5.21E-05 *	5.37E-05 *
Fatalities the Netherlands	1.92E-04 ns	9.23E-04 *	7.03E-04 ns	6.08E-04 ns
oldmvkms	4.56E-05 ns	1.39E-05 ns	3.02E-05 *	3.06E-05 *
Intervention and explanatory variables tests				
Intercept (oldmvkms) against nil	-0.0415207 *	-0.0450991 *	-0.0458697 *	-0.0449927 *
(Intervention level exposure in 1974)		-0.0478223 *	-0.0455646 *	-0.0483211 *
(Intervention level risk in 1974)		-0.196919 *	-0.193085 *	-0.189787 *
(Intervention level risk in 1994)		0.157198 *	0.145805 *	0.143351 *
(Intervention level risk in 2004)		-0.127332 *	-0.149038 *	-0.154266 *

3.2 Development of the state components:

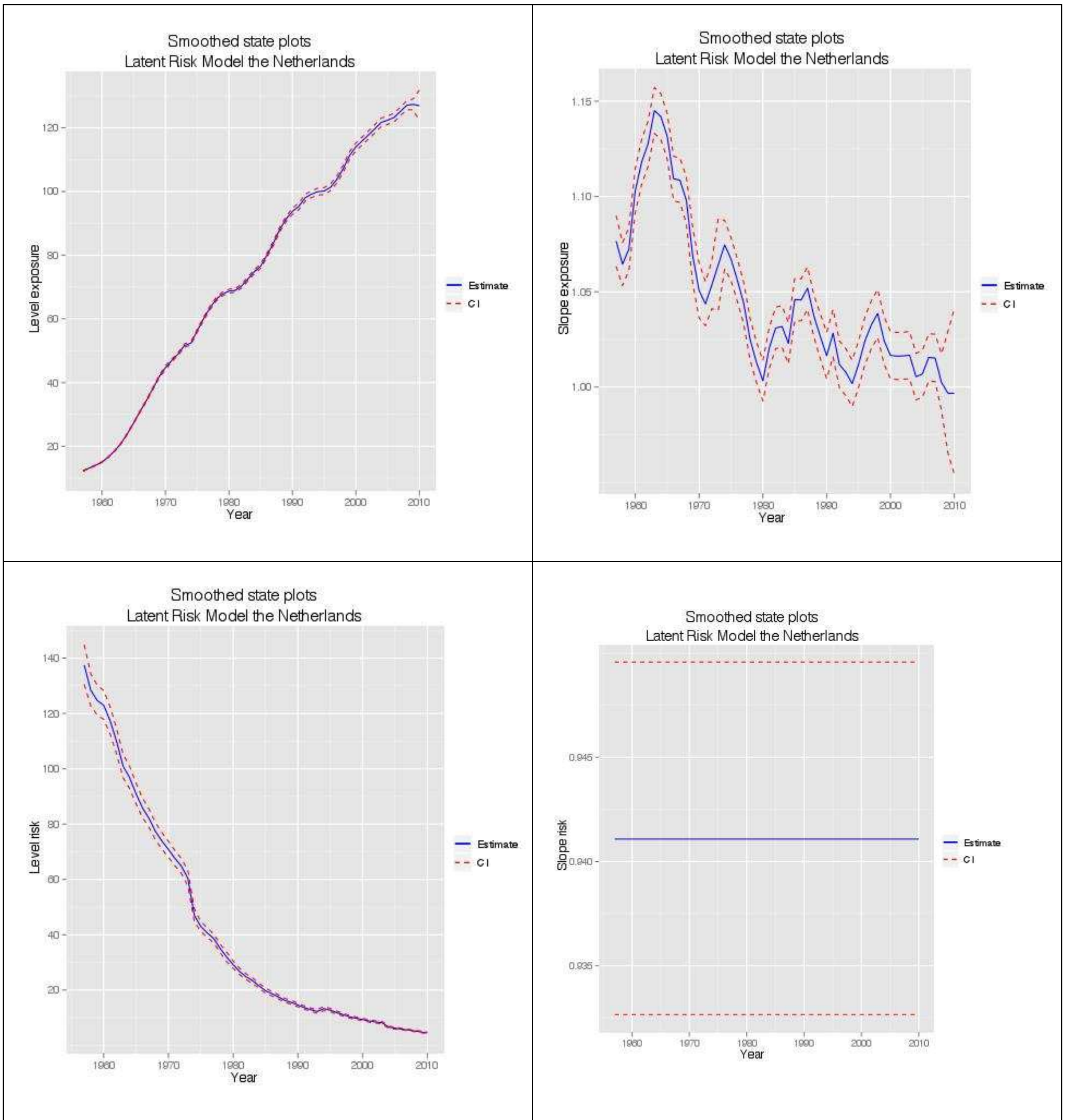


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the right-hand graphs, the slope developments in the left-hand graphs.

3.2.1 Exposure:

Only the slope component varies significantly over time for the exposure series.

The various values taken by the slope over the series are plotted in the upper right part of Figure 4. Each slope value indicates the percent change in the vehicle kilometres that has taken place from one year to the other.

Almost all these values exceed 1, which means that the number of vehicle kilometres has almost systematically increased from one year to the other. The “size” of these annual increases, however, obviously varies over the years: It became smaller between 1960 and 1980, and then stabilized.

The trend (level) for exposure is estimated around 30 billion kilometres at the start of the series and around 127 billion kilometres at the end. The trend increases smoothly.

3.2.2 Risk:

Contrary to the exposure series, the trend for risk varies significantly over time, while the slope does not.

The trend for the risk (i.e., the fatalities per billion vehicle kilometres) does not show the sharp increase that was visible at the start of the raw fatality series. This means that, while the fatality numbers were increasing over the first three years of the series, the *risk* was not. The increase in the fatality numbers was probably due to the increase of the vehicle kilometres. The fact that the fatalities started decreasing in 1973 despite that exposure continued to increase afterwards implies in turn that 1973 is the point where the risk decreased sufficiently to compensate for the increase in exposure.

The plot of the slope values over the years is flat: The slope values do not differ from each other, and correspond to a general annual decrease of the risk of about 5 – 6%. This is in agreement with the fact that the risk slope disturbances are not significant.

3.3 Quality of the predictions

This part has been omitted from the analysis.

4 Forecasts 2011 – 2020:

The forecasts obtained from the model provide an indication of the vehicle kilometres and fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.* Under this assumption, the annual number of vehicle kilometres should stay roughly the same, which is not very plausible, but of course not impossible. Although it is likely that traffic volume will start to rise in the future, it is not clear when it will start to rise.

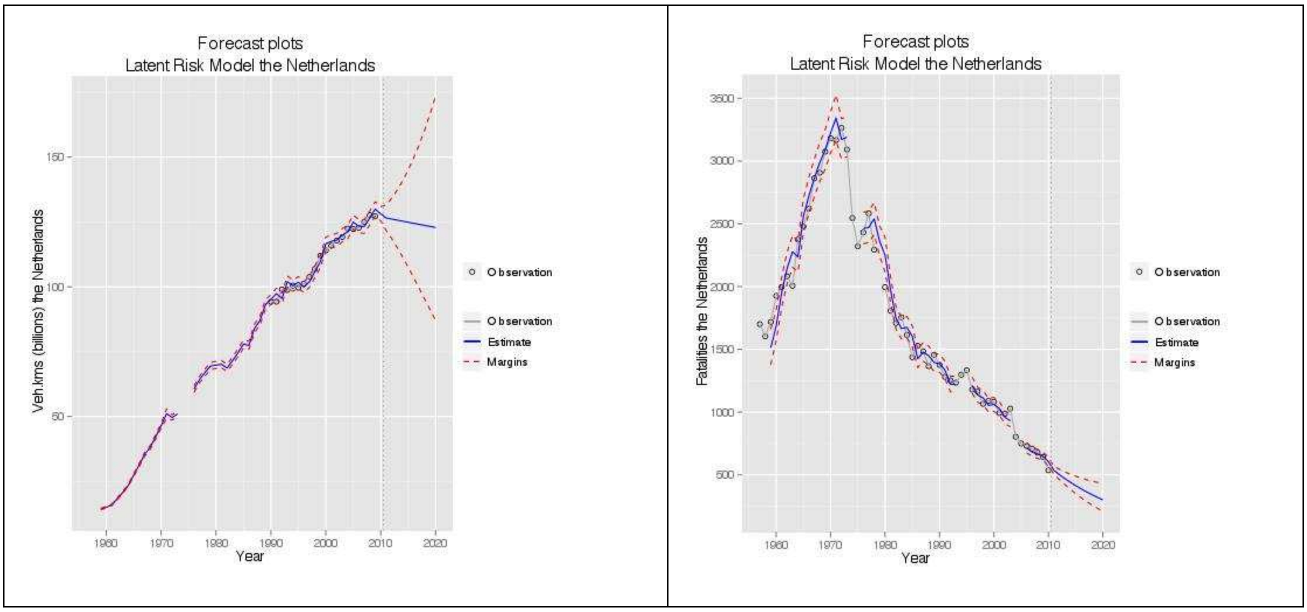


Figure 6: Plot of the vehicle kilometres (left-hand graph) and annual fatality numbers (right-hand graph) for the Netherlands forecasted between 2011 and 2020 (model 9).

Still assuming that past developments will extend into the future, the fatality numbers for the Netherlands should keep on decreasing after 2010. The predicted value for 2020 is 378 fatalities. Table 3 provides the details of the values forecasted for exposure and fatalities for all years from 2009 up to 2020.

	Vehicle kilometres (billion)			Fatalities		
Year	Predicted	Confidence interval		Predicted	Confidence interval	
2011	126.53	117.22	136.58	535.81	476.45	602.57
2012	126.12	111.72	142.37	502.60	428.59	589.39
2013	125.71	105.74	149.45	471.44	382.71	580.74
2014	125.30	99.46	157.84	442.22	339.52	575.97
2015	124.89	93.05	167.61	414.80	299.45	574.60
2016	124.48	86.62	178.89	389.09	262.70	576.29
2017	124.07	80.26	191.81	364.97	229.34	580.82
2018	123.67	74.04	206.56	342.34	199.30	588.06
2019	123.27	68.03	223.37	321.12	172.46	597.95

2020	122.87	62.25	242.49	301.22	148.63	610.47

Table 3: Forecasts of the Latent Risk Model (model 11)

5 Mobility Scenarios

Have not been considered.

NORWAY

1 Raw data

1.1 Exposure

The selected exposure measure is the vehicle kilometres (in billions) per annum (see Figure 1), which are considered from 1973 onwards. The latest available year is 2009. The data show a trend that is in general increasing linearly, with two slow-downs around 1980 and 1990 (and a higher increase in-between). These changes may be attributed to changes in the financial situation in Norway, but no concrete events could be identified that could be considered as discrete shocks to the time-series.

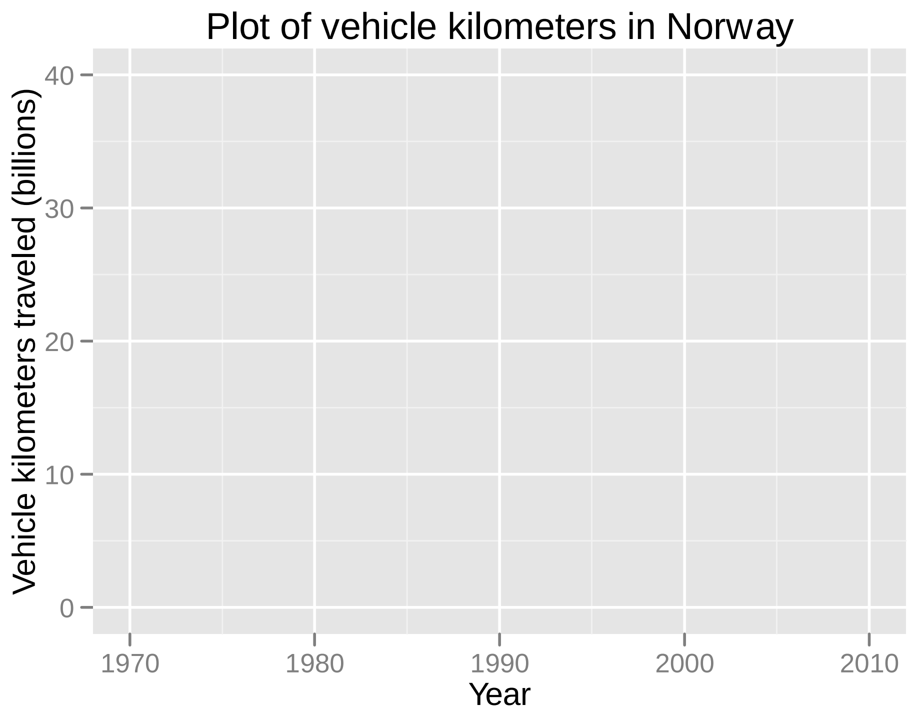


Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for Norway from 1973 to 2009.

1.2 Fatalities

In Figure 2, the Norwegian road accident fatalities from 1973 to 2009 are plotted. An overall consistent decreasing trend can be identified when looking at the time-series as a single line. It is also possible to identify three sub-sections with a steeper decreasing slope (1973-1981, 1986-1996 and 1998-2009), connected by short periods of increasing number of fatalities. However, since (i) there is no evidence of specific events occurring during these periods in Norway and (ii) it is unlikely that there was some actual increase in the number of fatalities, the approach that is followed in modeling the fatalities is to not consider any interventions.

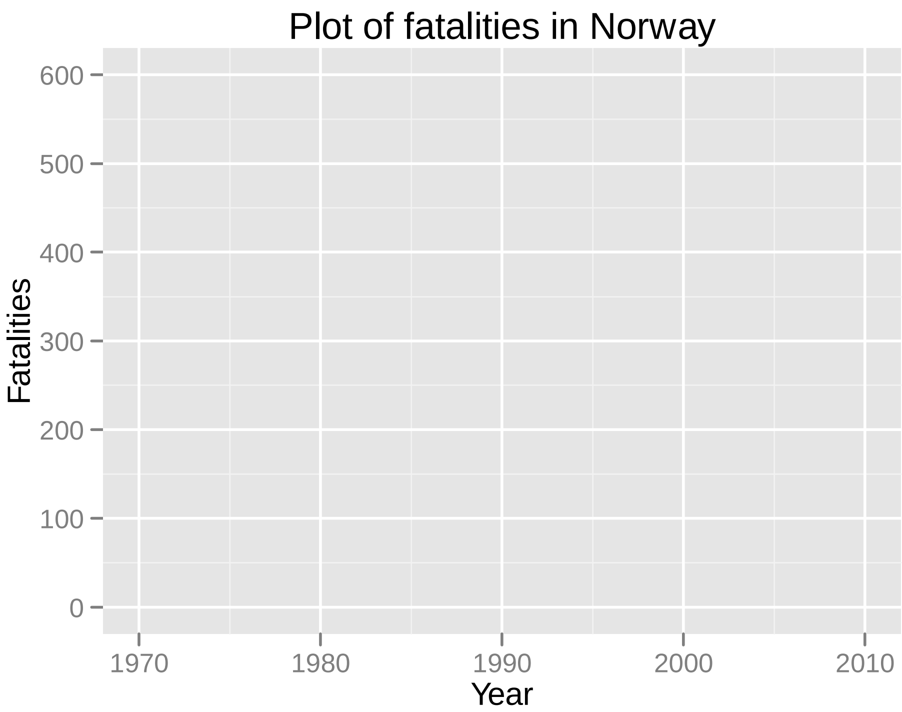


Figure 2: Plot of the annual fatality counts for Norway from 1973 to 2010.

2 The SUTSE Model

2.1 Development of the state components

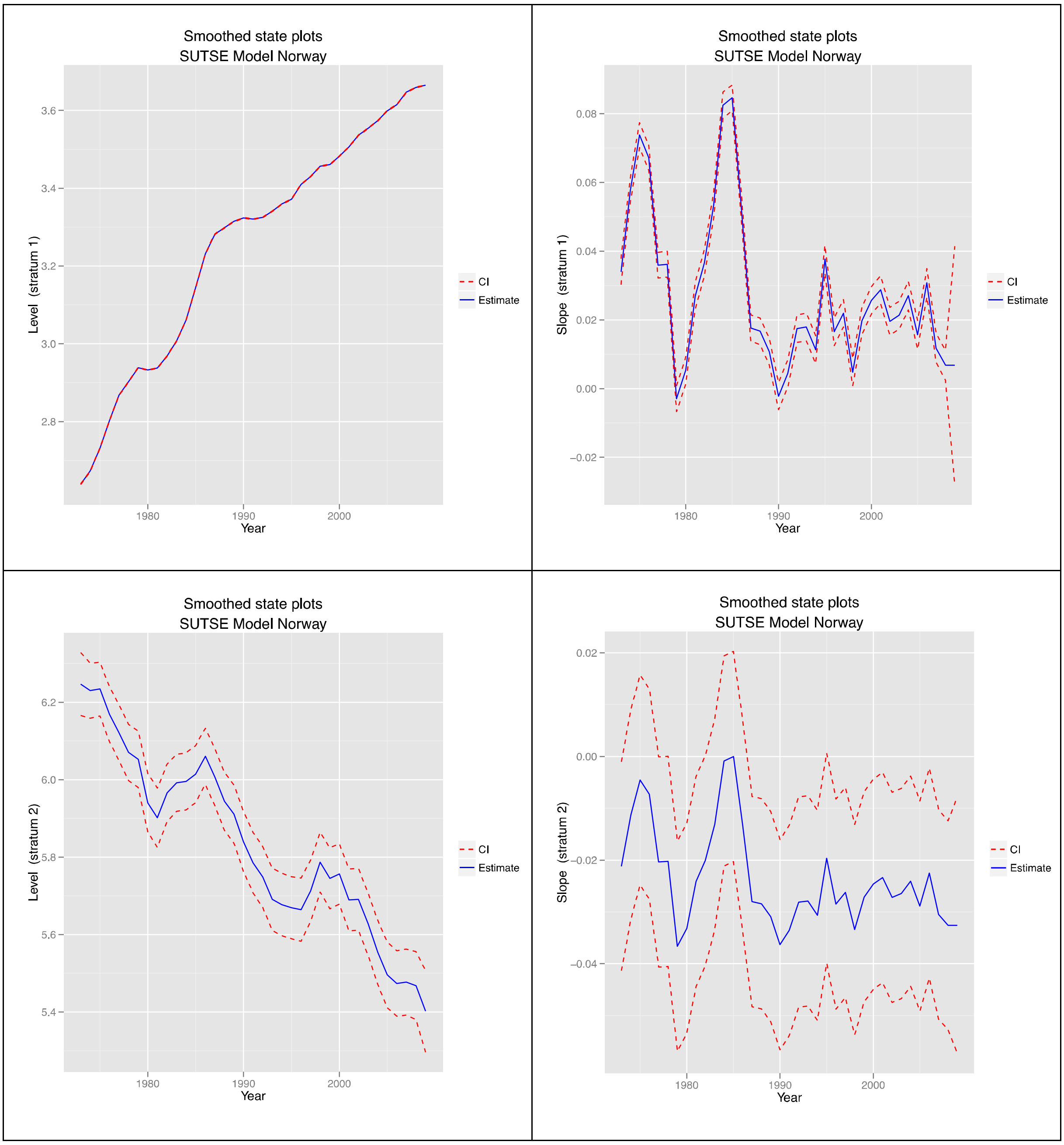


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The slope component varies significantly, while the trend does not. The Norwegian vehicle kilometres increased from 14 billion in 1973 to almost 40 billion in 2009. As the slope varies significantly, the increase did not take place at the same rate throughout this period. In the seventies and eighties the year-to-year change ranged between a 7-8% increase and marginal decreases. Since then, however, an average annual increase of about 2% has been observed (albeit with significant variability between 0 and 3-4%).

2.1.2 Fatalities

Both the level and slope components of the fatalities time series vary significantly. The fatalities have dropped from more than 500 in 1973 to 212 in 2009. Between 1973 and 1990 this decrease ranged between zero and more than 3%, while after 1990 it has increased and has been more consistently around 2.5%.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

Two state components, the level of exposure and the slope of the fatalities, cannot be considered stochastic. The correlation between the two levels (p=0.62) and two slopes (p=0.49) is not significant. The value of both correlations is 1.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 0.47, which is not significant (p=0.89).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 0.57 and is not significant (p=0.28)

Model title	***SUTSENorway1***	***SUTSEbetaNorway1***
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	157.38	157.25
AIC	-314.27	-314.08
Variance of the state components		
Level exposure	7.53E-06 nsc	5.00E-18 ns
Level risk	3.70E-03 *c	3.39E-03 *
Slope exposure	3.08E-04 *c	3.11E-04 *
Slope risk	5.38E-05 nsc	7.49E-17 ns
Correlations between the state components		
level-level	1	1
slope-slope	1	1
Observation variance		
Observation variance exposure	2.24E-07 ns	2.29E-06 ns
Observation variance risk	5.52E-04 ns	7.87E-04 ns
Beta		0.57 ns

Table 1: Overview of the results for SUTSE models – Norway.

3 The LRT Model

The investigation of the SUTSE model did not clearly indicate the presence of a relation between exposure and fatalities in Norway. However, there is also reasonable doubt that these two time series are unrelated. The coefficient (beta) that estimates the relation between the two series is not significant but with p=0.28 it is not small enough to confidently rule out a relation.

It was therefore decided to base the forecasting procedure on the LRT model.

3.1 Model selection

Three versions of the LRT model were run: the full model, the model with a fixed slope for risk and one where the risk slope and the level of exposure were fixed. The residual tests for the first two models indicate an issue with auto-correlation (lag 3) in the exposure data, however this is fixed in the third model. Fixing the two parameters does not also have a significant impact on the log-likelihood and AIC, providing additional evidence for this third model. The only minor observation against this model is that the full model has slightly better fit in terms of ME and MSE. However, this is not significant as all values are reasonably low. Therefore, the third model (LRT3) is selected, with fixed level exposure and slope risk.

Model title	***LRT 1***	***LRT 2***	***LRT 3***
Model description	LRT for Norway – full model	LRT for Norway – fixed slope risk	LRT for Norway – fixed level exposure, fixed slope risk
Model Criteria			
ME10 Fatalities	1.2	24.0	24.0
MSE10 Fatalities	497.2	966.3	967.3
log likelihood	157.38	156.94	156.94
AIC	-314.27	-313.51	-313.61
Model Quality			
Box-Ljung test 1 Exposure	1.36	1.33	0.15
Box-Ljung test 2 Exposure	2.73	2.34	1.34
Box-Ljung test 3 Exposure	11.19*	10.32*	2.35
Box-Ljung test 1 Fatalities	0.39	0.42	0.42
Box-Ljung test 2 Fatalities	0.39	0.43	0.42
Box-Ljung test 3 Fatalities	1.71	1.91	1.91
Heteroscedasticity Test Exposure	0.31	0.34	0.34
Heteroscedasticity Test Fatalities	1.15	1.11	1.10
Normality Test standard Residuals Exposure	1.41	1.63	1.63
Normality Test standard Residuals Fatalities	1.58	1.34	1.35
Normality Test output Aux Res Exposure	0.61	0.82	0.84
Normality Test output Aux Res Fatalities	0.49	0.56	0.55
Normality Test State Aux Res Level exposure	0.64	0.76	0.76
Normality Test State Aux Res Slope exposure	1.08	1.71	1.71
Normality Test State Aux Res Level risk	2.36	1.71	1.76
Normality Test State Aux Res Slope risk	0.29	0.06	0.06
Variance of state components			
Level exposure	7.52E-06 nsc	4.85E-08 nsc	-
Level risk	3.37E-03 *c	3.87E-03 *c	3.84E-03 *
Slope exposure	3.08E-04 *c	3.17E-04 *	3.16E-04 *
Slope risk	1.04E-04 nsc	-	-
Correlations between state components			
level-level	1	1	-
slope-slope	-1	-	-
Observation variance			
Observation variance exposure	2.24E-07 ns	1.24E-06 ns	1.45E-06 ns
Observation variance risk	5.53E-04 ns	5.04E-04 ns	5.40E-04 ns

Table 2: Overview of the results for LRT models.

3.2 Development of the state components

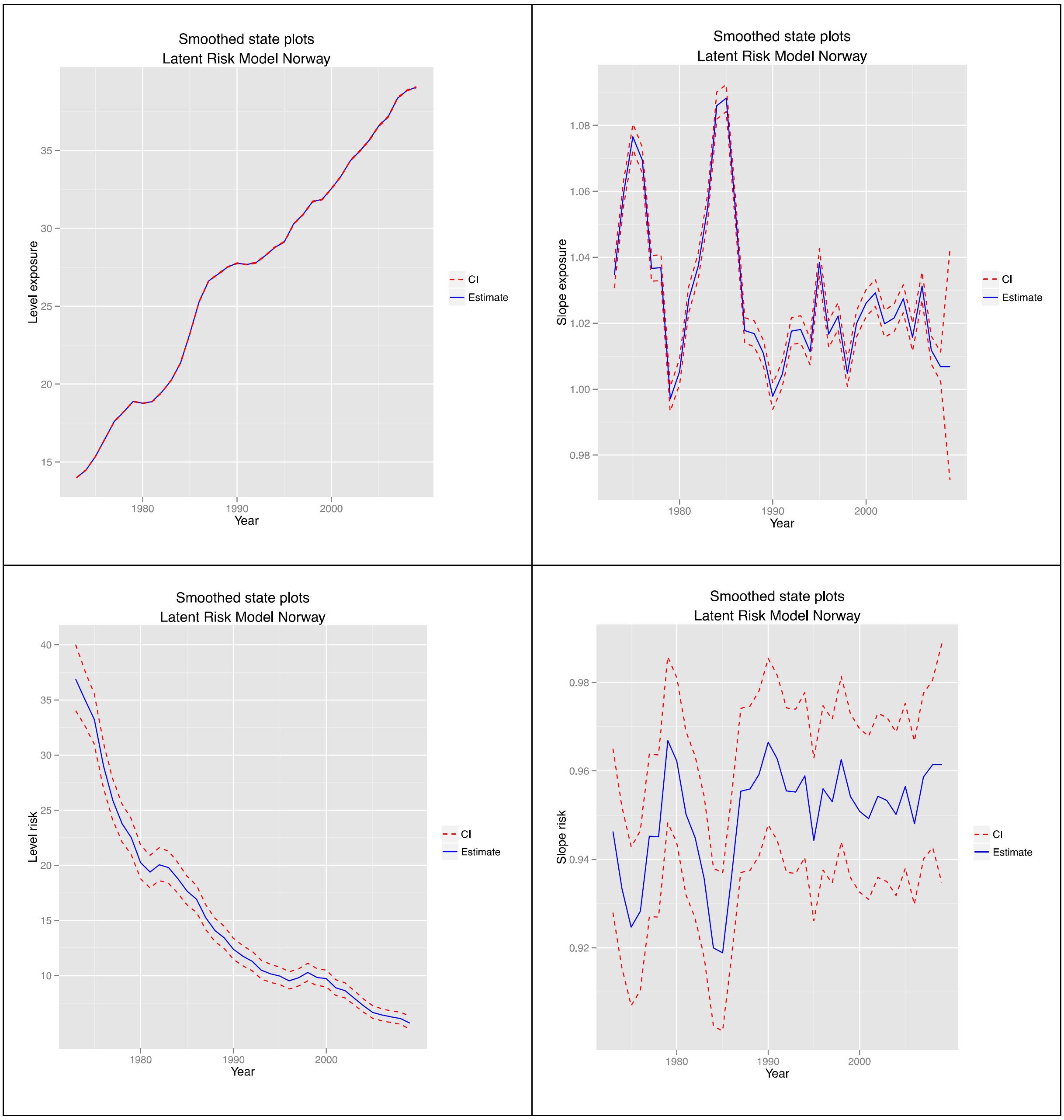


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The vehicle kilometres in Norway increased from 14 billion in 1973 to almost 34 billion in 2009. This increase did not take place at the same rate throughout this period however. In the seventies and eighties there was a range between a marginal decrease and an increase of more than 8%, but since than the yearly increase has been oscillating around 2% annually.

3.2.2 Risk

The risk for fatalities has been reduced in Norway from more than 37 per billion vehicle kilometres in the early 70s to about 5 per billion vehicle kilometres in the most recent years. This decrease of about 5% on average annually is expressed in the negative slope of the risk in the lower left panel of Figure 4.

3.3 Quality of the predictions

To evaluate how well models implemented here have done in the past, the data up to 1999 are used to forecast the fatalities between 2000 and 2009. Figure 5 below shows a comparison between the predicted and actually observed values. For the predicted period 2000-2009, all three model variants underestimate the actually observed development in a very similar way.

3.3.1 Exposure

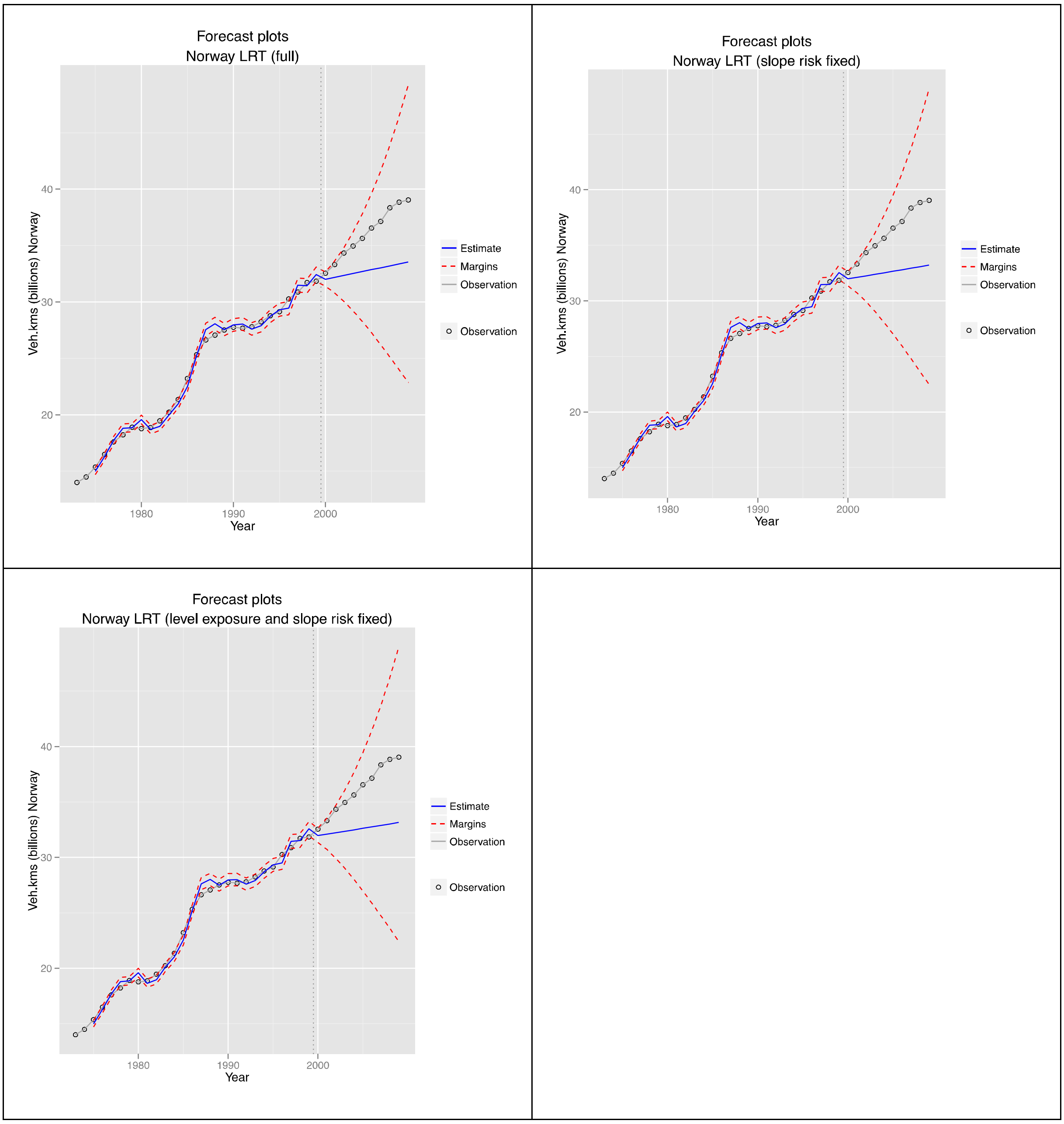


Figure 5: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the exposure numbers in Norway.

3.3.2 Fatalities

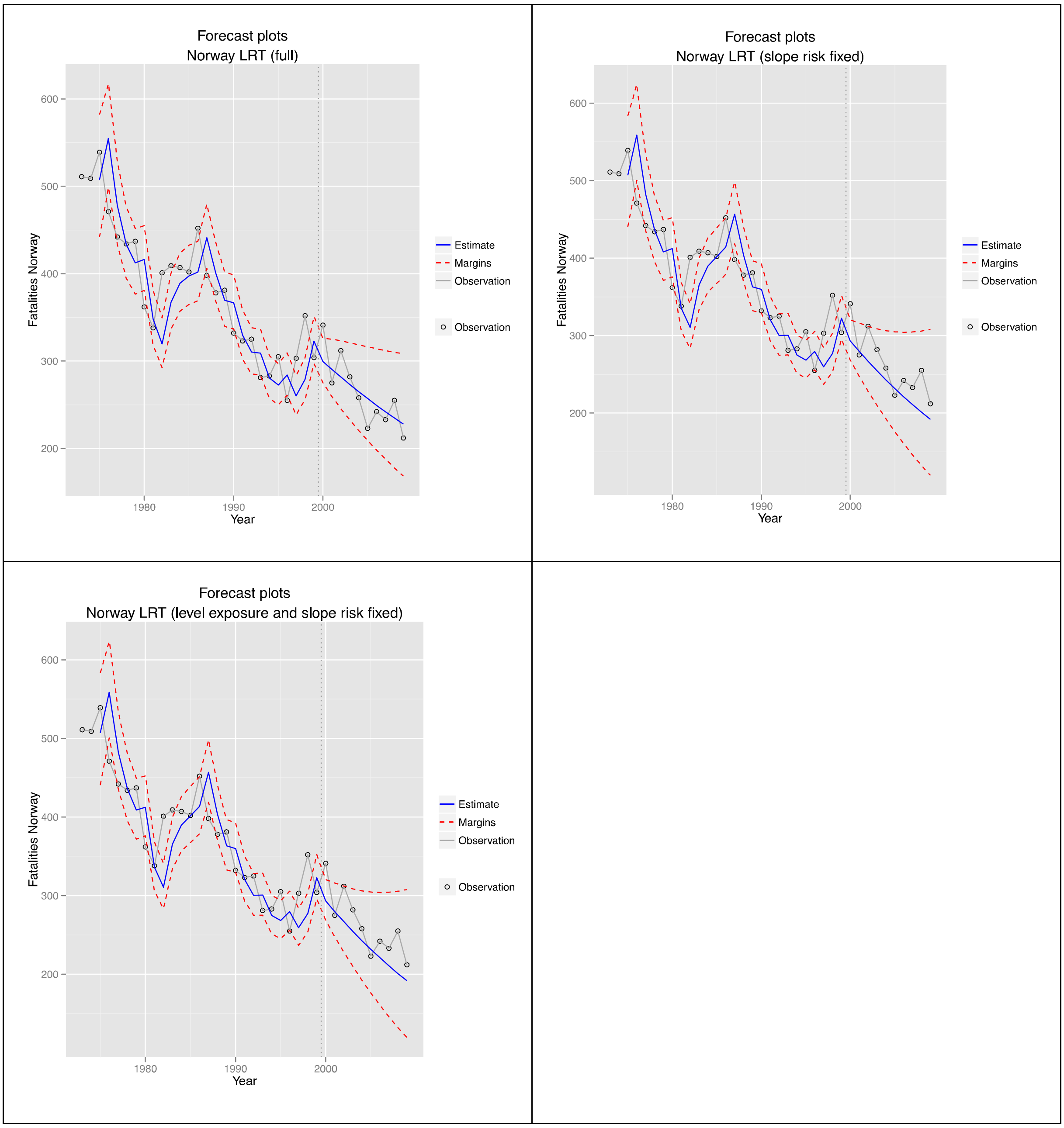


Figure 6: Plots comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Norway.

In Figure 6, the Norwegian fatalities are forecasted up to 2009 with different variants of the Latent Risk model using data up to the year 1999. As indicated by the summary statistics, the three models are rather similar. Therefore, since the additional degrees of freedom do not improve the model, the third model in which the slope risk and level exposure are fixed (LRT3) is chosen.

4 Forecasts 2010 - 2020

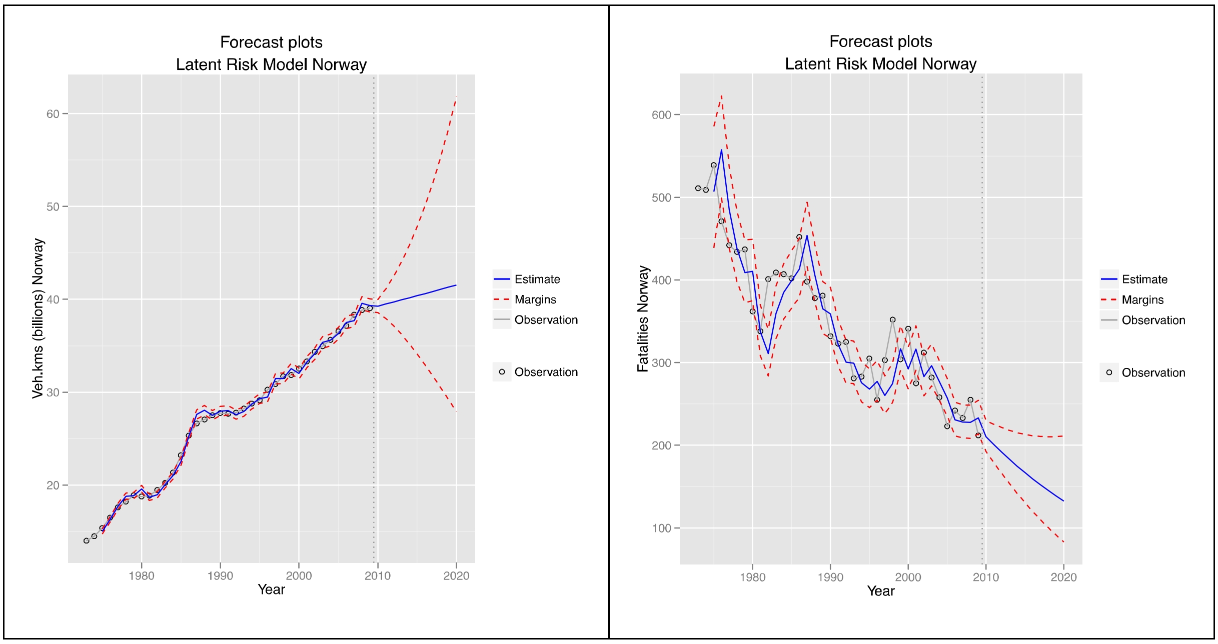


Figure 7: Plot of the vehicle kilometres (left) and annual fatality numbers (right) for Norway forecast between 2010 and 2020.

The forecasts in Figure 7 and Table 3 provide an indication of the vehicle kilometres and the fatality numbers to be expected between 2010 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Vehicle kilometres (billion)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2010	**39**	38	41	**210**	177	251
2011	**39**	37	43	**201**	160	252
2012	**40**	35	45	**192**	144	255
2013	**40**	33	48	**183**	130	258
2014	**40**	31	52	**175**	116	263
2015	**40**	29	56	**167**	103	270
2016	**41**	27	61	**159**	91	279
2017	**41**	25	67	**152**	80	289
2018	**41**	23	74	**145**	70	301
2019	**41**	21	82	**139**	61	316
2020	**42**	19	91	**132**	53	333

Table 3: Forecasts of selected Latent Risk Model (LRT 3) for Norway.

5 Scenarios

In Figure 7 it can be seen that there is a reasonable uncertainty about the development of the exposure in Norway. Given that the exposure influences the prediction of the fatalities it is interesting to demonstrate how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 8 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

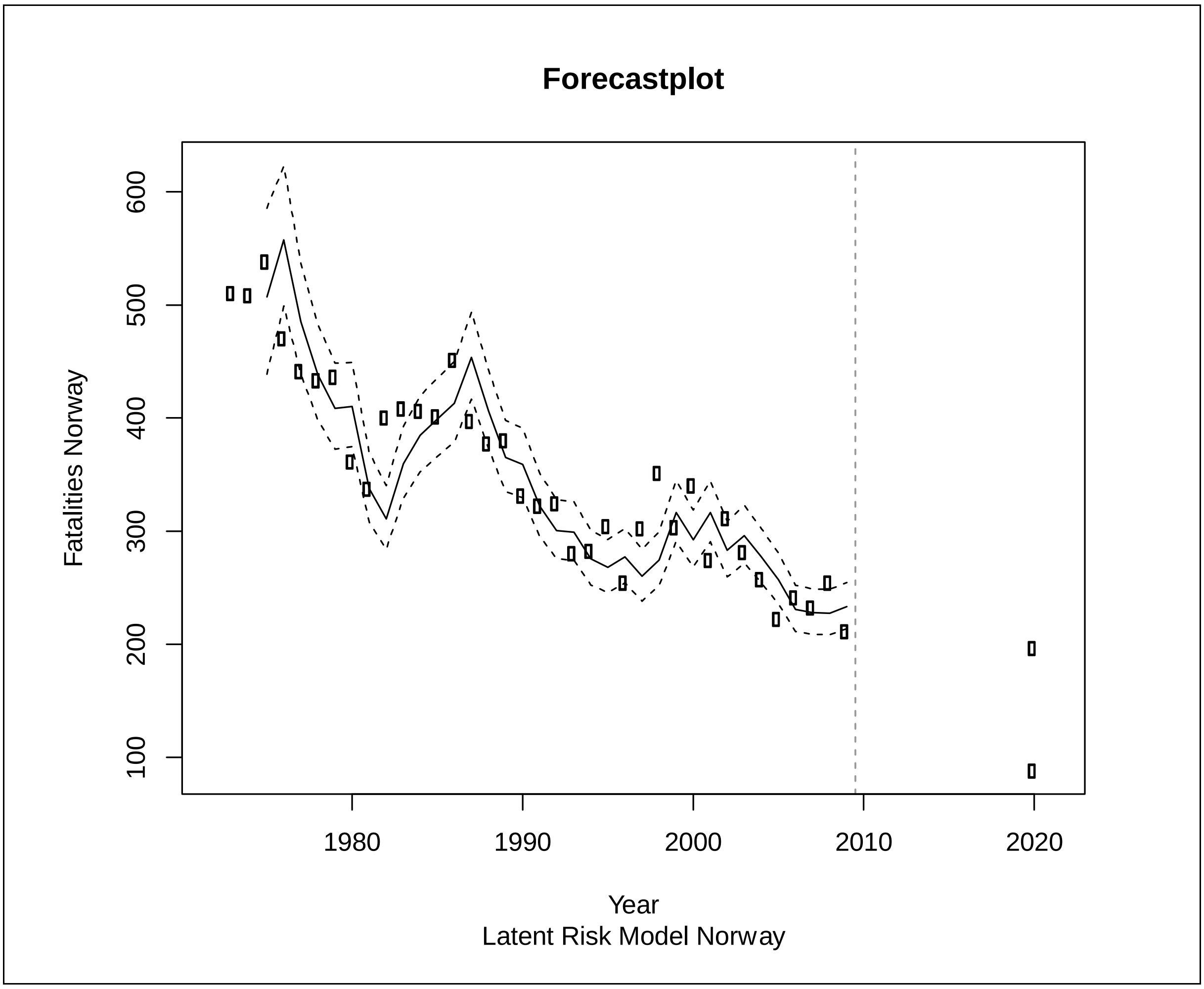


Figure 8: Fatality forecasts Norway 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the vehicle kilometres as predicted from the LRT model plus/minus one standard deviation. Assuming that these predictions are correct, and thus ignoring the uncertainty surrounding the forecasts for the exposure, what would be the consequences for the number of fatalities to be expected in 2020?

The full dot in Figure 8 is the expected number of fatalities given that mobility keeps developing as it has before (prediction 41 billion veh.km per year). The circles indicate the estimated number of fatalities for an optimistic scenario for exposure (forecast plus one standard deviation: 61 billion veh.km) and for a pessimistic scenario (forecasted value minus one standard deviation[17]: 28 billion veh.km). The predictions that are achieved under these three scenarios are summarized in Table 4.

	Vehicle kilometres (billions)	Road traffic fatalities
Situation 2009:	39	212
Prediction for 2020 according to mobility scenarios:		
Continuation of development	41	131
Stronger growth	61	196
No growth	28	89

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRT 3). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation.

[17] Note that 68% of all cases are between the estimated value +/- one standard deviation (under the assumption of a normal distribution).

POLAND

1 Raw data:

1.1 Exposure:

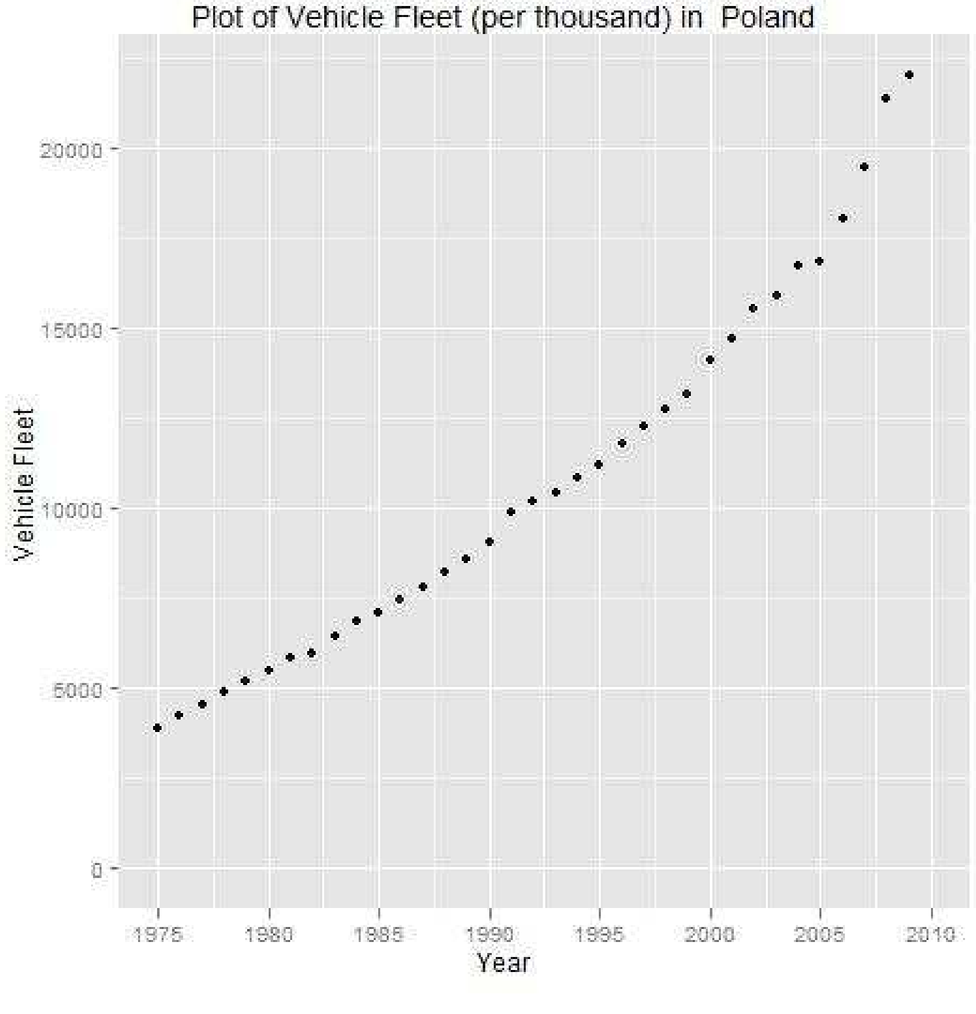


Figure 1: Plot of the annual vehicle fleet (in thousand) for Poland from 1975 to 2009.

As exposure measure we consider the total number of vehicles (excl. mopeds). Yearly data for the vehicle fleet are available from IRTAD for the years 1975, 1980, 1985 and for the period 1990 to 2009. However, the intervening data were obtained from [18] (source = central statistical office).

In general, the graph shows a gradual increase in the vehicle fleet in Poland. However, in 1991 and 2000 there was a stronger increase while the fleet barely changed between 2004 and 2005. In addition, there was a very strong increase in vehicle fleet in 2006-2008.

As alternative exposure measure we also consider the number of motor vehicle kilometres. Data were obtained from the EC national expert (source = motor transport institute) for Poland for a shorter period, i.e. 1996-2008 (the value for 2006 is missing).

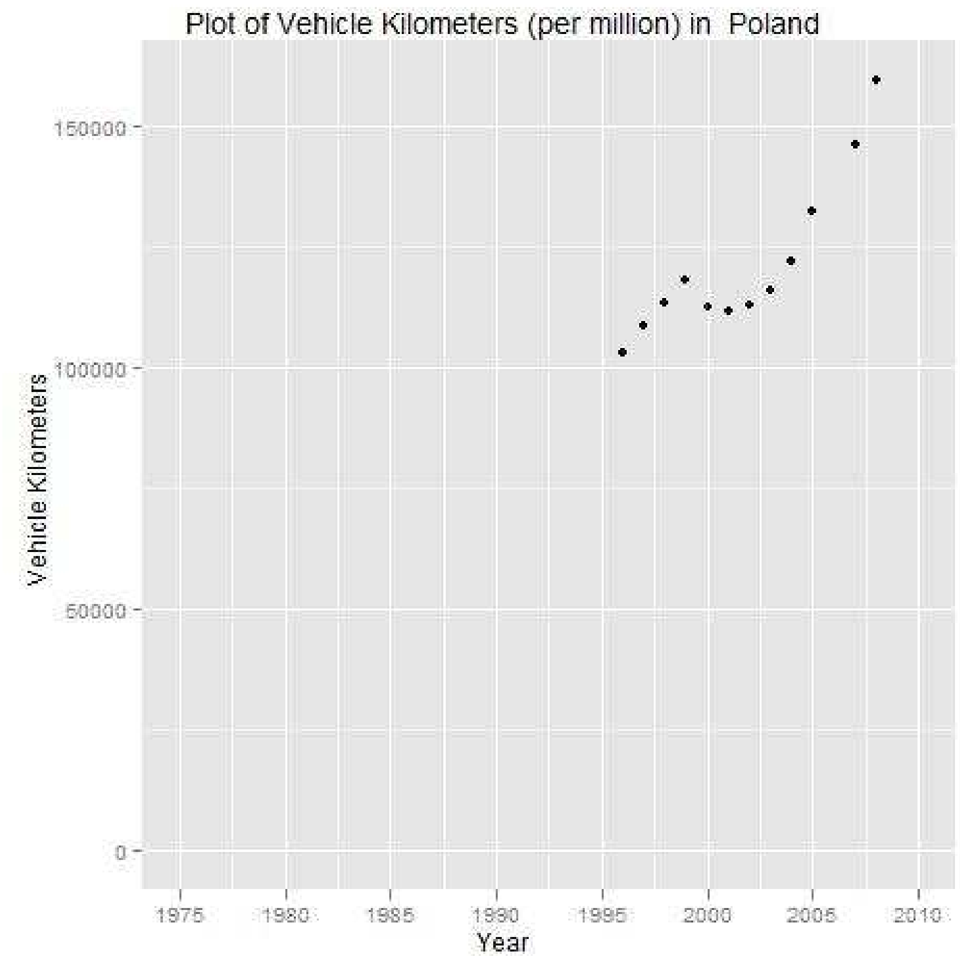


Figure 2: Plot of the annual number of vehicle kilometres (in million) for Poland from 1996 to 2008 (2006 missing).

[18] EC National Expert for road accident statistics and road safety performance indicators.

1.2 Fatalities:

The plot below shows the number of fatalities in Poland from 1975 to 2010. Data are from CARE and IRTAD, except for the period 1991-2000 (data provided by EC national expert).

In general, there is a decrease in the number of fatalities over the years.

The numbers of fatalities are estimated on the basis of a single source: police data. The registration method has not changed since the 70s, although there has been a change in the institution collecting the data: up to 1996, a bureau was specifically in charge of collecting these data, from 1996 on, the police is doing that.

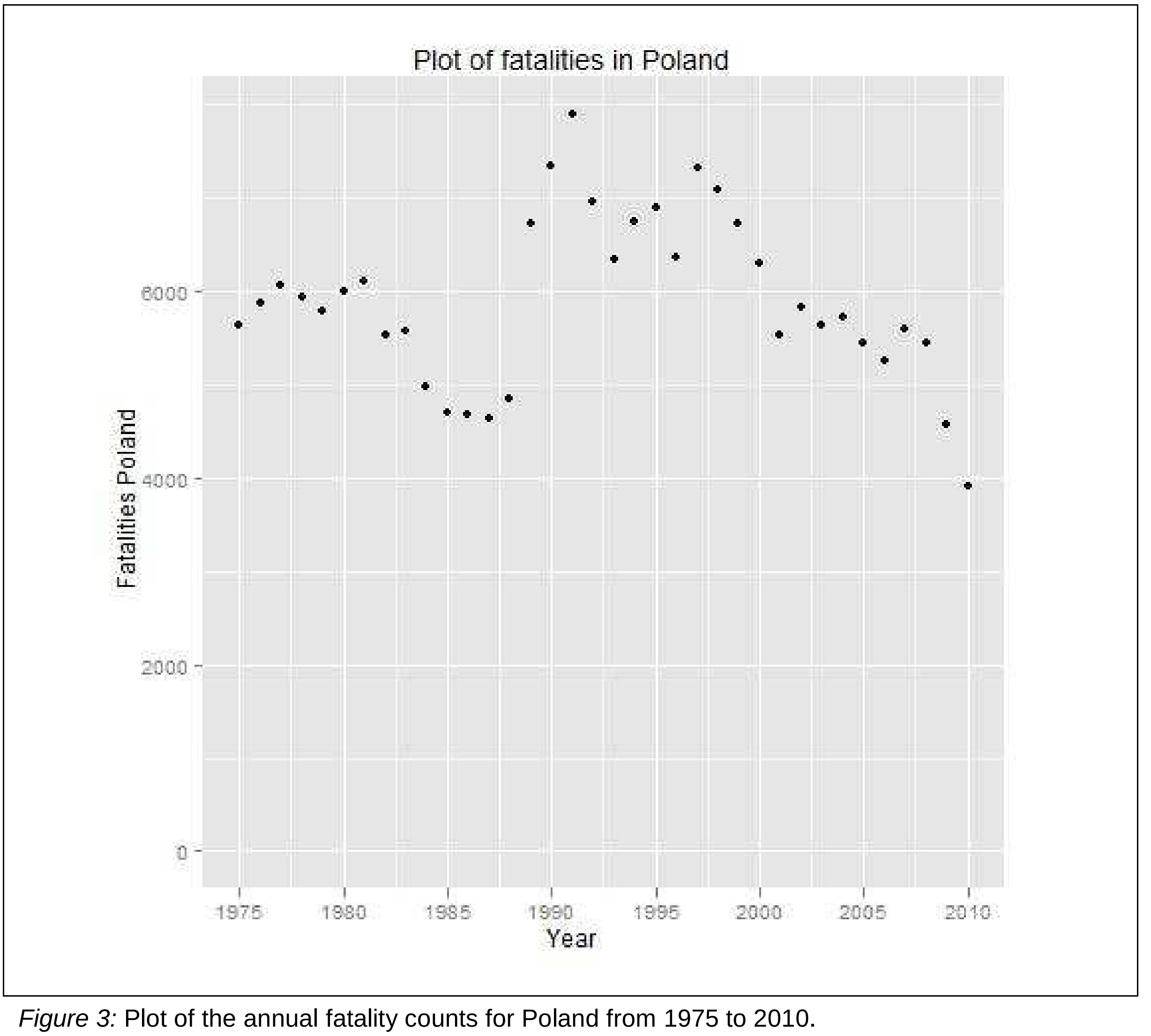


Figure 3: Plot of the annual fatality counts for Poland from 1975 to 2010.

2 The SUTSE Model:

2.1 Development of the state components:

Below, we present the varying level and slope estimation results of the SUTSE model: in particular the smoothed state plots for the exposure (top) and fatality (bottom) variables. The left subfigure in each row shows the level estimate for the corresponding variable and the right subfigure shows the slope estimate. First, the figure concerning the SUTSE model considering vehicle fleet as exposure is shown, followed by the figure concerning the SUTSE model considering vehicle kilometres as exposure.

Using vehicle fleet as exposure:

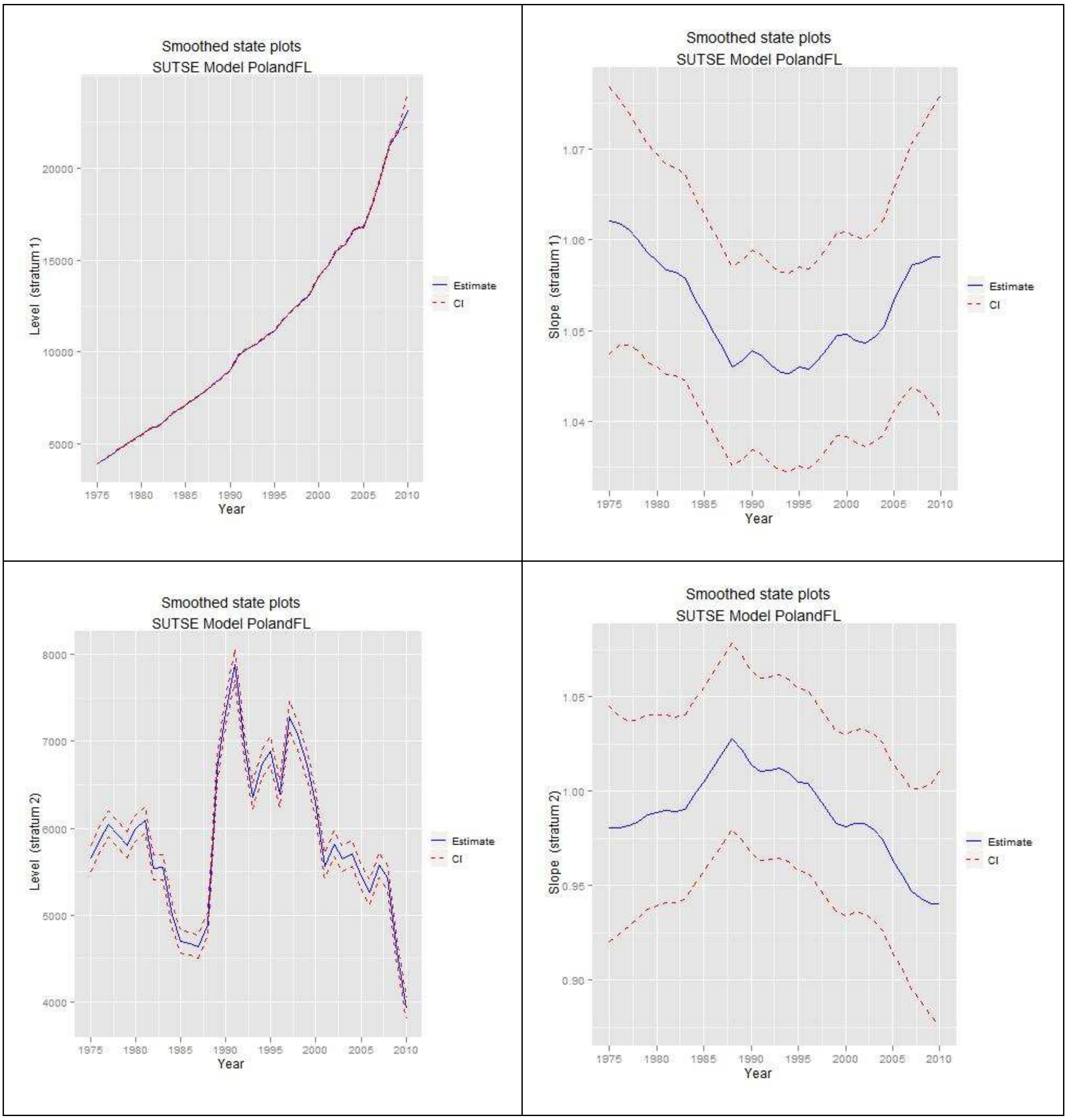


Figure 4: Developments of the state components for the Exposure, i.e. vehicle fleet (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

Using vehicle kms as exposure:

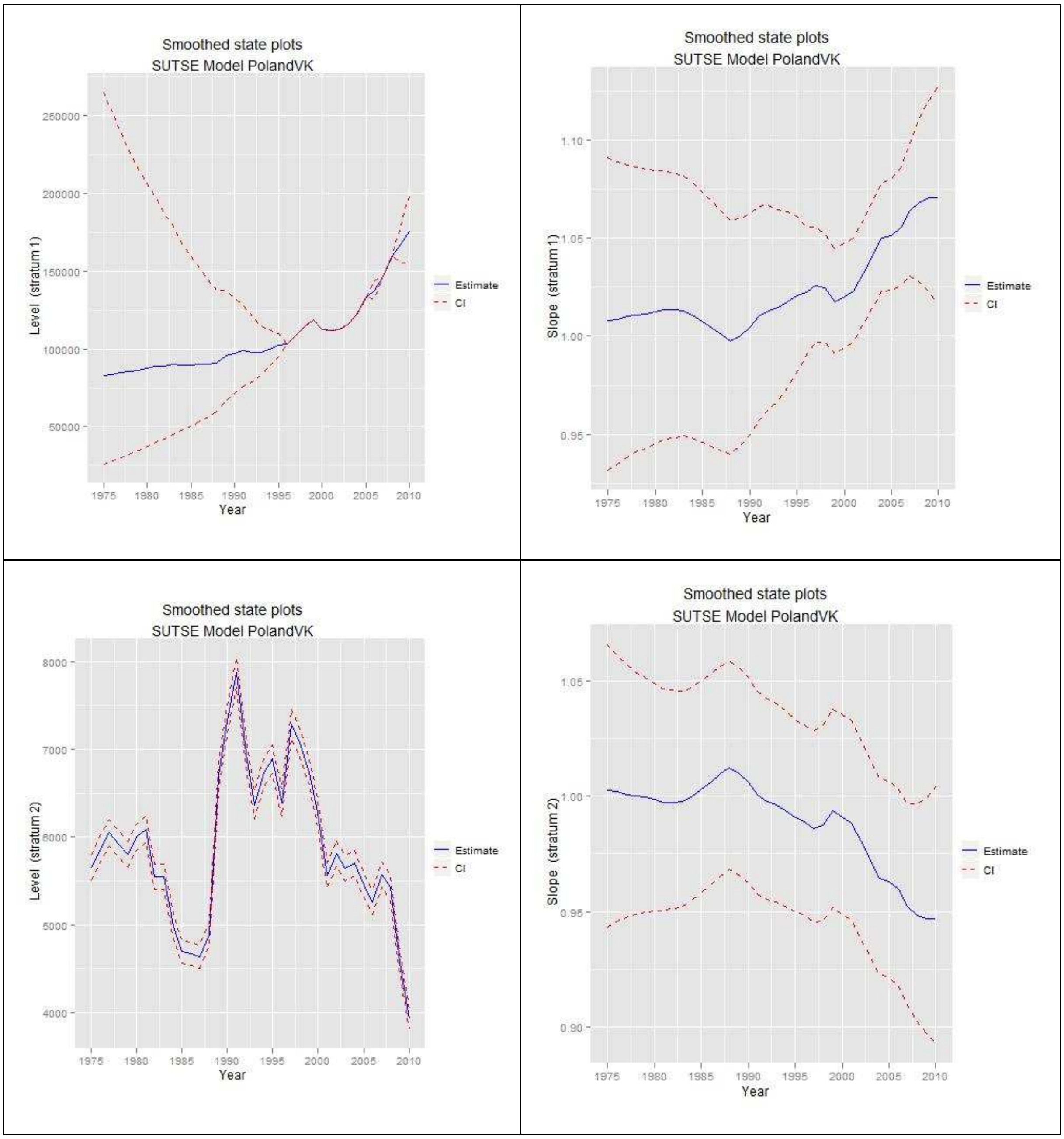


Figure 5: Developments of the state components for the Exposure, i.e. vehicle kilometres (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend in the number of vehicles in Poland largely increased over the studied time period (i.e. the vehicle fleet became around six times larger between 1975 and 2010). The slope of the exposure (top right subfigure in Figure 4) has been positive (fluctuating between 4.5% and 6% increase per year). The annual increase was smaller between 1986 and 2004. In terms of vehicle kilometres (see Figure 5), there is also an increase in trend. The slope values exceeding 1 indicate a systematic increase in the number of vehicle kilometres from one year to the other.

2.1.2 Fatalities

The level component shows a clear peak in the number of fatalities around 1991 with almost 8000 fatalities in Poland. In 2010, the lowest value of the period 1975-2010 is obtained, i.e. 4000 fatalities. The slope values (see bottom right subfigure in Figure 4 and Figure 5) fluctuate around 1 but show a decrease in the annual fatality number during the last decade.

2.2 Relation between the exposure and fatality series:

In Table 1a and 1b respectively, model criteria and results for the SUTSE models considering vehicle fleet as exposure are shown, followed by the model criteria and results for the SUTSE models considering vehicle fleet as exposure.

2.2.1 Correlation between the disturbances of the state components

In both cases (so irrespective of the exposure measure used) the correlation between the two levels (p=0.18 respectively p=0.46) and two slopes (p=0.49 respectively p=0.53) is not significant.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 0.18 respectively -0.00, which is in both cases not significant (p=0.97 respectively p=1).

2.2.3 Estimation of the relationship by means of a coefficient

In both cases, a SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1a & b). The beta coefficient for the relationship between the latent developments of the two series is equal to 1.25 and is not significant (p=0.28) when considering vehicle fleet data respectively 0.08 and not significant (p=0.90) when considering vehicle kilometres data.

2.2.4 Conclusion

It can be concluded that the fatalities and exposure series (whether we consider vehicle fleet or vehicle kilometres data) are not related and therefore further modeling can be made using the LLT model (instead of the LRT).

Using vehicle fleet as exposure:

Model title		***SUTSE PolandFL1***	***SUTSEbetaPolandFL1***
Model description		SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	146.93	146.53
	AIC	-293.37	-292.62
Hyperparameters			
	Level exposure	3.44E-04 *	3.61E-04 *
	Level fatalities	7.52E-03 ns	6.86E-03 *
	Slope exposure	1.22E-05 nsc	7.71E-06 ns
	Slope fatalities	2.44E-04 nsc	2.93E-04 ns
Correlations			
	level-level	0.33	
	slope-slope	-0.69	
Observation variances			
	Observation variance exposure	2.74E-06 ns	1.27E-09 ns
	Observation variance fatalities	5.85E-06 ns	4.51E-09 ns
Beta		/	1.25 (p= 0.28)

Table 1a: Model criteria and results for SUTSE models considering vehicle fleet – Poland

Using vehicle kms as exposure:

Model title	***SUTSE PolandVK1***	***SUTSEbetaPolandVK1***
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	61.57	61.30
AIC	-122.64	-122.16
Hyperparameters		
Level exposure	1.10E-03 nsc	3.99E-04 ns
Level fatalities	7.80E-03 nsc	7.90E-03 ns
Slope exposure	1.51E-04 nsc	7.34E-04 ns
Slope fatalities	1.37E-04 nsc	1.12E-04 ns
Correlations		
level-level	0.47	
slope-slope	-1	
Observation variances		
Observation variance exposure	3.10E-09 ns	1.11E-09 ns
Observation variance fatalities	4.41E-09 ns	1.00E-09 ns
Beta	/	0.08 (p= 0.9)

Table 1b: Model criteria and results for SUTSE models considering vehicle kilometres – Poland

3 The LLT Model:

3.1 Model selection:

Given that no relationship could be identified between exposure and fatalities on the basis of the data at hand, a Local Linear Trend model was fit to model the fatalities.

In the full model (LLTPoland1), the assumption concerning the normality of the residuals seemed to be violated. Therefore, a second LLT model was run (LLTPoland2) including an intervention (in 1989 at the level of fatalities; selected based on the residual graphs). In this model, all residual assumptions were met. Moreover, the slope appeared to be non-significant, therefore, a third LLT model was run (LLTPoland3) in which in addition to the intervention, a fixed slope was considered.

Given the satisfactory residual test results and the smaller prediction errors (ME10 and MSE10), LLTPoland2 and LLTPoland3 are to be preferred over LLTPoland1. In the end, we select the most parsimonious model, i.e. LLTPoland3, as the forecasting model.

Model title	*LLT Poland1*	*LLT Poland2*	*LLT Poland3*
Model description	Full Model	Intervention 1989 (level fatalities)	Intervention 1989 (level fatalities) and fixed slope
Model Criteria			
ME10	-1168.93	-712.11	-712.11
MSE10	1766631.96	714125.48	714125.70
log likelihood	48.09	47.04	46.97
AIC	-96.01	-93.91	-93.84
Model Quality			
Box-Ljung test 1	2.28	1.31	1.26
Box-Ljung test 2	4.25	1.60	1.29
Box-Ljung test 3	4.38	1.62	1.51
Heteroscedasticity Test	1.97	1.80	1.83
Normality Test standard Residuals	27.17***	0.44	0.35
Normality Test output Aux Res	0.39	0.51	0.57
Normality Test State Aux Res Level	19.87***	0.41	0.49
Normality Test State Aux Res Slope	0.12	0.01	0.00
Variance of state components			
Level	7.94E-03 *	5.00E-03 *	5.16E-03 *
Slope	1.06E-04 ns	2.42E-05 ns	-
Observation variance			
Observation variance	1.00E-09 ns	1.00E-09 ns	1.00E-09 ns
Interventions			
		fat level 1989	fat level 1989
		0.35 *	0.35 *

Table 2: Overview of the results for the LLT models – Poland.

3.2 Development of the state components:

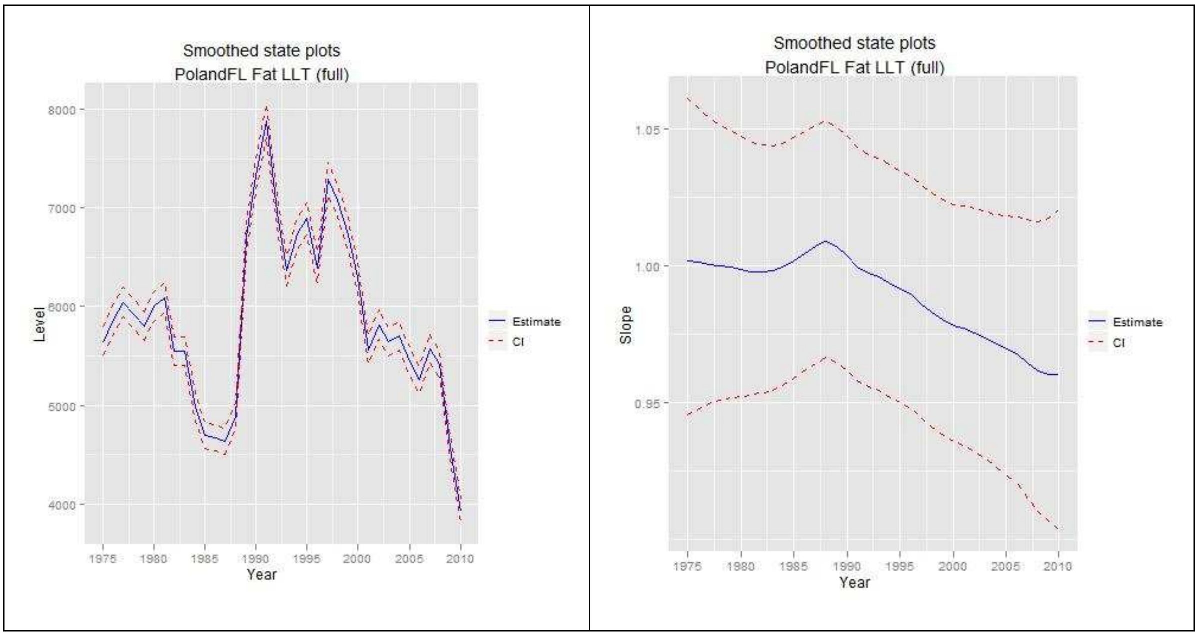


Figure 6: Developments of the state components for the fatalities, as estimated on the basis of the full LLT model.

3.2.1 Fatalities:

The level component shows a clear peak in the number of fatalities around 1991 with almost 8000 fatalities in Poland. In 2010, the lowest value of the period 1975-2010 is obtained, i.e. 4000 fatalities. The slope value fluctuates around 1 but shows a continuous decrease in the annual fatality number from 1990 onwards (on average -2% per year).

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 7 below shows a plot of the predicted and observed values for the whole series.

Given the strong decrease in the number of fatalities in 2001 and 2009, the model predicts larger fatality numbers than actually observed, yet predicts the decreasing trend fairly well.

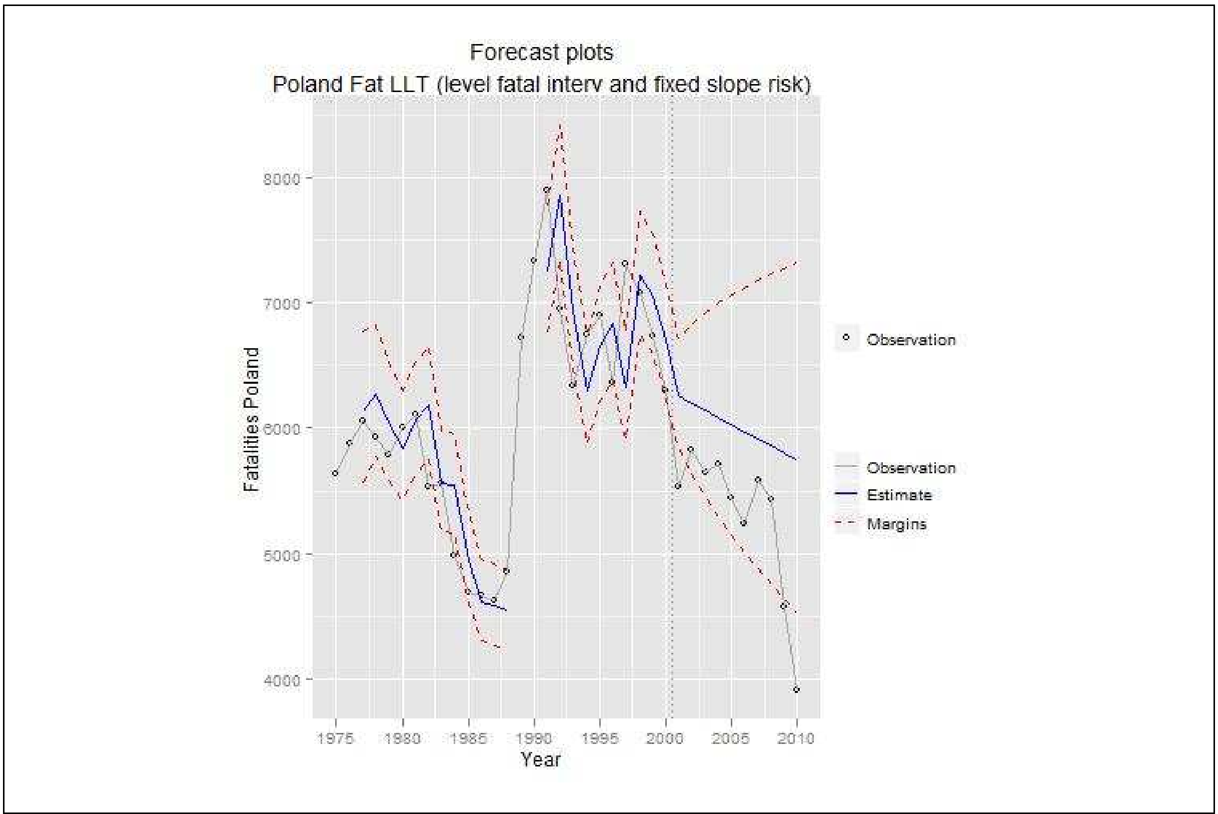


Figure 7: Plot comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Poland for the LLTPoland3 model.

4 Forecasts 2011 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.*

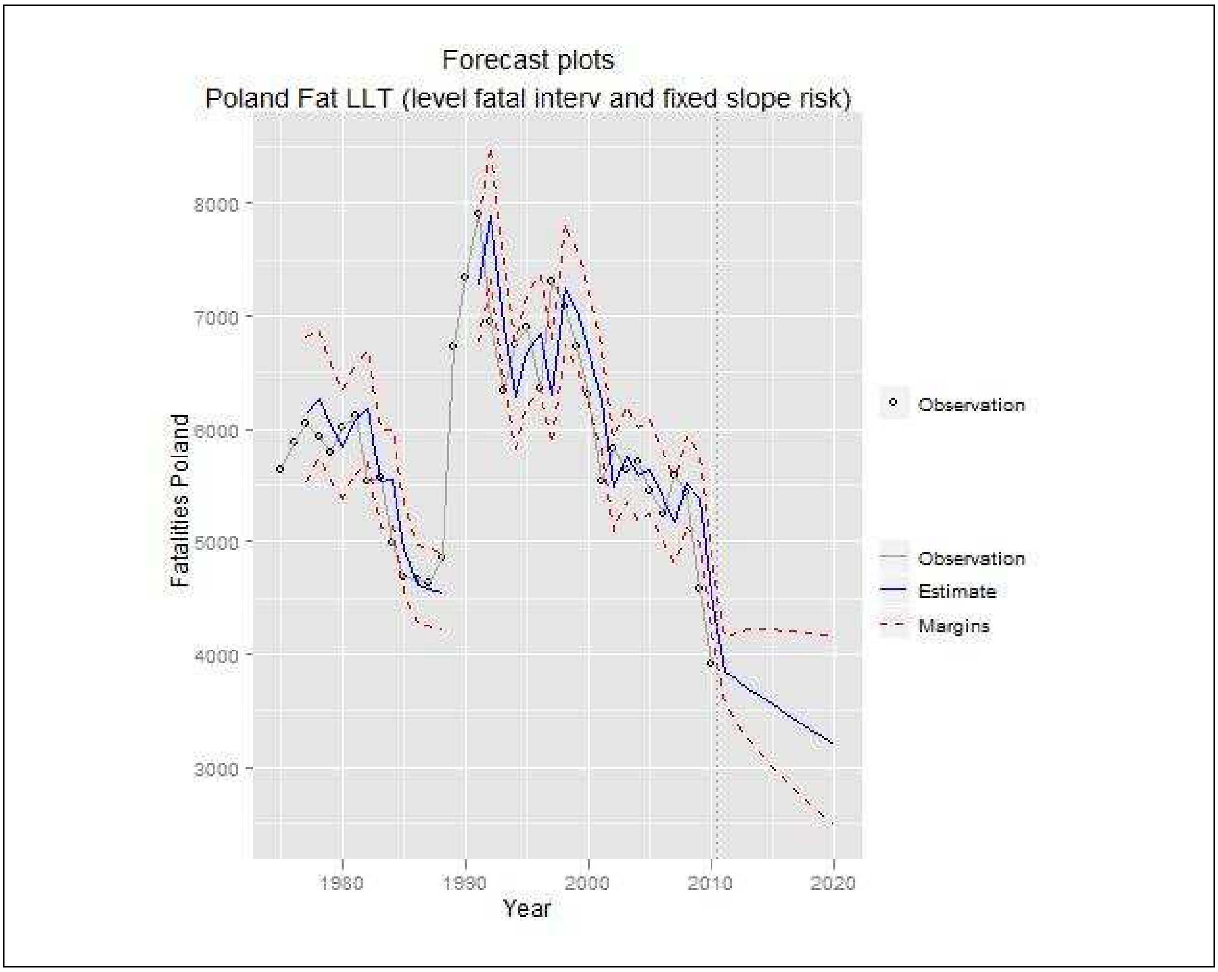


Figure 8: Plot of the annual fatality numbers for Poland and the forecast for 2020 (based on the Local Linear Trend Model LLTPoland3).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**3853**	3329	4460
2012	**3775**	3068	4645
2013	**3699**	2862	4781
2014	**3624**	2686	4890
2015	**3551**	2530	4984
2016	**3480**	2390	5066
2017	**3409**	2261	5140
2018	**3340**	2143	5208
2019	**3273**	2032	5271
2020	**3207**	1930	5330

Table 3: Forecasts of the Local Linear Trend Model LLTPoland3

PORTUGAL

1 Raw data

1.1 Exposure

The selected exposure measure is the number of vehicle fleet (in thousand) per year (see Figure 1), since 1970.

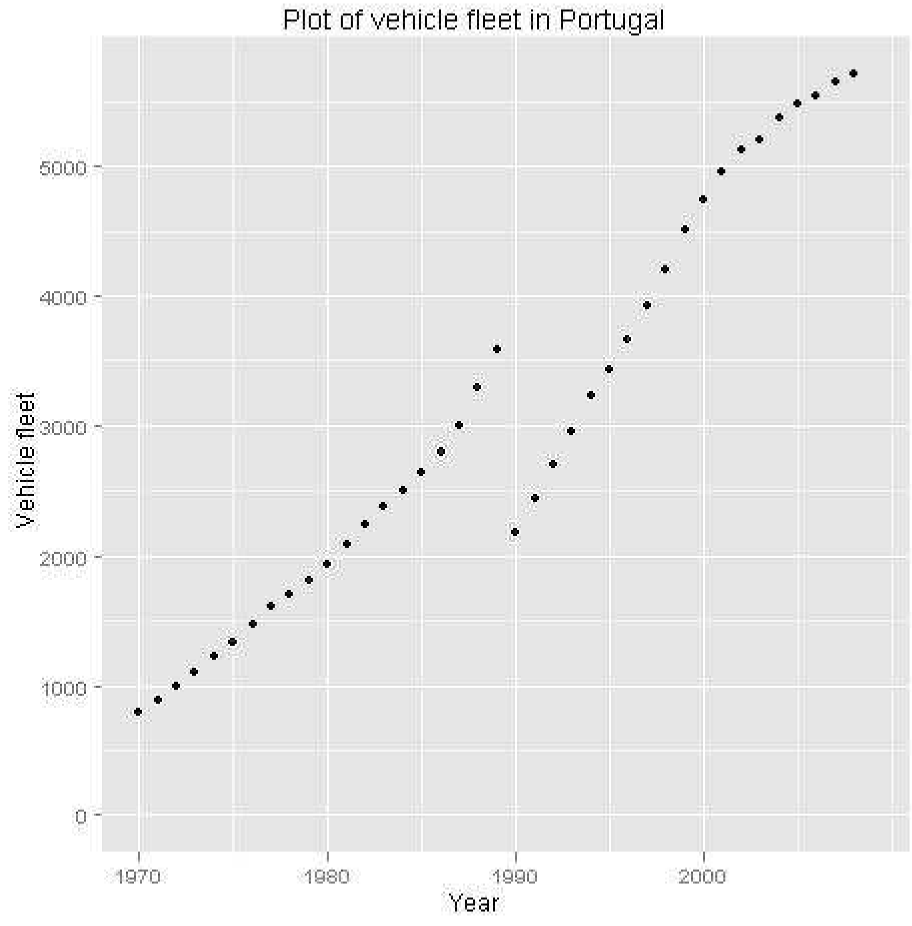


Figure 1: Plot of the annual number of vehicle fleet (in thousand) for Portugal from 1970 to 2008.

The annual vehicle fleet is available for Portugal from 1970 to 2008. There is an obvious break in the series that took place in 1990: there has been a huge and sudden decrease in the number of registered vehicles. In 1990 there was a change in the data source. In the period before 1990 data on motor vehicles was provided by the National Authority of Transport but the numbers were overestimated because not all the scrapped vehicles were removed from the database. From 1990 onwards this data was replaced by an estimation of the number of vehicles in circulation done by ACAP (a Portuguese automobile association).

When modelling the development of exposure, we specified an intervention in the measurement equation to account for the change in 1990.

1.2 Fatalities

Portuguese road traffic fatalities from 1970 to 2008 are plotted In Figure 2. Before 2010 the Portuguese definition for road traffic fatality was “Any person who died at the scene of the accident or while was being carried to a hospital”. Therefore, Portugal needed to apply a correction factor to the fatality data in order to obtain the number of deaths within 30 days of a road accident. However, from 2010 onwards the conversion factor was no longer applied to the national fatalities because we adopted the international methodology.

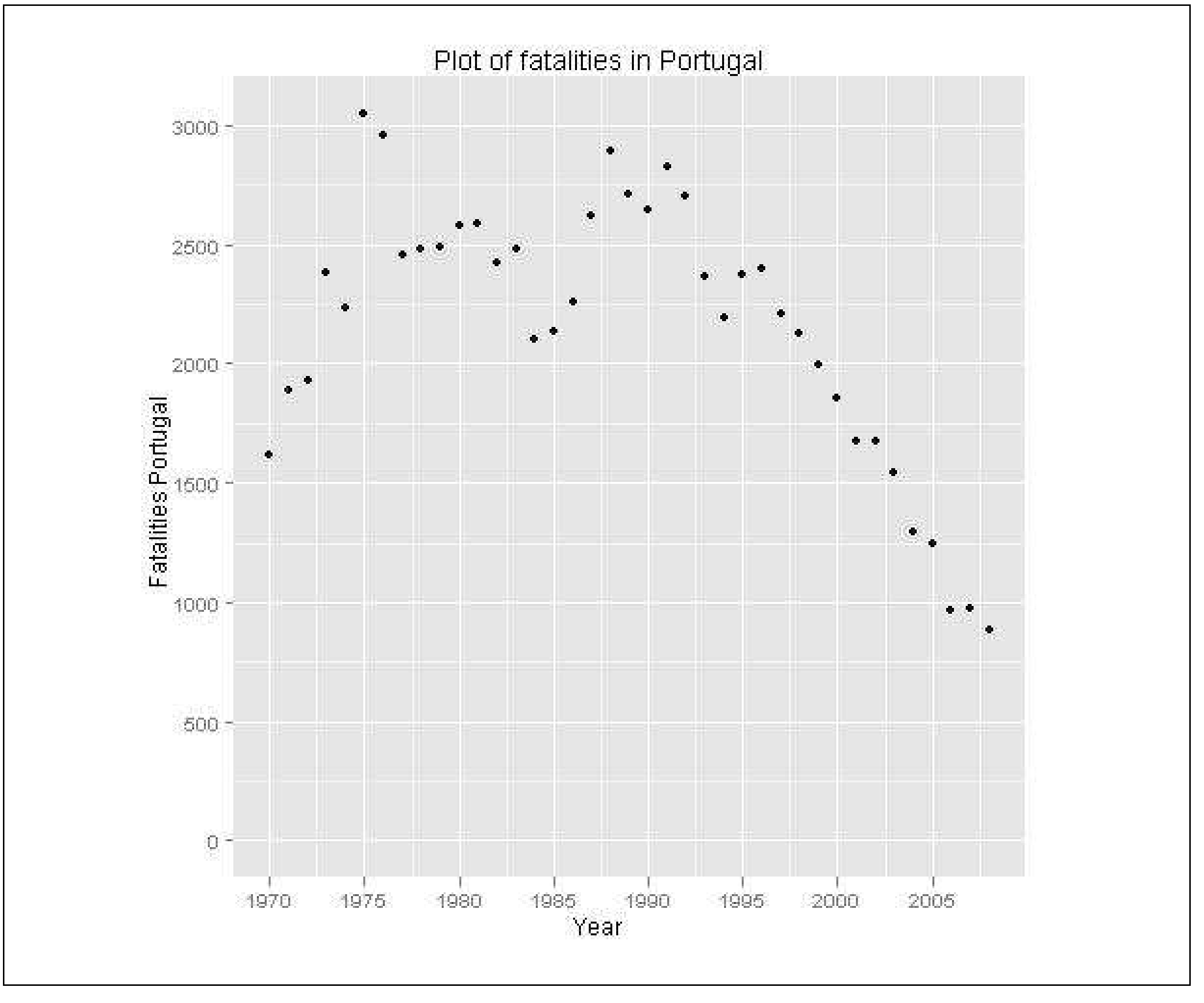


Figure 2: Plot of the annual road traffic fatality counts for Portugal from 1970 to 2008.

There is no general pattern, but a high variability in the annual number of Portuguese fatalities between 1970 and 2008. As can be seen on the basis of Figure 2, there is an initial period with a strong increase, then a period with a high variability and finally a period of strong decrease.

2 The SUTSE Model

An intervention in the measurement equation has been specified to account for the change in 1990.

2.1 Development of the state components

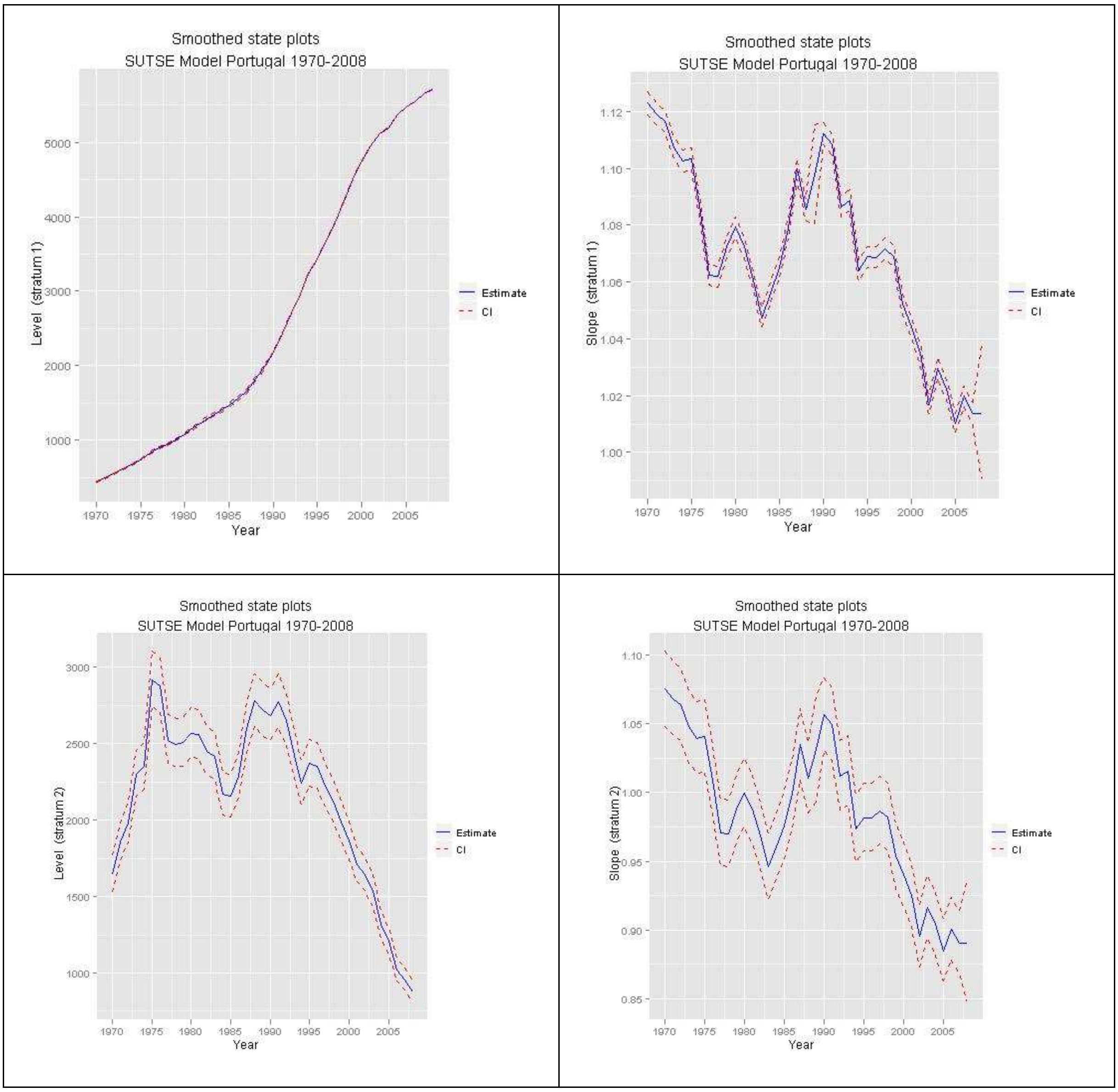


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

As seen in figure 3, the slope component varies over time, while the trend does not. The trend increases smoothly in a seemingly linear trend. The Portuguese vehicle fleet increased from 788 thousand in 1970 to 5,716 thousand in 2008.

2.1.2 Fatalities

Both the level and the slope components vary significantly over time. Variation in the slope values are visible in the graphs for the state developments presented in Figure 3. There are slope values above and below 1, which respectively indicate periods of increase and decrease of the annual fatality numbers, and several significant changes in the slope over the series. In the early seventies, the annual increase was about 12%. From 1975 the annual fatality numbers decreased until the middle eighties, when it rose again from 5% to 11% in 1990. Since early nineties it showed a decreasing pattern again. The period with the greatest reduction in the number of road traffic fatalities in Portugal is from 1996. The figure showing the development of the slope values for exposure and for the fatalities are almost identical (Figure 3).

The inspection of the trend for the fatalities leads to very similar conclusions than that of the raw series. The fatalities increased until 1975 (from 1,615 fatalities in 1970 to 3,051 in 1975), although the strongest increase occurred between 1974 and 1975 (from 2,236 to 3,051). Then, from 1977 to 1996 there has been a period of high variability with fatality numbers ranging between 2,099 and 2,889. Finally there is a period of a strong decrease reaching 885 in 2008.

The variance of the level and slope values over the years are significant (Table 1).

2.3 Relation between the exposure and fatality series

2.3.1 Correlation between the disturbances of the state components

Three of the four state components, the slopes of exposure and of fatalities and the level of fatalities, show a significant variance, which indicates that they can be considered stochastic.

The two slopes, in addition of presenting significant variance, show a significant covariance (the covariance between the two slopes deviate significantly from 0; p=0.027). The test for common components is not significant for the slopes, which means that their correlation does not significantly differ from 1 (p=0.5). It suggests that the slopes can be considered common components.

The level of fatalities shows a non significant variance.

2.3.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 0.68 wich is not significant (p=0.98).

2.3.3 Estimation of the relationship by means of a coefficient

A new SUTSE model is estimated to assess the relationship between the two series on the basis of a fixed regression coefficient (SUTSEbeta). The beta coefficient for the relationship between the latent developments of the two series is equal to 1.54552 and is significant (p=0.051). As a consequence, the two series can be considered to be related.

Model title	***SUTSEPortugal1***	***SUTSEbetaPortugal1***
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	171.88	171.32
AIC	-343.31	-342.23
Variance of the state components		
Level exposure	1.02 E-05 nsc	2.88 E-16 ns
Level risk	5.76 E-03 *c	5.75 E-03*
Slope exposure	1.35 E-04 *c	1.40 E-04*
Slope risk	4.58 E-04 *c	2.84 E-05 ns
Correlations between the state components		
level-level	-1	
slope-slope	1	
Observation variance		
Observation variance exposure	3.66 E-09 ns	2.51 E-06 ns
Observation variance risk	1.11 E-03 ns	1.31 E-03 ns
Intervention and explanatory variables test		
Intervention in 1990 for the exposure measurement	0.59*	0.59*
Beta		1.55 (p=0.05)

Table 1: Overview of the results for SUTSE models – Portugal.

3 The LRT Model

The SUTSE model indicates the presence of a relationship between exposure and fatalities in Portugal, and that the slopes can be considered common components. Furthermore, the coefficient (beta) that estimates the relation between the two series is also significant with p=0.051.

Therefore it was decided to base the forecasting procedure on the LRT model with slope risk component fixed, and an intervention in the measurement equation to account for the change in 1990.

3.1 Model selection

Three versions of the LRT model, with an intervention in the measurement equation (in 1990), were run: the full model (LRT1), the model with a fixed slope for the risk (LRT2), and the model with a fixed slope for the risk and a fixed level for the exposure (LRT3). In the SUTSE model exposure and fatalities had a common slope. Consequently, the risk slope in the LRT (that is based on the relation between fatalities and exposure) can be fixed. This is done in LRT2. Then, because of the non-significant variance of the level exposure we run the LRT3 model (LRT slope risk and level exposure fixed model).

Model title	***LRT 1***	***LRT 2***	***LRT 3***
Model description	LRT for Portugal– full model	LRT for Portugal– slope risk fixed model	LRT for Portugal– Slope risk and level exposure fixed model
Model Criteria			
ME10 Fatalities	-13.63	-132.18	-151.11
MSE10 Fatalities	3868.30	24354.69	29758.63
log likelihood	171.88	170.56	170.24
AIC	-343.31	-340.75	-340.22
Model Quality			
Box-Ljung test 1 Exposure	1.04	0.86	0.26
Box-Ljung test 2 Exposure	2.34	2.26	0.66
Box-Ljung test 3 Exposure	3.15	2.91	1.69
Box-Ljung test 1 Fatalities	0.62	0.19	0.35
Box-Ljung test 2 Fatalities	0.71	0.25	0.43
Box-Ljung test 3 Fatalities	1.36	1.95	2.1
Heteroscedasticity Test Exposure	1.14	1.07	0.96
Heteroscedasticity Test Fatalities	0.29*	0.34	0.38
Normality Test stand Residuals Exposure	0.27	0.18	0.08
Normality Test stand Residuals Fatalities	0.04	0.11	0.13
Normality Test output Aux Res Exposure	0.19	0.16	0.16
Normality Test output Aux Res Fatalities	0.19	0.14	0.12
Normality Test State Aux Res Level Exposure	0.51	0.39	0.43
Normality Test State Aux Res Slope Exposure	1.09	0.66	0.38
Normality Test State Aux Res Level Risk	0.44	2.86	3.3
Normality Test State Aux Res Slope Risk	0.00	0.00	0.00
Variance of state components			
Level exposure	1.02 E-05 nsc	3.95 E-06 nsc	-
Level risk	6.25 E-03 *c	8.40E-03 *c	7.59 E-03 *
Slope exposure	1.35 E-04 *c	1.47 E-04 *	1.42 E-04 *
Slope risk	9.56 E-05 nsc	-	-
Correlations between state components			
level-level	-1	-1	
slope-slope	1		
Observation variance			
Observation variance exposure	3.73 E-09 ns	8.82 E-09 ns	2.25 E-06 ns
Observation variance risk	1.11 E-03 ns	3.41 E-04 ns	7.19 E-04 ns
Intervention and explanatory variables test			
Intervention in 1990 for the exposure measurement	0.59*	0.59*	0.59*

Table 2: Overview of the results for LRT models.

Although LRT3 model leads to a slightly greater AIC, a slightly smaller loglikelihood and larger prediction errors than LRT2 model, we considered LRT3 as the final model because it fulfils the assumptions, all the non fixed components have non significant variability and the quality of the model and of predictions is not worse than LRT2 model.

3.2 Development of the state components

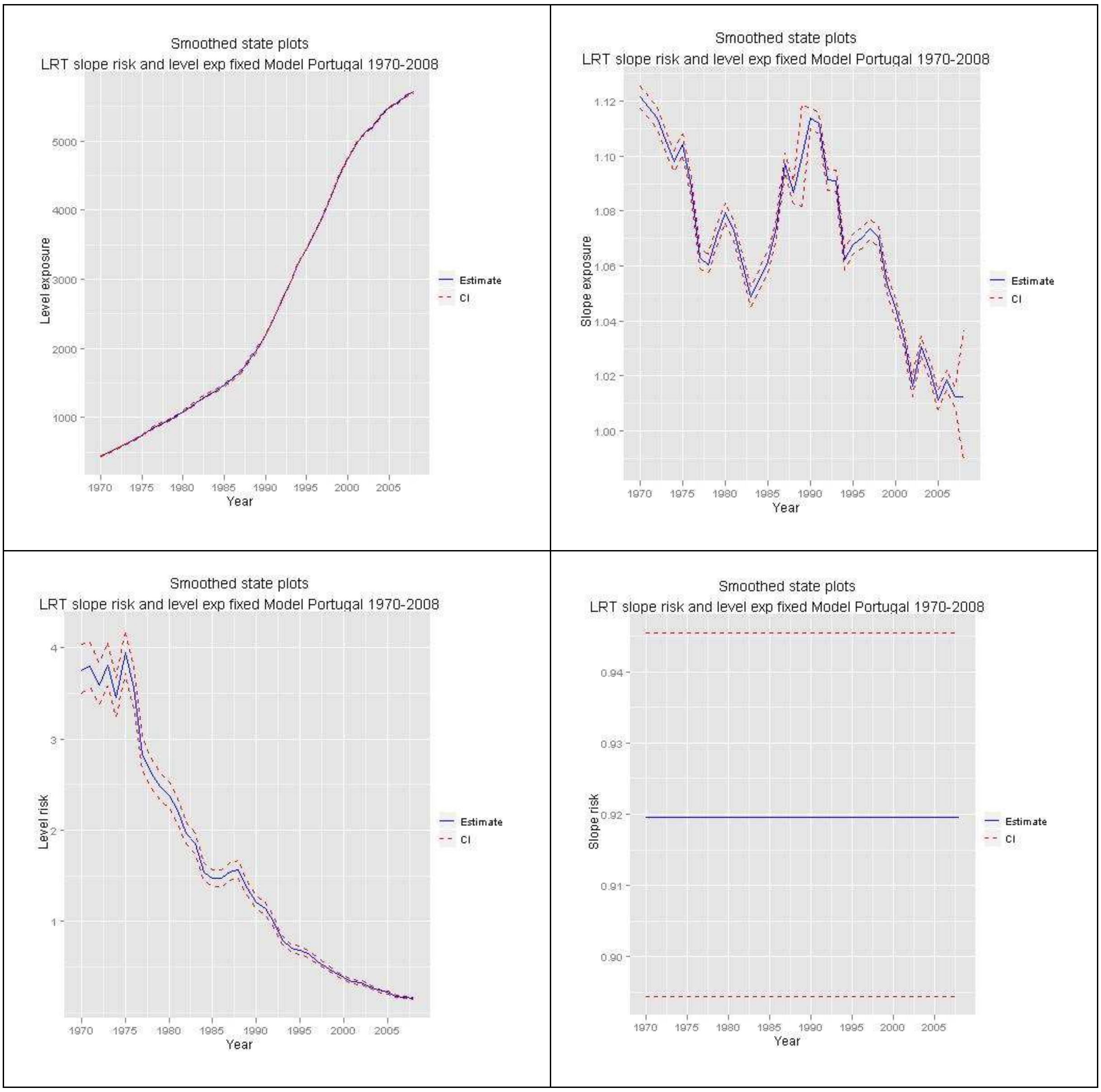


Figure 4: Developments of the state components for the exposure (above) and the risk (below), estimated on the basis of the LRT slope risk and level exposure fixed model (LRT3). The trend (level) developments are represented in the left-hand graphs, the slope developments in the right - hand graphs.

3.2.1 Exposure

As seen in figure1, although there is a break in 1990, vehicle fleet in Portugal has been continuously increasing from 1970 to 2008. Despite the slope do not vary significantly the increase did not take place at the same rate throughout this period. In the early seventies the annual increase was about 12%, but later on the increase was smaller, until the early eighties when it rose again from about 5% to 11,5%. From 1990 it decreased again until 2002-2003 where the increase was smaller, around 1% in 2007.

3.2.2 Risk

Contrary to the development of the fatalities, the risk has been decreasing almost constantly since the 70s. There are two notable exceptions to this. Between 1970 and 75, the risk has been stagnating. From 1975 on, it has continuously decreased, except in the years 1985 to 1987, where the risk rose again after a particularly steep drop in the early 80s. In recent years until 2008 the decrease of the risk has become less steep.

In the late 60's and early 70's there was a boom in private consumption following a strong industrial development that began in the final years of the previous decade, transforming Portugal's social landscape from a rural country. A political change in the ruling regime ("the marcelist spring") is also an explanation for these changes, in a context of a war in Africa (1961 - 1974) and a strong migratory movement. Due to the war and the emigration movement the resident population decreased (-3% between 1965 and 1971), but there was a big improvement in GDP per capita (at constant 2006 prices) and in vehicle registration, that rose, respectively, by 32% and 82% in that period. The oil crisis of 1973 had a big impact in 1974 public and private consumption, as the inflationary tensions that were hidden in the previous years arose in a significant way. The 1974 revolution added a social dimension to these movements and caused a big impact in the Portuguese society. Huge improvements in wages, even in an inflationary environment and the arrival of circa .7 million people from the former colonies who brought a significant number of vehicles (of all kinds and state), created an enormous tension to all the infrastructures, including the road environment. To help an almost chaotic social and economic situation, a part of those "new" inhabitants, coming from Mozambique with lhd vehicles, were used to drive on the left hand side of the road. In the 1971 to 1975 period the population grew by 7%, GDP by 19%, and vehicle registration by 47%. The following ten years were of social and economic stabilization in a way that led to the adhesion to the EEC. In 1977 there was a slump in the economic situation with a first intervention by the International Monetary Fund. The balancing of the national accounts was followed by another expansion period, especially in private consumption, that led to the necessity of another intervention, in 83, by the IMF. In the 1975/1980 period population grew by 5% and vehicle registration by 32% with a steady pattern. Between 1980 and 1985 the population growth began to slow down (2%) but vehicle registration was still growing by 28%. In 1985 Portugal joined the EEC. This situation prompted a big surge in public expenditure (mainly in infrastructures) and in private consumption in the next decade, with a deceleration at the end of the period. In the 1985/1990 period population decreased by 1% and vehicle registration went up by 43%. Between 1990 and 1995 these indicators grew by 1% and 56%, respectively. In the 1990 to 1995 period driving licenses issuing grew by 41%. In 1985/1990 the growth rate was 61% and 161% between 1990 and 1995.

In terms of road safety we can trace two important changes in the next decade: in 1998 Portugal altered the accountability of the “death at 30 days”, from 1.3 to 1.14, which brought a big change in statistics; the surge in investment saw a flux of immigration from Brazil, Africa and Eastern countries (former Warsaw pact). Those new road users were a challenge in cultural terms. In this decade population grew by 2% and 3% (in each five years’ period), vehicle registration by 38% and 16%, driving licenses by 24% and 15%, motorway network by 58% and 60%. At the end of 2005 female drivers represented 38% of all drivers.

3.3 Quality of the predictions

To assess how well models implemented here have done in the past, the data up to 2001 are used to forecast the fatalities between 2002 and 2008. Figure 5 below shows a comparison between the predicted and the actually observed values.

Figures below shows a comparison between the predicted and actually observed values for the exposure (Figure 5) and for the fatalities (Figure 6), with de “full model” (left-hand), the “fixed slope risk model” (right-hand) and the “fixed slope risk and level exposure model” (below left-hand). The quality of forecasts of all three models is similar.

3.3.1 Exposure

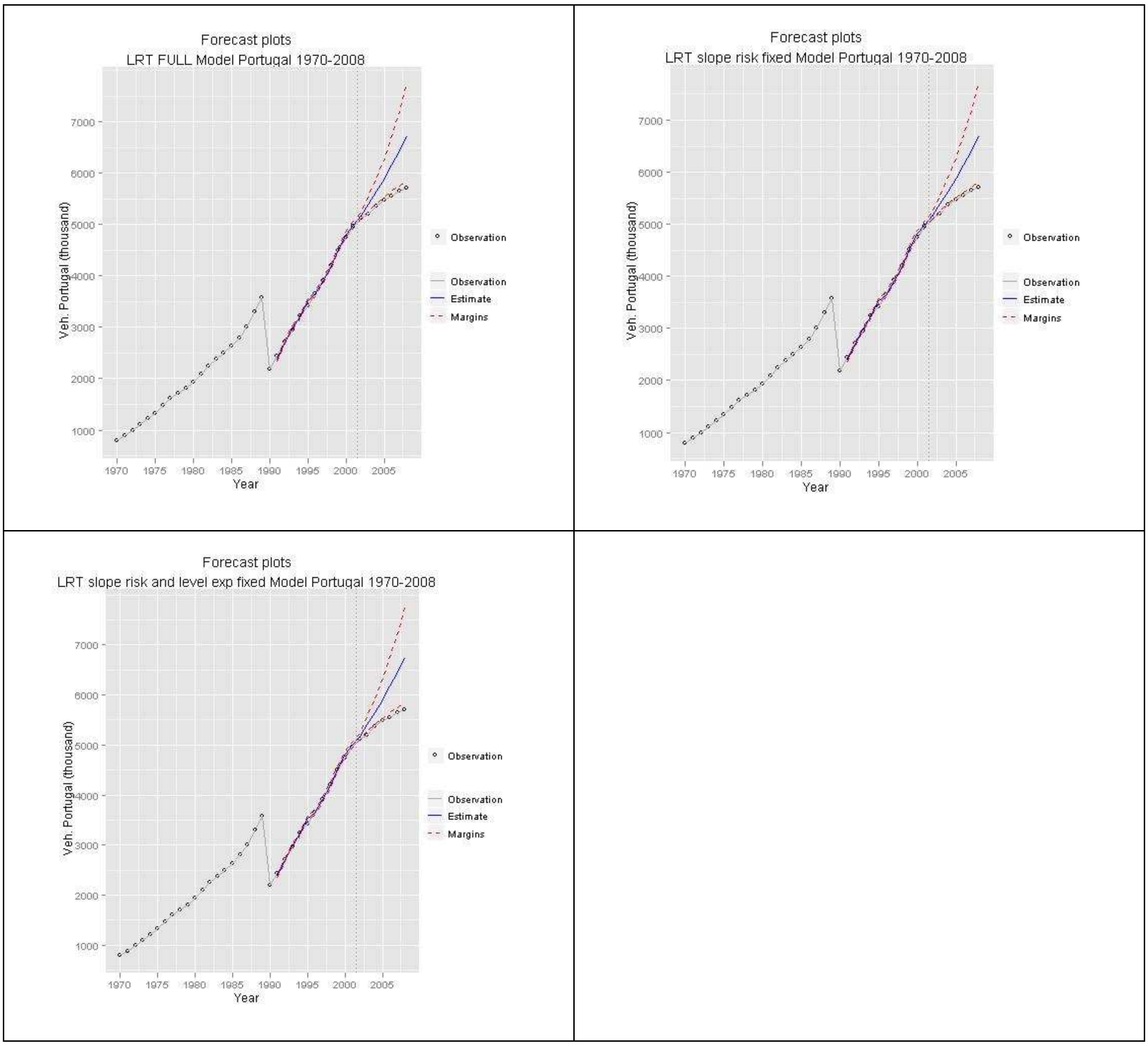


Figure 5: Plots comparing the model (Full, LRT2 and LRT3) predictions (straight line) with the actual observations ("bullets") for the exposure numbers in Portugal.

3.3.2 Fatalities

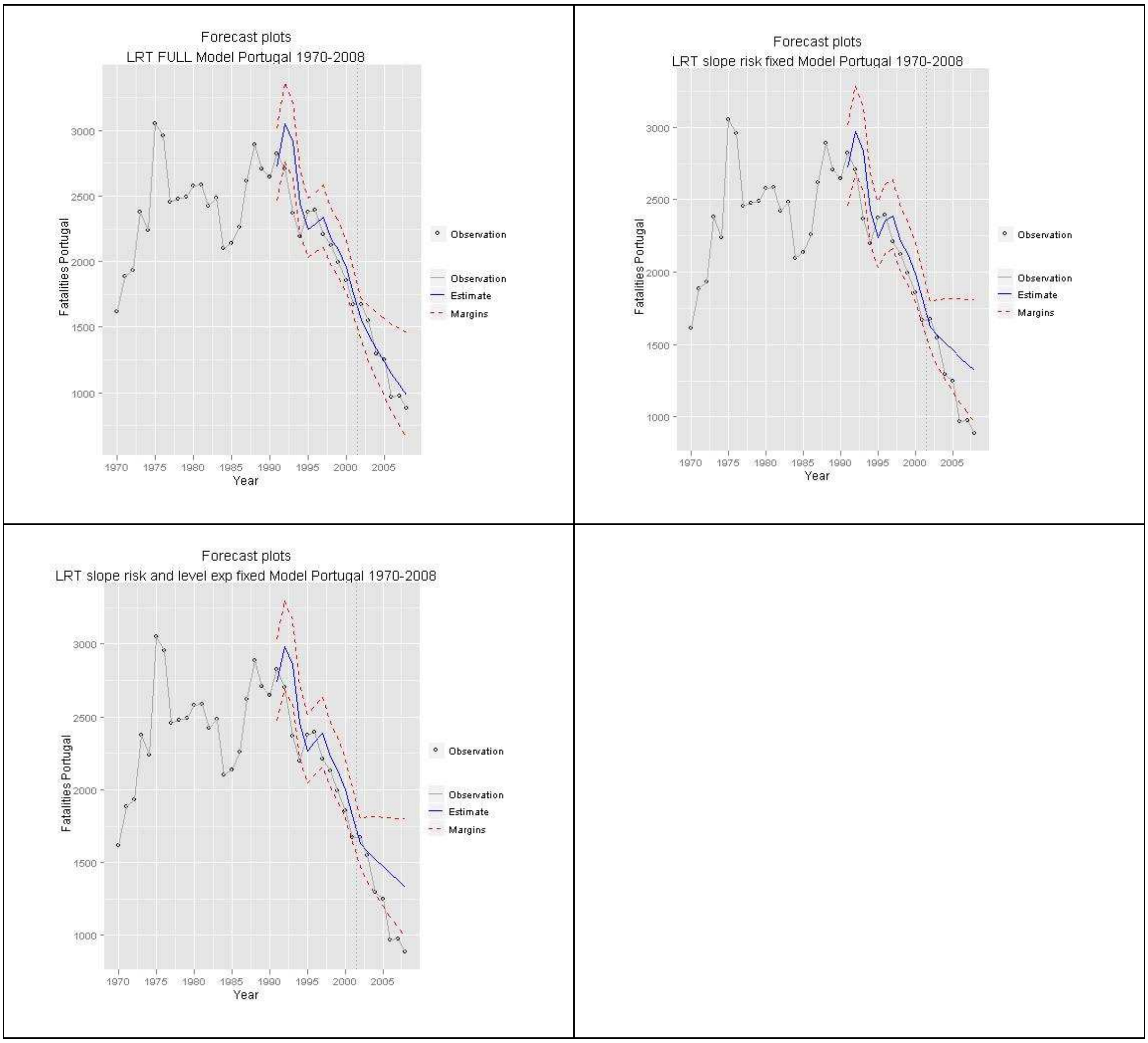


Figure 6: Plots comparing the model (Full, LRT2 and LRT3) predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in Portugal.

4 Forecasts 2009 - 2020

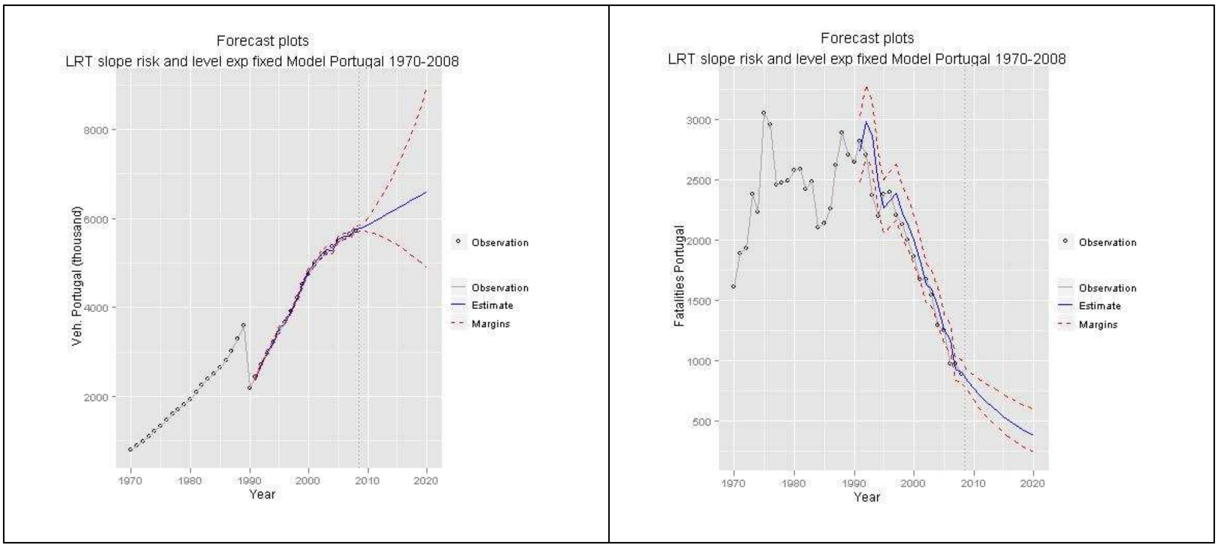


Figure 7: Plot of the vehicle fleet (left -hand graph) and annual fatality numbers (right-hand graph) for Portugal forecasted from LRT3 model between 2009 and 2020.

The forecasts in Figure 7 and Table 3 provide an indication of the vehicle fleet and the fatality numbers to be expected between 2009 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Vehicle fleet (thousand)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2009	**5786**	5647	5928	**826**	677	1006
2010	**5857**	5554	6177	**768**	587	1007
2011	**5929**	5428	6476	**715**	513	998
2012	**6001**	5276	6827	**666**	449	986
2013	**6075**	5103	7231	**620**	394	974
2014	**6149**	4916	7692	**577**	346	962
2015	**6225**	4717	8215	**537**	303	952
2016	**6301**	4509	8806	**500**	265	944
2017	**6378**	4295	9472	**465**	231	937
2018	**6456**	4078	10221	**433**	201	933
2019	**6536**	3860	11065	**403**	175	931
2020	**6616**	3643	12013	**375**	151	931

Table 3: Forecasts of Latent Risk Model (LRT 3).

5. Scenarios

In Figure 7 it can be seen that there is strong uncertainty about the development of the exposure in Portugal. Given that the exposure influences the prediction of the fatalities it is interesting to see how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 8 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

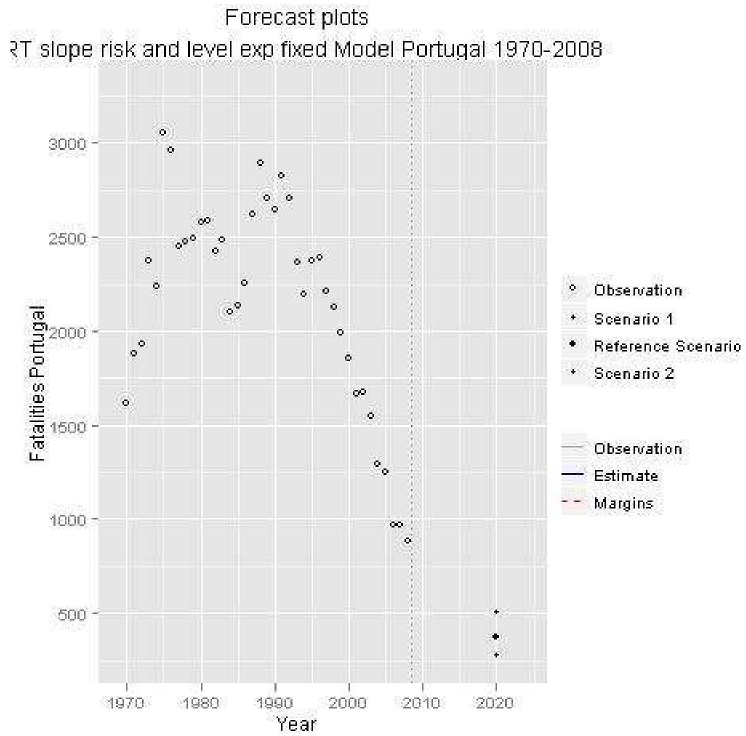


Figure 8: Fatality forecasts Portugal 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the vehicle kilometres as predicted from the LRT model plus/minus one standard deviation.

The full dot in Figure 8 is the expected number of fatalities given that mobility keeps developing as it has before (prediction 6,616 thousand vehicles). The circles indicate the estimated number of fatalities for a stronger growth for exposure (forecast plus one standard deviation: 8,954 thousand vehicles) and for a decrease in mobility (forecast value minus one standard deviation: 4,888 thousand vehicles). The prediction that we achieve under these three scenarios are summarized in Table 4.

	Vehicle fleet (thousand)	***Road traffic fatalities***
Situation 2008:	5716	885
Prediction for 2020 according to mobility scenarios:		
Continuation of development	6616	375
Stronger growth	8954	507
No growth	4888	278

Table 4: Forecasting scenarios on the basis of the Latent Risk model (LRT 3). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation.

ROMANIA

1. Raw data

1.2 Exposure

For Romania there are vehicle kilometres (per million) for the last 5 years. The number of measurements is not enough to use this information in a time series. However, the information about mobility in the most recent years will turn out to be interesting to interpret the development of the fatalities.

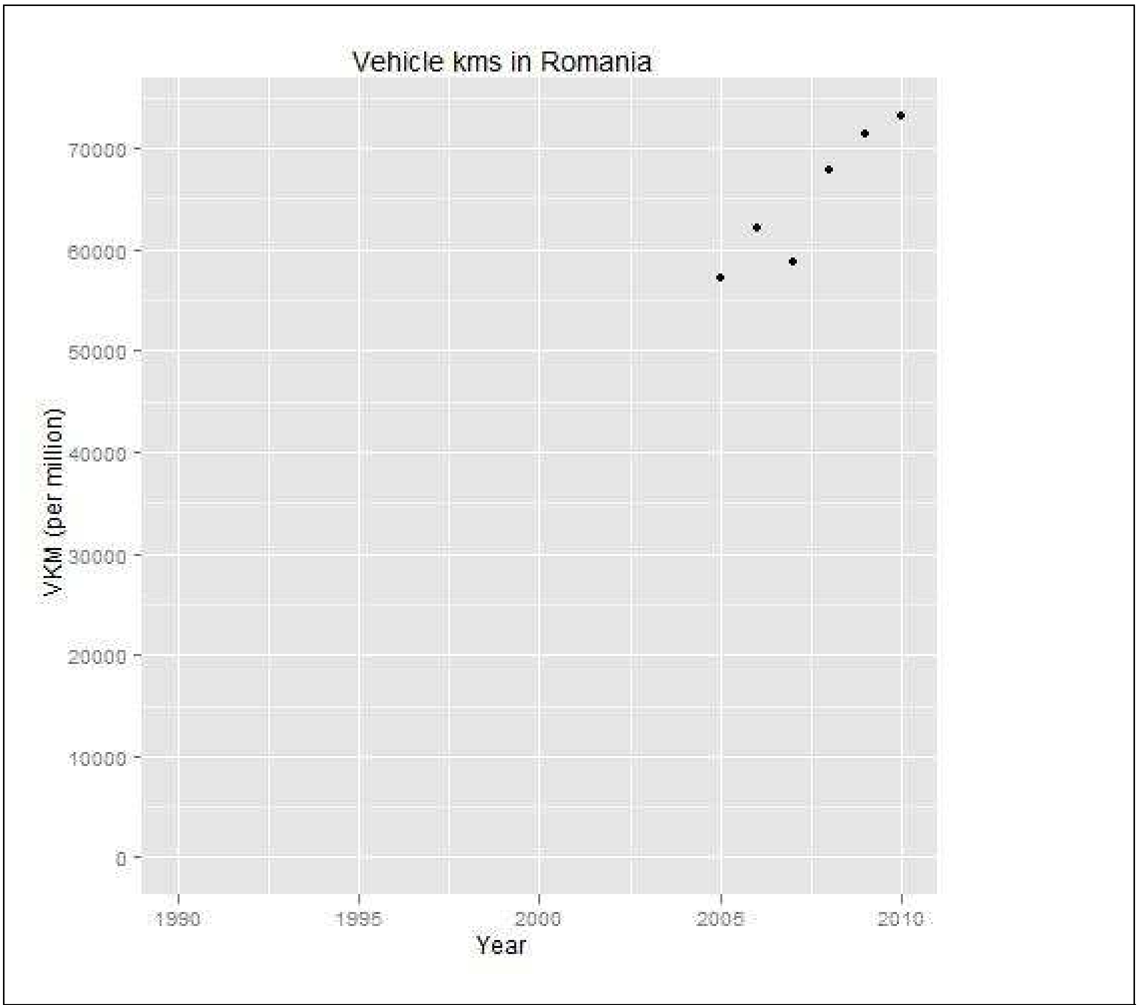


Figure 1: Plot of the Vehicle kms (per million) for Romania from 2005 to 2010.

1.2 Fatalities:

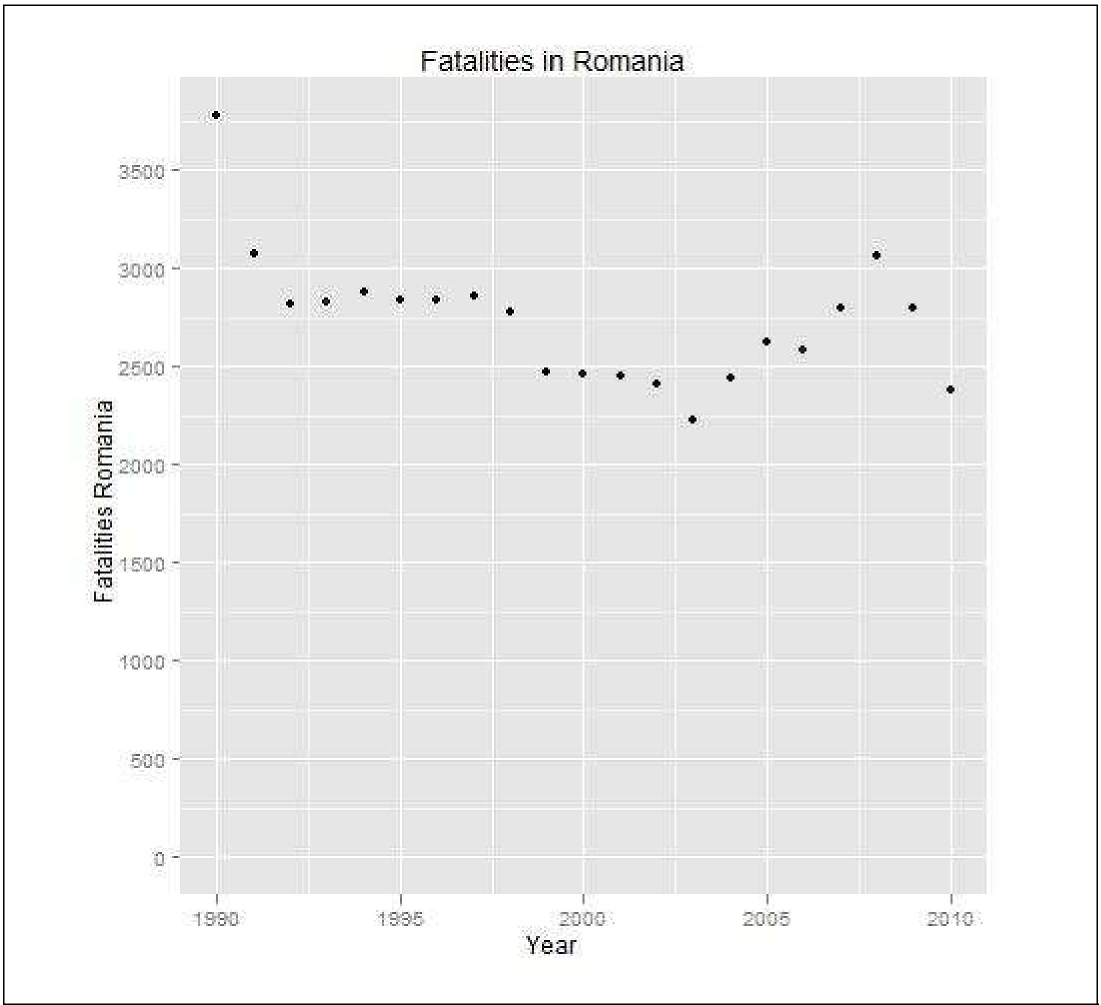


Figure 2 : Plot of the annual fatality counts for Romania from 1990 to 2010

The analyses begin in 1990, when a new regime was put in place. In the first place after its introduction, the fatalities were reduced. This is a relatively unique phenomenon, as most of the Eastern European countries experienced a strong increase of the number of fatalities after the fall of the iron curtain. Possibly the economic problems after the revolution kept the mobility in the early nineties in Romania low.

Between 2003 and 2008 the number of fatalities increased strongly so that in 2008 the number of fatalities was back at the high level that it had in 1991. In these years of economic progress, road safety was not a priority and no strategy or plan existed to improve it. After 2008, the police made a huge effect to decrease the number of road traffic accidents, which is visible in the strong drop in fatalities visible for the last two years [1].

2. SUTSE model

To calculate a SUTSE or an LRT model, an exposure measure is necessary. This is available in Romania only for the last 5 years in the form of the vehicle kilometres. A model based on these 5 years can consequently not be satisfactory. However, these 5 years include a crucial moment in time, namely the trend change of the fatality number in 2008. We have shown that the fatalities showed a significant change in slope at that moment. A bivariate model, although probably not satisfactory in some aspects, can therefore indicate whether this should be attributed to a change in exposure, or whether it is still significant when exposure (at that moment) is accounted for.

2.1 SUTSE model: development of the state components:

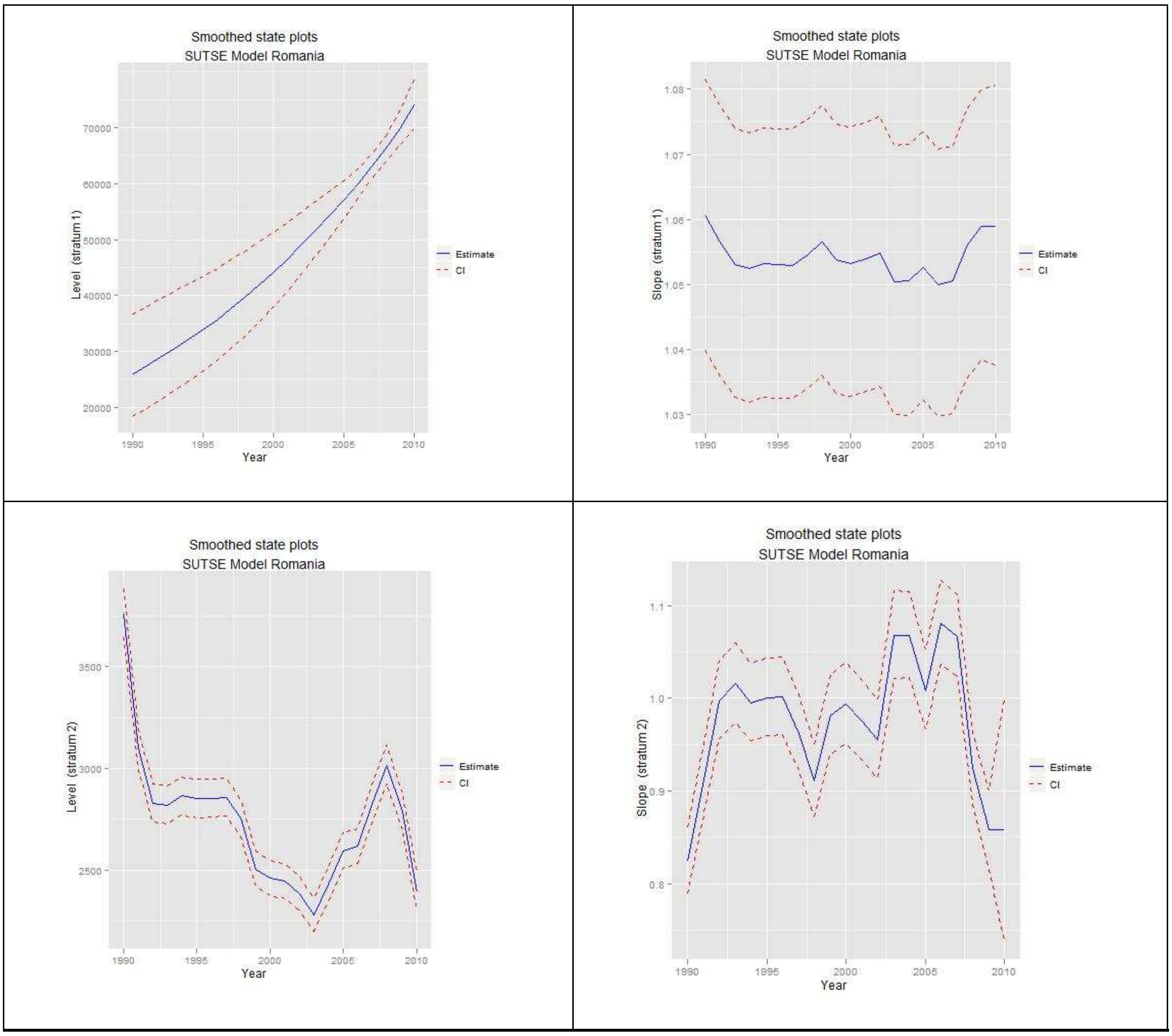


Figure 3: Developments of the state components for the Vehicle kms (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the right-hand graphs, the slope developments in the left-hand graphs.

2.1.1 Vehicle kilometres

The kilometres between 2005 and 2010 show a more or less constant increase. There is no evidence against a deterministic development of the exposure. The model assumes that the development observed in 2005 to 2010 has been a continuation of a same process in the years before. An observed increase of 5 to 6% yearly leads to an estimation of 25 Billion (10^9 Vehicle kms in 1990.

Neither the trend nor the slope show significant stochastic variation.

It is noteworthy that the latest recession, which is clearly visible in the development of the GDP from 2009 on, is not visible in the development of the mobility estimated by the vehicle kilometres.

2.1.2 Fatalities

The trend in the fatalities shows a decrease after 1990 until 2003. From 2003 to 2008, the number of fatalities increased and since 2009 they have been decreasing.

Like the state variances for the exposure, those for the fatalities are not significant. This suggest that the model, with just 5 measurements for exposure is not sensitive to the development that is actually contained in the data.

2.2 Relation between the exposure and fatality series:

No variances and no covariances are significant for the model. In the SUTSE beta model the relation between the states for exposure and the states for fatalities is estimated by a coefficient (beta). This coefficient is not significant however either. It can be concluded that the inclusion of the vehicle kilometres does not have an effect on the model and forecasts of the fatalities.

The Romanian fatalities are therefore modelled without any exposure measure in a Local Linear Trend Model (LLT).

Model title		***SUTSE***	***SUTSE beta***
	Model description		Indipendent components coefficient estimated
Model Criteria			
	log likelihood	51,61	51,61
	AIC	-102,37	-102,46
Variance of state components			
	Level exposure	3.37E-04 nsc	3.37E-04 *
	Level risk	2.72E-04 nsc	3.06E-13 ns
	Slope exposure	3.04E-08 nsc	6.18E-16 ns
	Slope risk	7.25E-04 *c	7.28E-04 ns
Correlations between state components			
	level-level	-1	
	slope-slope	1	
Observation variance			
	Observation variance exposure	1.07E-06 ns	1.15E-06 ns
	Observation variance risk	2.22E-03 ns	2.22E-03 ns
Beta			0.382 ns

Table 1: Overview of the results for SUTSE models - Belgium

The Romanian fatalities are therefore modelled without any exposure measure in a Local Linear Trend Model (LLT).

3. The LLT Model:

3.1 Model selection

Analysing the fatalities by themselves in a latent linear trend model yields the results presented in the table below.

Model title	***LLT1***	***LLT2***	***LLT3***	***LLT4***	***LLT5***
Model description	full model	fixed level	fixed slope and level	fixed level + intervention 2008	fixed slope
Model Criteria					
ME10	437	437	435	437	614
MSE10	310077	310077	318367	310078	550647
ME7	926	926	616	926	756
MSE7	978974	978974	450936	978974	656524
ME4	68	140	540	140	319
MSE4	80323	82123	338058	82123	144331
log likelihood	23.5483	23.5483	15.3135	17.1667	22.64
AIC	-46.8109	-46.9061	-30.5317	-34.1429	-45.08
Model Quality					
Box-Ljung test 1	2.98805	2.36432	12.2652***	1.82137	4.17*
Box-Ljung test 2	4.40481	2.98805	17.7677***	1.99355	5.185
Box-Ljung test 3	8.35159*	4.40481	21.0478***	4.54018	6.016
Heteroscedasticity Test	4.40203	4.40203	3.76031	2.22812	1.535
Normality Test standard Residuals	0.322235	0.322235	0.406178	0.709745	2.492
Normality Test output Aux Res	0.513184	0.513183	2.55604	0.358179	0.670
Normality Test State Aux Res Level	1.03049	1.03049	0.825641	2.03474	1.103
Normality Test State Aux Res Slope	0.0891277	0.0891279	0.00239502	0.756101	0.614
Variance of state components					
Level	7.81E-15 ns	-	-	-	6.25E-03 *
Slope	5.46E-03 ns	5.46E-03 *	-	3.53E-03 *	-
Observation variance					
Observation variance	1.00E-09 ns	1.00E-09 ns	9.94E-03 *	1.00E-09 ns	1.00E-09 ns
Interventions					
Slope intervention in 2008				-0.192717 *	

Table 2: Overview of the results for LRT models for Belgium

To investigate whether an intervention is implied by the time series, the auxiliary residuals for LLT2 (fixed level) were used.

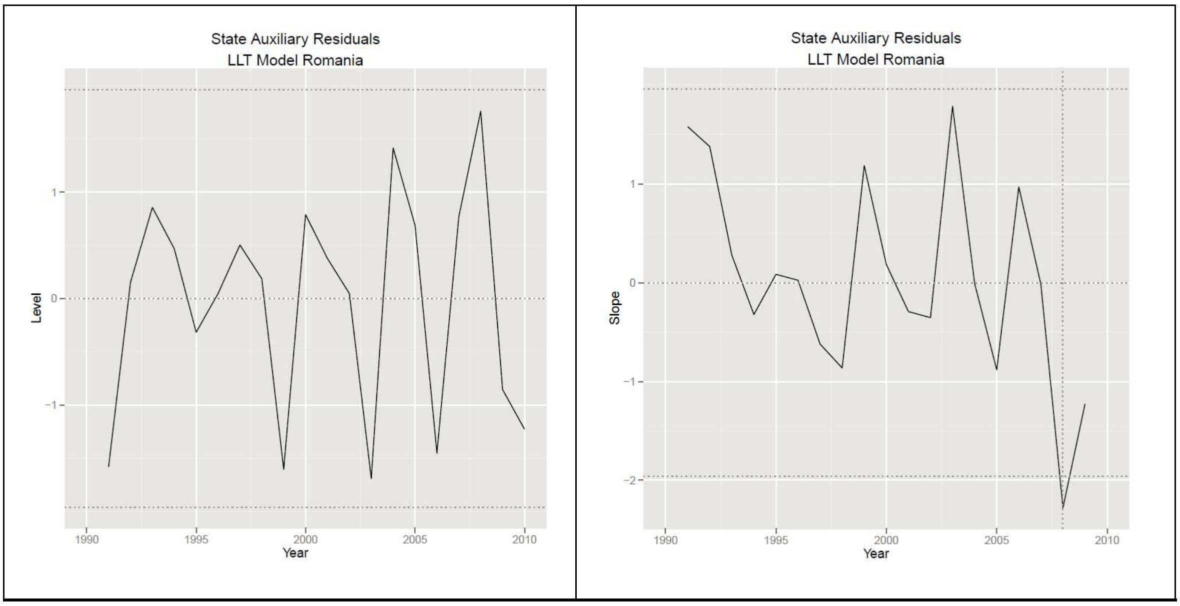


Figure 4: auxilliary residuals for model LLT fatalities 2 (fixed level). Left hand panel: Residuals of the level. Right hand panel: residuals of the slope.

The (standardized) auxilliary residuals indicate to which extent the time series departs from the model that was fit on the data. Residuals between 1.96 and -1.96 are within the range of to be expected deviations from the model. If the deviation exceeds this interval, an intervention can be considered to model this abnormality in the series. In Figure 4 we can see that there are no particularly strong deviations in the level variance, but in the slope variance there is peak downwards in 2008. This means that from 2008 on, there is a decrease that is significantly stronger than what could be expected on the basis of the years before.

In the fourth LLT model, the fixed level model (LLT2) was rerun but with a slope intervention in 2008 that adds the change of direction to the system dynamics. The intervention indicates that there was a significant change of direction in the fatality development in 2008.

Given that the slope variance was not actually significant, one could also start from the full model with fixing the slope only. LLT5 shows that this leads to a model that is only marginally worse than the models in which the level has been fixed. However, one significant test of autocorrelation (Box Ljung 1), a marginally lower Likelihood and less favourable values for the prediction error criteria (for 4 and 10 year predictions) all point in the same direction: a model with a fixed slope is statistically preferable to one with a fixed slope.

As the final model, the fixed level model with a slope intervention in 2008 (LLT4) is selected. This means that the fatalities in Romania have been following a smooth trend model, with decreases, increases, and stagnations in different phases. No clear trend can be identified and most recently in 2008 a significant change in direction has been observed.

3.2 Development of the state components

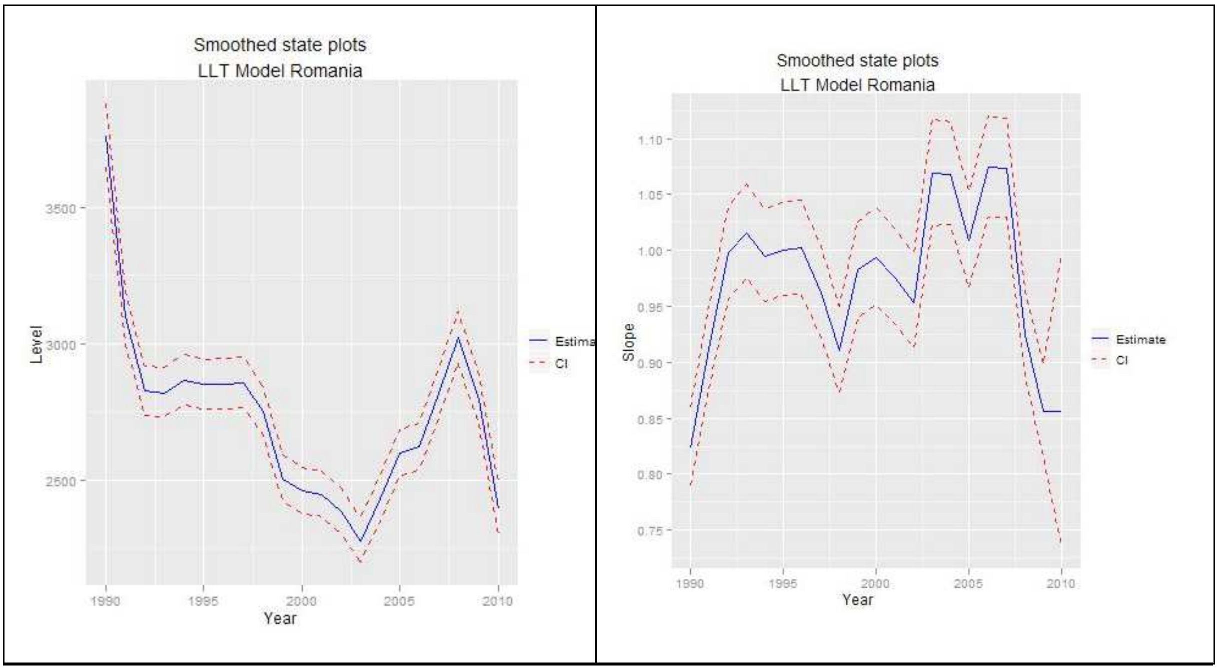


Figure 3: Developments of the state components for the fatalities, as estimated on the basis of the full Local Linear Trend model (LLT1). The trend (level) developments are represented in the right-hand graph, the slope developments in the left-hand graph.

3.3 Quality of the predictions:

In Figure 5, we can see the predictions of different models based on the data up to the year 2000 for the number of fatalities observed since then. It can be seen that all models in which the slope is *not* fixed (LLT1, LLT2, LLT4) make very similar predictions. The show an undershoot of the actual observations, but these fall into the 68% confidence interval, which is extremely wide.

The model with a fixed slope (LLT5) predicts a much lower number of fatalities, which strongly undershoots the actually observed values. The confidence interval is relatively small … but the observed values fall beyond its borders.

In general fixing the slope leads to much smaller confidence interval, and it can be seen here, that the Romanian fatalities have not followed such a clear trend to allow predictions with a small confidence interval.

The selected forecast model LLT4, therefore has a very wide confidence interval.

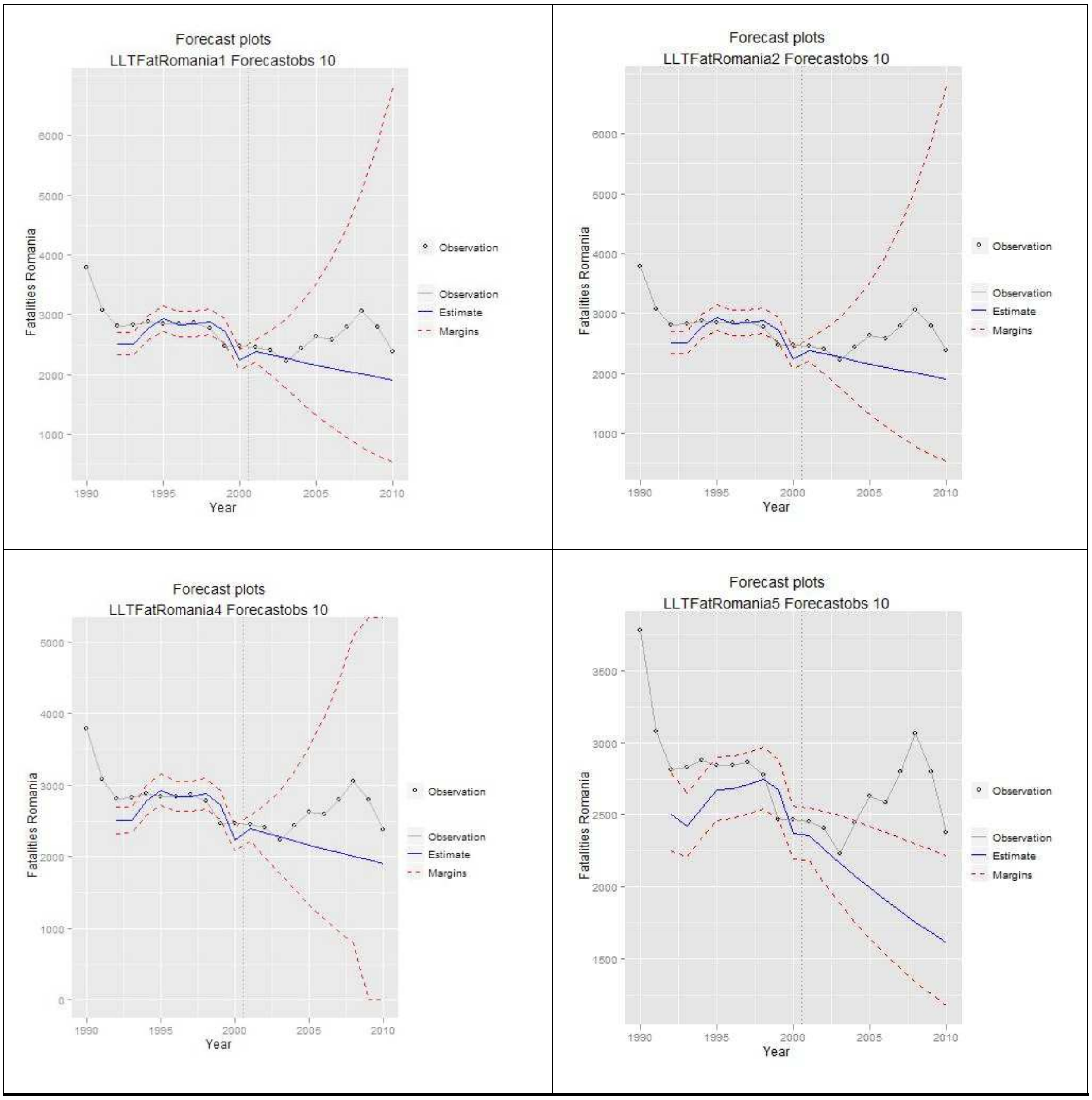


Figure 5: Plot of the annual fatality numbers for Romania and the forecasts for 2010 based on data until 2000. Upper left: LLT1 full model; upper right: LLT2 fixed level; lower left: LLT4 fixed level, intervention in 2008; lower right: fixed slope model.

4. Forecast 2020:

The forecasts are based on a model with a stochastic slope (LLT4) and a slope intervention in 2008 (LLT4). The stochastic slope means that the rate of change has varied significantly over the years, and indeed Romania has seen periods of decrease, increase, and stagnation. Nevertheless, a slope intervention in 2008 was significant, suggesting that the drop from 2008 to 2010 was steeper than could have been expected from the past developments. As the slope is allowed to vary, for the forecasts it takes the value of the last two years, which amounts to the assumption that the fatalities up to 2020 will decrease at the same rate as they have between 2008 and 2010.

Under this assumption, the following forecasts can be made:

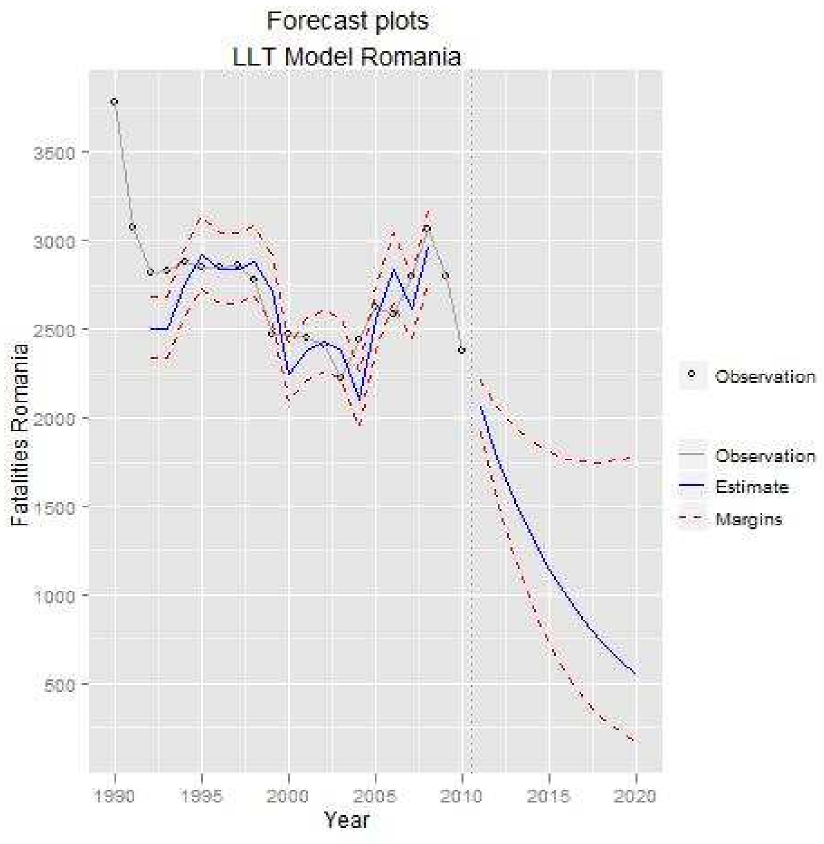


Figure 6: Plot of the annual fatality numbers for Romania and the forecasts for 2020. Based on LLT4 smooth trend model with intervention in 2008.

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**2062**	1792	2373
2012	**1779**	1334	2373
2013	**1535**	962	2449
2014	**1324**	676	2596
2015	**1143**	464	2816
2016	**986**	311	3121
2017	**851**	205	3527
2018	**734**	133	4059
2019	**633**	84	4752
2020	**546**	53	5655

Table 3: Forecasts of the Latent Risk Model (LLT4 – fixed slope + intervention 2008)

It must be noted that an alternative model (LLT5) which assumed the average rate of change over all years since 1990 (-2.5%) shows only a slightly reduced fit and does not differ significantly from the selected model**. While the selected model leads to a forecast of just *546* fatalities in 2020, this alternative model leads to a forecast of *1916* fatalities.**

The fact that two models that cannot be statistically distinguished from each other produce so radically different forecasts, underlines what the large confidence intervals also imply: the past development of the Romanian fatalities does not really allow a useful forecast

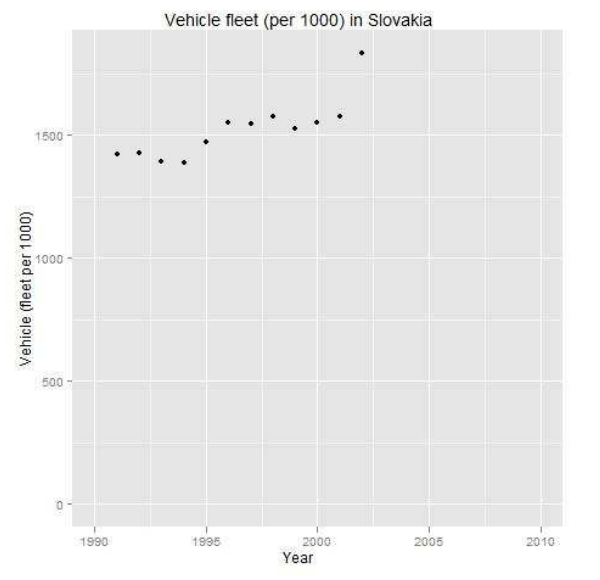
SLOVAKIA

We decided to begin our model in 1990, after the change of the political regime.

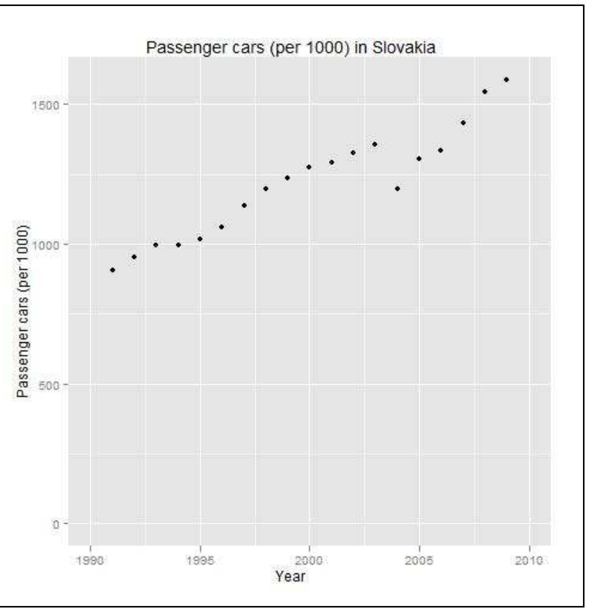
Raw data

1.1 Exposure

For Slovakia there is a total count of vehicles and a count of passenger cars.



Total number of motor vehicles in Slovakia 1991 to 2002.



Number of passenger cars in Slovakia in thousands 1991 to 2009.

The count of motor vehicles ends in 2002 (source: IRTAD). While there is only a very small increase in the years 1991 to 2001, there is a very strong increase in the last counts. The reason for this `jump` is not known. Data about the total number of vehicles is not available after 2002. Moreover, the last measurement (2002) seems an unlikely continuation of the series.

The number of passenger cars is available for a longer time and is more recent. It has one visible inconsistency, namely, the strong and sudden decrease from 2003 to 2004. This drop co-occurred with the moment at which Slovakia joined the EU. This involved the obligation to acquire a new licence plate for each registered car. Cars that were not actually in use did not get new plates, leading to a cleaning of the database. As a consequence, this drop will be corrected for by means of an intervention in subsequent analyses.

1.2 Fatalities:

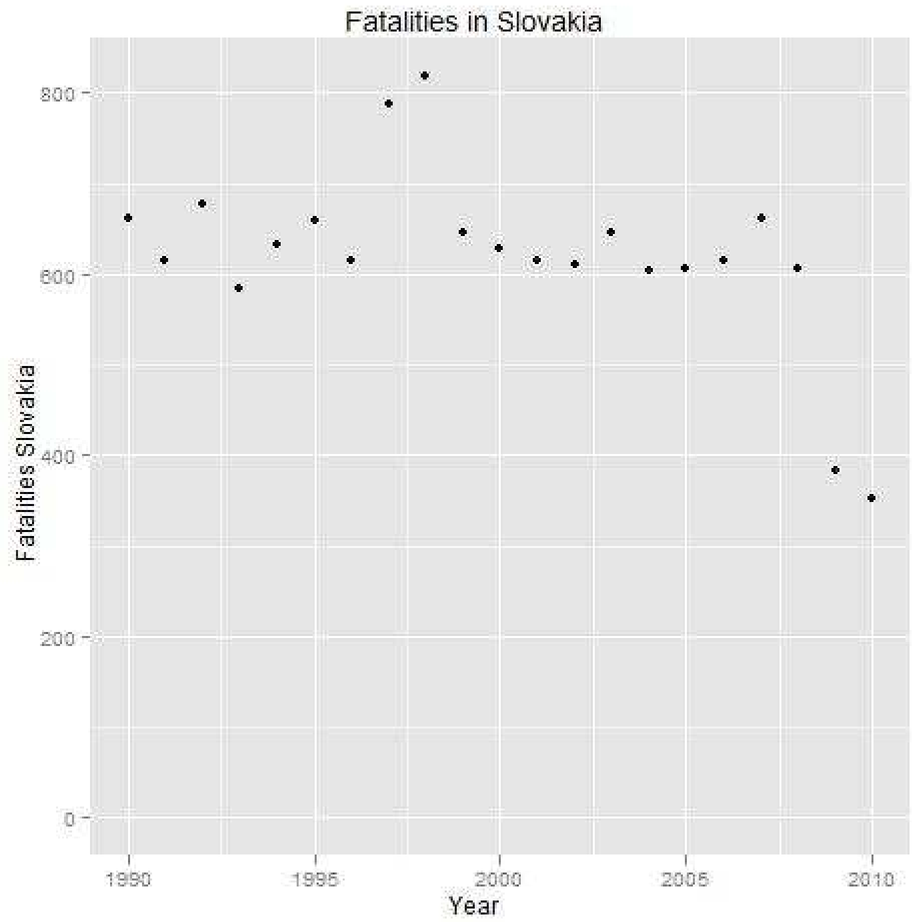


Figure 2: Plot of the annual fatality counts for Slovakia from 1990 to 2010.

The number of fatalities has been more or less stagnating throughout the years. There are two strong exceptions to this general trend: In 1997 and 1998 there was a very strong peak in the number of fatalities while it was greatly reduced in 2009 and 2010. Both developments appear to be `real` in the sense that they are not due to a shift in the registration method.

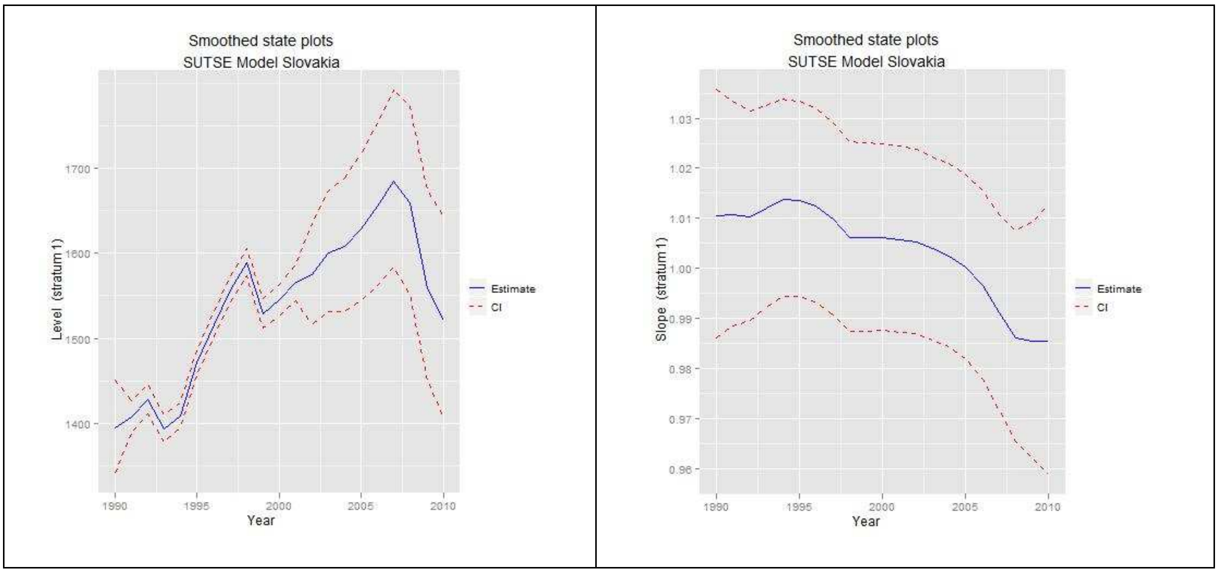
In 2009, higher fees for traffic violations were introduced and violations can since then be punished by permanent license withdrawal. In parallel, many other measures have been taken, like RS education in schools, awareness raising campaigns, promotion of visibility aids for pedestrians and cyclists, etc.. Road safety got moreover a lot of media coverage. The drop in fatalities goes together with a drop in the RSPI´s [1].

2 The SUTSE Model:

Two different SUTSE models were calculated, involving the different types of exposure variables: total number of vehicles (Total fleet), number of passenger vehicles (passenger fleet). For the total fleet, the last value (2002) was declared missing and for the passenger fleet an intervention was added in 2004, to account for the sudden drop in vehicle numbers.

2.1 Development of the state components:

Below the resulting states from two SUTSE models are presented: SUTSE 1 with the total vehicle fleet and the fatalities and SUTSE 2 with the passenger vehicle fleet and the fatalities. The exposure states for both analyses are presented in the upper (SUTSE1) and middle graph (SUTSE2). The fatality states are only presented for SUTSE2 (lower graph). Those for SUTSE 1 look identical.



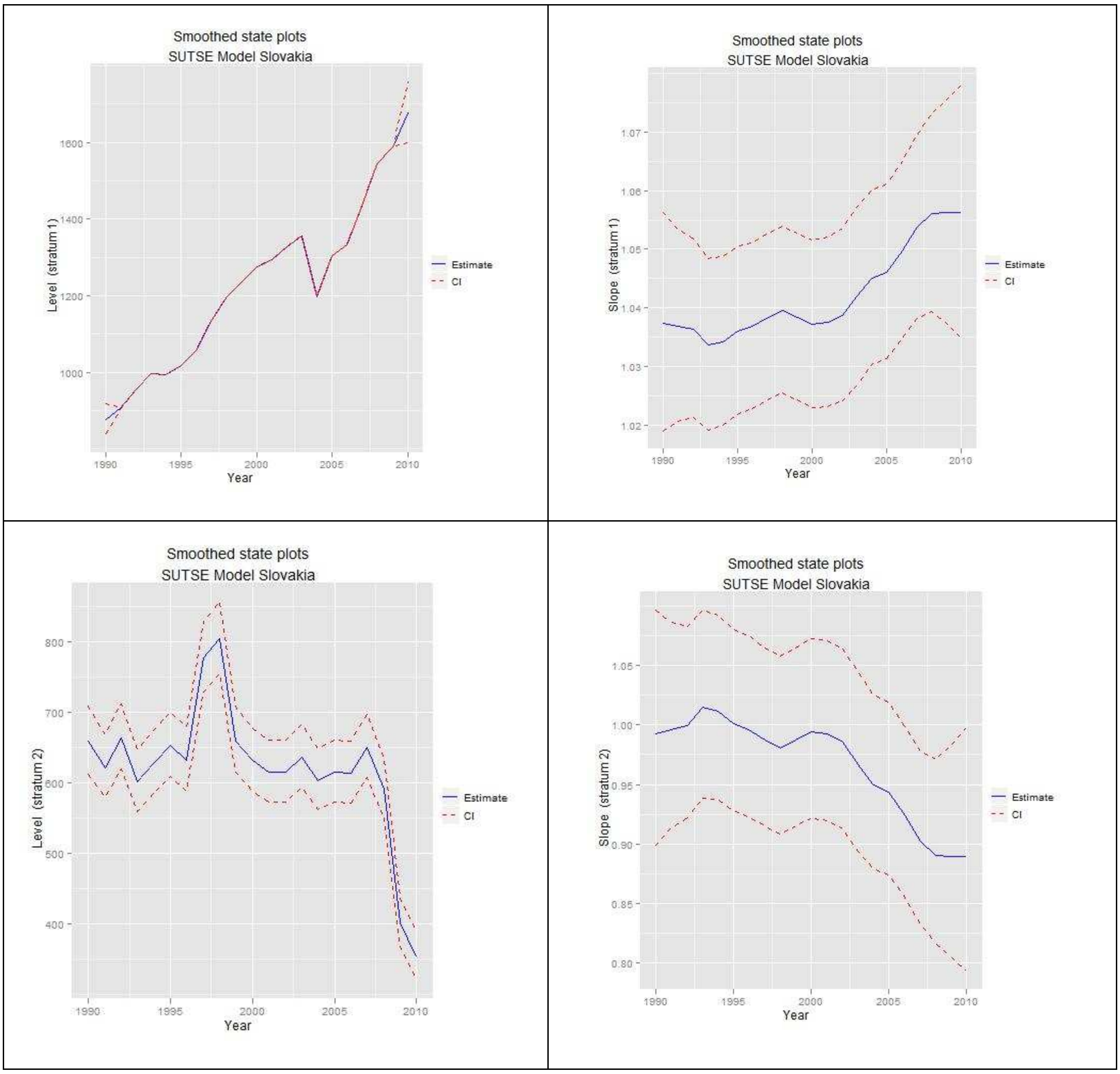


Figure 3: Slovakia - Developments of the state components for the *total vehicle fleet* (per 1000 vehicles) (upper graphs), the *passenger car fleet* (per 1000 vehicles) (middle graphs) and the *fatalities* (lower graphs), as estimated on the basis of the SUTSE1 (middle and lower graph) and SUTSE2 (upper graph). The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Total vehicle fleet

Neither the trend nor the slope for the total vehicle fleet is significant. The observed data for this series stop in 2001. From 2002 to 2010 the total number of vehicles has been estimated on the basis of the fatality development and the assumed relation of the fleet therewith.

2.1.2 Passenger cars

The passenger car fleet shows a big drop in 2004, which is modeled by an intervention. After the inclusion of this intervention neither the level disturbances nor the slope disturbances are significant.

2.1.3 Fatalities

Basically, the trend of the number of fatalities is stagnating between 1990 and 2007, however, this is interrupted by a dramatic increase for two years (1997, 1998) followed by an similarly dramatic drop to the earlier level. In the last three years (2008 – 2010) the trend has changed to a strongly decreasing one.

Neither the level nor the slope variance of the fatalities is significant in the full model.

Model title		***SUTSE 1***	***SUTSE 2***
	Model description	With total fleet (2002 missing)	With pass.fleet (intervention 2004)
Model Criteria			
	log likelihood	25.55	42.89
	AIC	-50.24	-84.92
Variance of state components			
	Level exposure	6.56E-04 nsc	5.11E-04 nsc
	Level risk	9.06E-03 nsc	1.40E-02 nsc
	Slope exposure	4.67E-05 nsc	2.30E-05 nsc
	Slope risk	9.29E-04 nsc	8.62E-04 nsc
Correlations between state components			
	level-level	1	0.37
	slope-slope	1	-1
Observation variance			
	Observation variance exposure	1.14E-04 ns	1.03E-09 ns
	Observation variance risk	2.85E-03 ns	1.02E-09 ns
Interventions			
	2004 exposure level		-0.16 *
Beta		3.84	0.34
p(Beta)		0.18	0.72

Table 1: Model criteria and results for SUTSE models Slovakia.

2.2 Relation between the exposure and fatality series

First, the presence of a relationship between the fatality series and each of the two possible exposure indicators was investigated. First the correlations between the state components were evaluated. Then, for each model a restricted version of the model was ran, where the relation between both series is estimated by means of one coefficient (beta).

2.2.1 Correlation between the disturbances of the state components

Neither the total vehicle fleet, nor the number of passenger cars are found to be significantly related to the number of fatalities on the basis of the disturbances of the state components Correlation between the measurement errors

2.2.2 Correlation between the irregulars

In none of the analyses the measurement errors of fatalities and exposure were related (all correlations < .002; all p´s > .3).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is not significant for either SUTSE model.

3 The LLT Model:

As the SUTSE indicated no significant relation between fatalities and the two available exposure measures, in the following we will model the fatalities by means of an LLT model.

3.1Model selection:

Model title	***LLTFat1***	***LLTFat2***	***LLTFat3***
Model description	Full model	Fixed slope	Fixed level
Model Criteria			
ME10	-72.33	-72.33	-168.44
MSE10	15471.84	15471.83	42271.15
ME7	-83.7	-83.7	-50.35
MSE7	19695.67	19695.67	13025.07
ME4	-103.81	-103.81	-82.67
MSE4	28146.87	28146.87	22651.51
log likelihood	12.27	12.12	11.27
AIC	-24.26	-24.05	-22.357
Model Quality			
Box-Ljung test 1	1.1	1.03	1.44
Box-Ljung test 2	1.74	1.09	1.44
Box-Ljung test 3	1.96	1.61	1.93
Heteroscedasticity Test	2.22	2.38	2.61
Normality Test standard Residuals	6.58	6.85*	7.25*
Normality Test output Aux Res	0.34	0.37	0.45
Normality Test State Aux Res Level	5.91	8.38*	2.07
Normality Test State Aux Res Slope	0.1	0.00	1.61
Variance of state components			
Level	1.55E-02 ns	1.75E-02 *	-
Slope	4.44E-04 ns	-	4.35E-03 *
Observation variance			
Observation variance	1.00E-09 ns	1.00E-09 ns	5.20E-03 *

Table 2: Model criteria and results for LLT models for RS fatalities in Slovakia.

In Table 2 it can be seen that in the full LLT model, neither state components is significant. This means that a model where only one of the components is fixed does not lead to an important reduction in model fit (i.e., the likelihood).

In LLT2 however, where the slope is fixed, the level does become significant. Conversely, in LLT3 where the level is fixed the slope is significant. For LLT2, the fixed slope model, the fit is somewhat better. This model is therefore selected as basis for the forecasts.

In all 3 models, the residuals show a deviation from normality. This is due to the strong drop of fatalities between 2008 and 2009. Although a break is indicated here, due to a lack of knowledge on its interpretation (progress in Road Safety Management, Economic recession,…), no intervention is included.

3.2 Development of the state components:

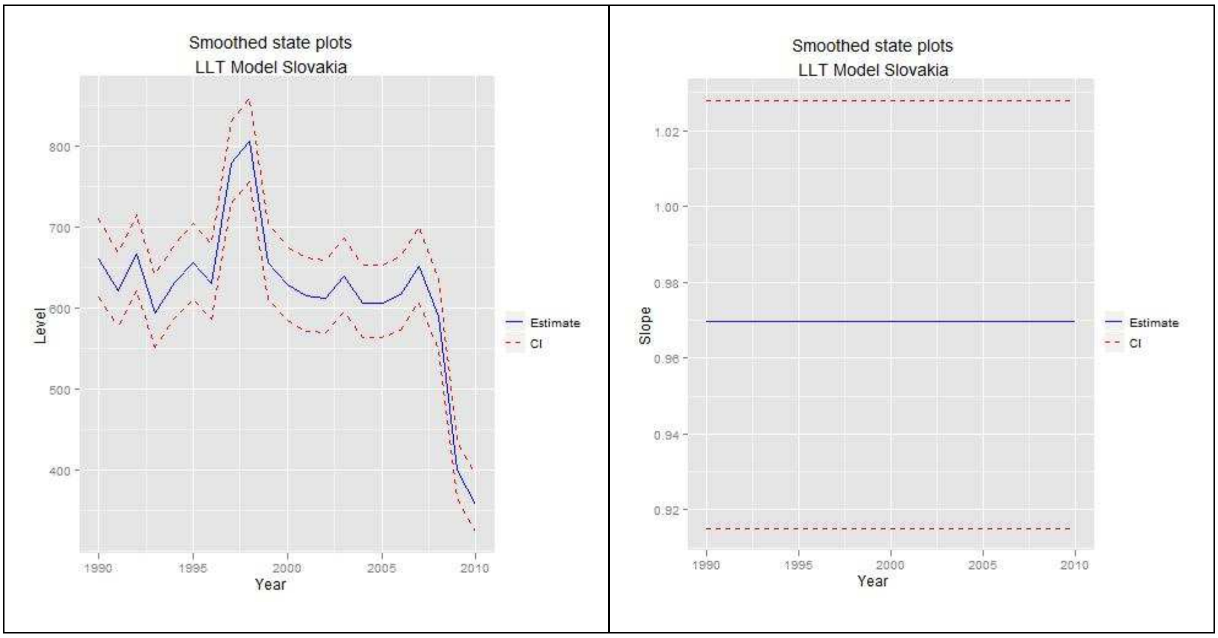


Figure 23.4.: Developments of the state components for the fatalities in Slovakia, as estimated on the basis of fixed slope model LLT2.

3.2.1 Fatalities

The best fitting model is the fixed slope model. This means that the dynamics are of the fatalities are best explained with a fixed slope, indicating a constant annual decrease of 3%, and random level changes added to this.

Figure 5: Auxilliary residuals for level (left panel) and slope (right panel) of fixed slope model LLT2.

The analysis of the auxiliary residuals presented in Figure 23.5 indicates that 2008 corresponds to a break of the trend observed until then. Given the information available, it cannot be determined whether a level break or slope break is more appropriate to model this change. A level break means that there is a step down but afterwards, the development continues in a similar way as before (like in 1997-1998). A slope break means a change of direction, meaning that the fatalities would keep dropping as they have between 2008 and 2009. Although statistically we cannot say yet which is true, the development in 2010 suggests that the fatalities will not keep dropping in the way they have the year before that.

3.3 Quality of the predictions:

To evaluate the models performance in the past, the data from 1990 to 2000 have been used to forecast these numbers for the years 2001 to 2010. For those last years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values where the predictions for the post-2000 years are based on the observed values up to 2000.

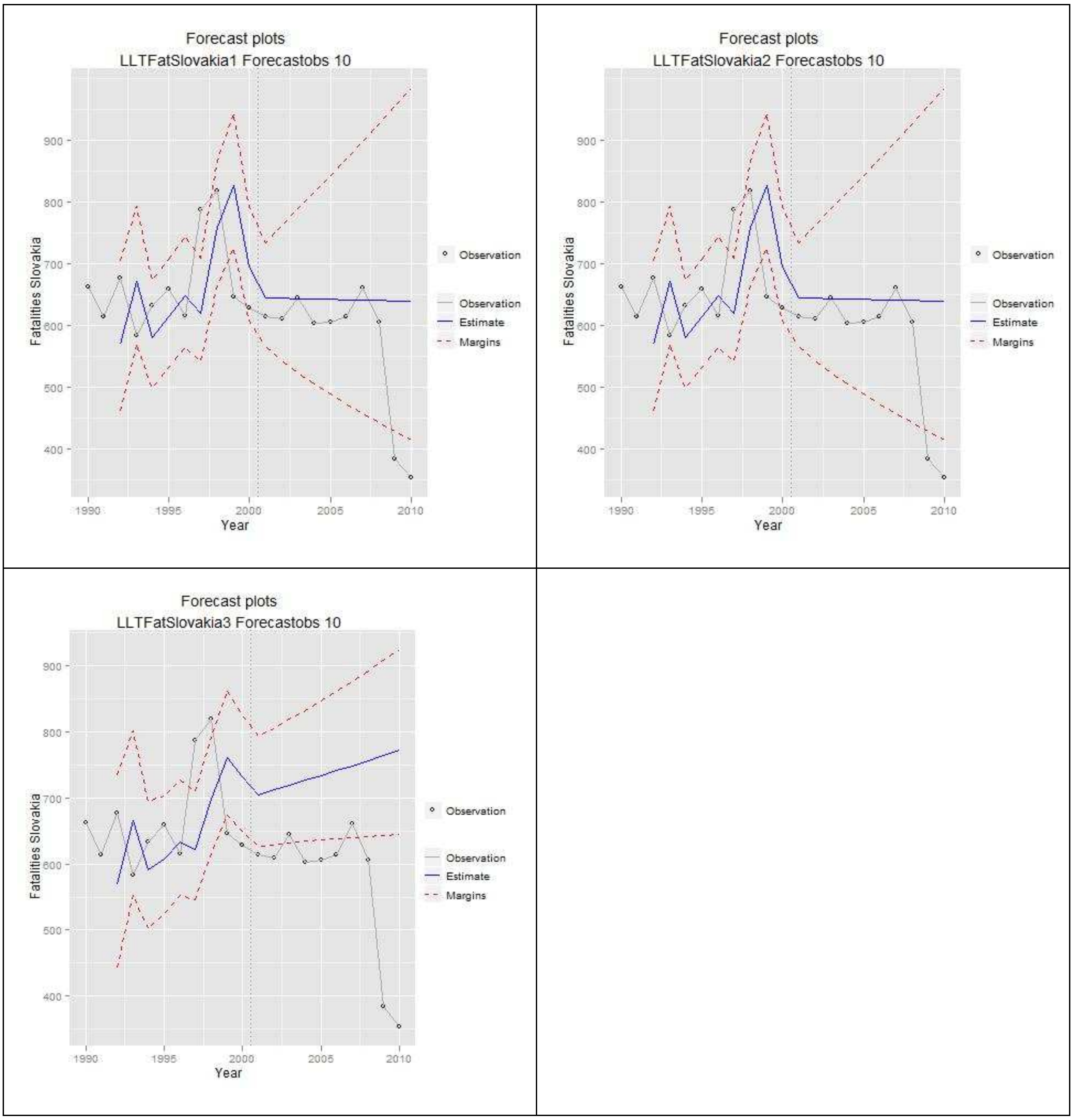


Figure 6: Plot of forecasts based on data until 2000.

None of the models appears to be able to predict the dramatic drop of the fatalities in 2008 on the basis of the pre-2000 data. This illustrates that the forecasts based on past developments are not necessarily accurate predictions of what is actually going to happen. The full model (LLT1) and the fixed slope model (LLT2) make essentially the same forecast.

A fixed slope model is a conservative model. Recent changes affect the forecasts only to a limited extent. The forecast of the fixed level model (LLT3) demonstrate that in a moment of dramatic changes such a conservative model might be the wiser choice.

4 Forecasts 2011 – 2020:

The model selected is the linear latent trend model with a fixed slope. The forecasts up to the year 2020 based on this model are presented in Figure 23.6 and Table 23.4.

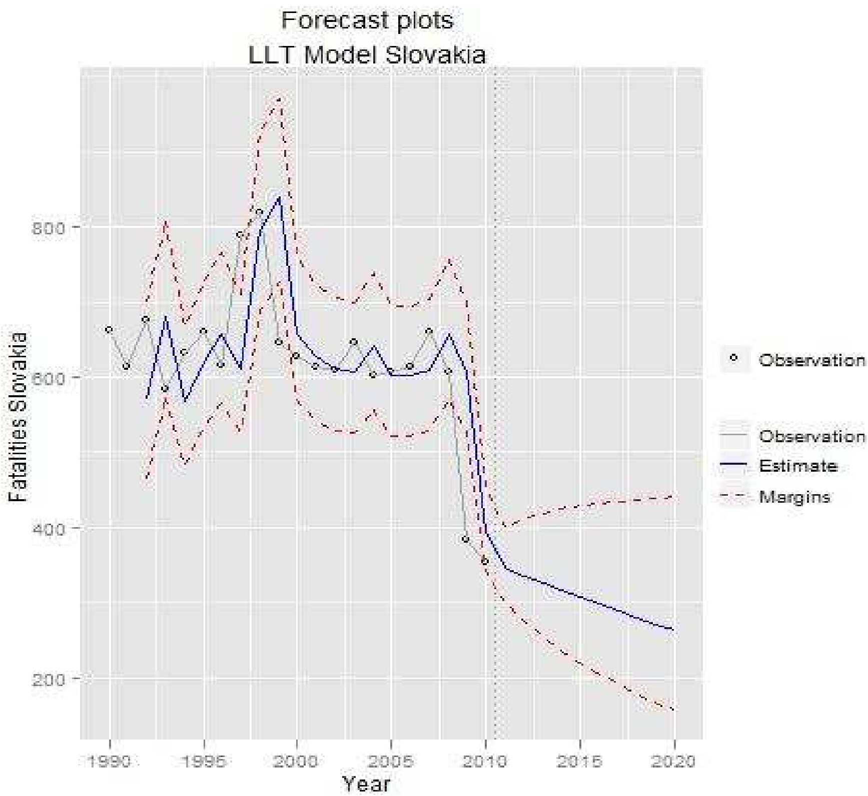


Figure 7: Plot of the annual fatality numbers for Slovakia and the forecasts for 2020. Based on a linear latent trend model with a fixed slope (LLT).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**347**	261	461
2012	**336**	226	501
2013	**326**	199	535
2014	**316**	177	565
2015	**307**	159	593
2016	**298**	143	621
2017	**289**	129	647
2018	**280**	116	674
2019	**271**	105	700
2020	**263**	95	726

Table 4: Forecasts of the Latent Risk Model (LRT1 – full model)

References

[1] EC National Expert

SLOVENIA

1 Raw data

1.1 Exposure

The selected exposure measure are the vehicle kilometres (in billions) per annum (see Figure 1), which are considered from 1970 onwards.

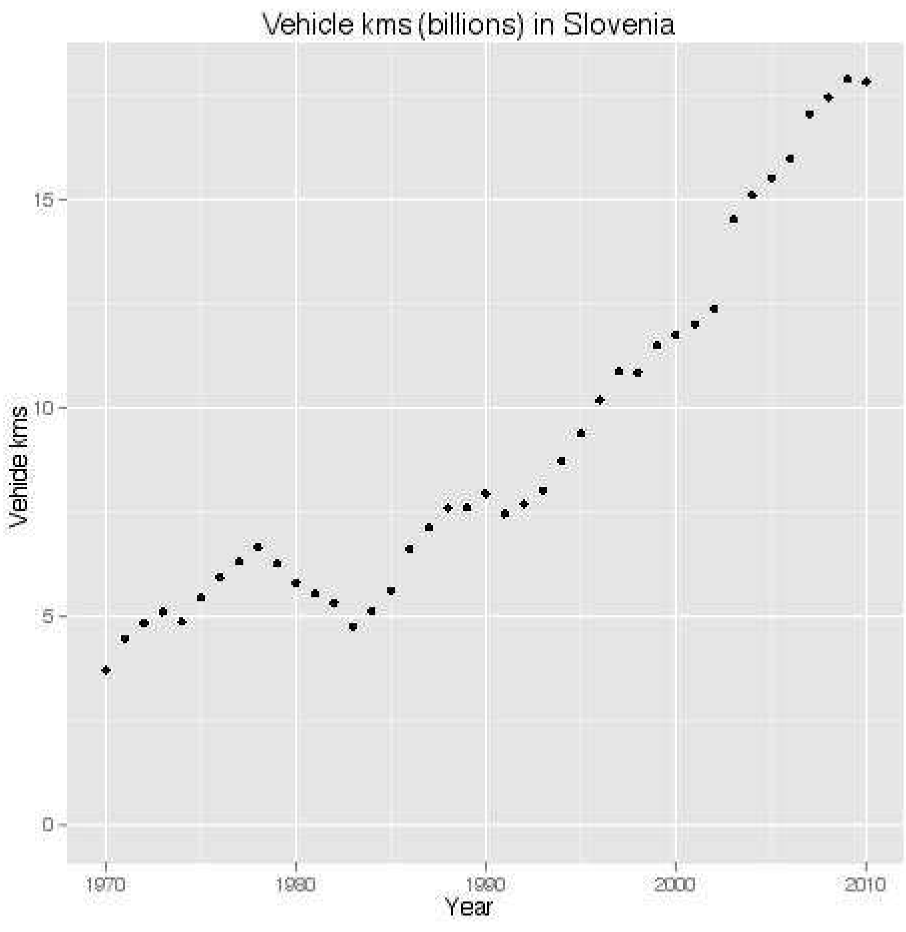


Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for Slovenia from 1970 to 2010.

In 1979 fuel prices exponentially increased. Traffic was very low at that time and people were allowed to drive their car every second day (cars had odd and even number plates, the two groups were not allowed to drive on the same day). In 1980 following president Tito death, police checks were very frequent and a lot of police officers were on the road. Then because of the crisis, government launched coupons for fuel. This serious crisis lasted until 1985.

In June 1991 Slovenia became independent, which led to a 10 day war. Few months later a war started in Croatia as well, resulting in reduced traffic on roads. There are many possible reasons for the large increase in number of vehicle kilometres observed between 2003 and 2004: increase in transit traffic towards Hungary (Slovenia became part of the European union), relatively low cost of fuel, increase transport of goods, etc...[19]

1.2 Fatalities

In Figure 2, the Slovenian road accident fatalities from 1970 to 2010 are plotted.

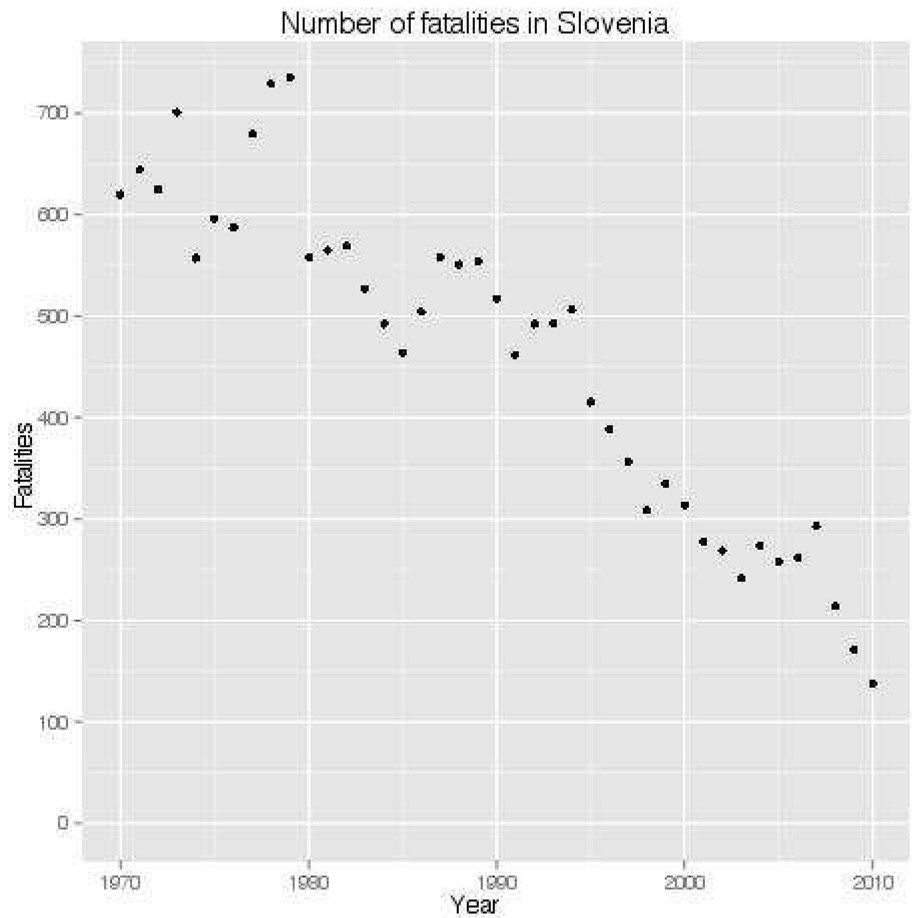


Figure 2: Plot of the annual fatality counts for France from 1957 to 2010.

[19] EC National Expert for road accident statistics and road safety performance indicators.

The number of fatalities is chaotic during the 70s. due to the first and second oil crisis (1973 and 1979 respectively).

In the 80s there were big changes in the political situation which lasted until 1991 (independence). The fatalities were affected by the following factors.

- Bad state of infrastructure
- No enforcement for seat belt and helmet usage.
- Fines became ineffective due to inflation.
- Restricted access to fuel.

Since 1991, the trend is decreasing with a burst in 2007.

2 The SUTSE Model

2.1 Development of the state components

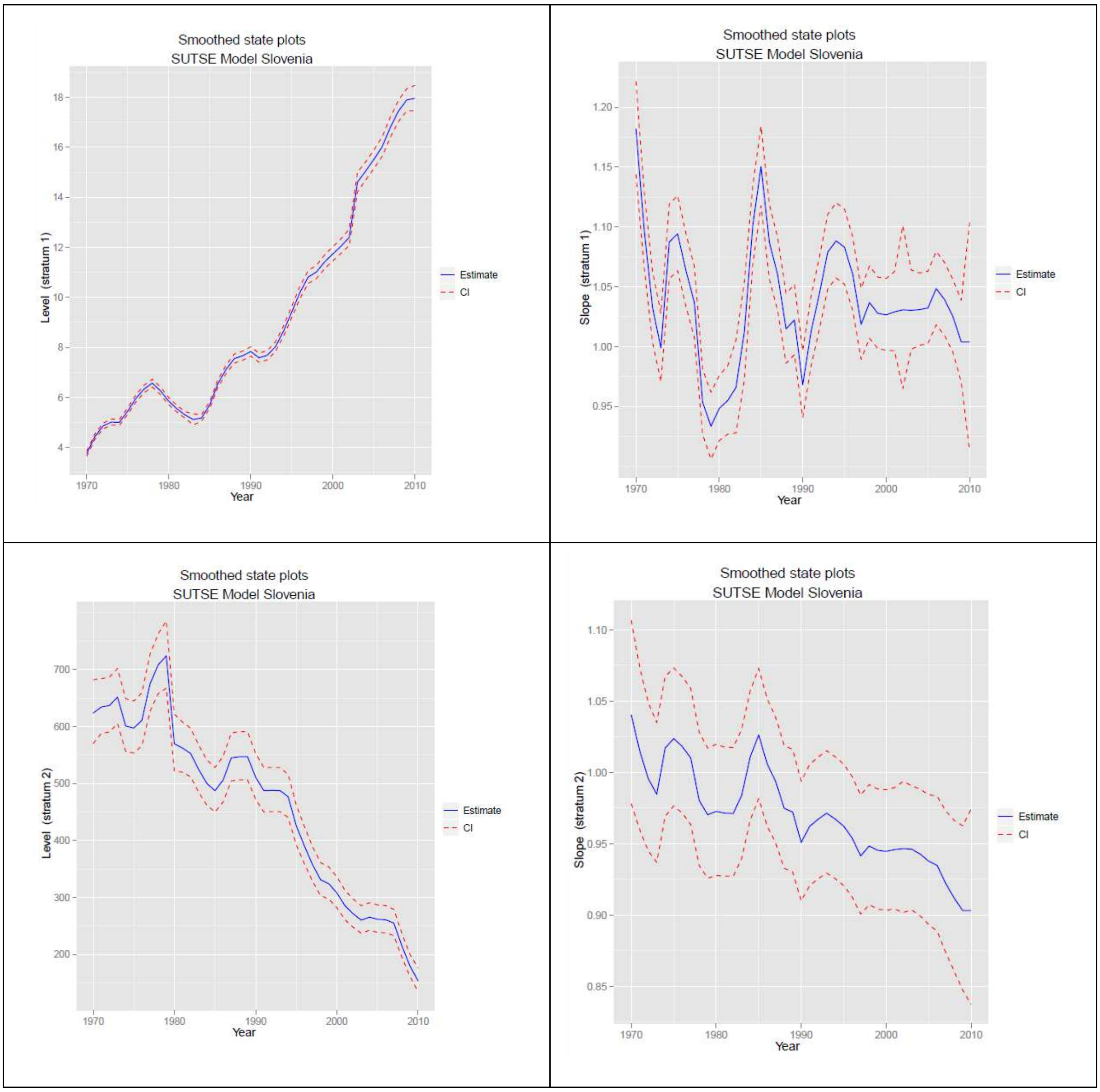


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The slope is erratic, especially in the 70 and 80s. It stabilizes round 5% in the beginning of the 2000's and then declines a little bit.

2.1.2 Fatalities

The slope is decreasing over the period from +5% to -10% with some variations in the first part. The pattern is not similar to the one of exposure.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

The slopes are correlated to 0,74, significantly different from 1 (no common slope), and non significantly different from 0. The levels can be considered as fixed.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 0.64 which is significant ($p=0.058$), but the variances are not different from 0.

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 0.59 and is nearly significantly different from 0 ($p= 0.06$ H0beta=0).

Some interventions have been introduced. In 1980 as a level break for fatalities, and in 2003 as level break in exposure and in 1983 as an irregular intervention.

Model title	***SUTSESlovenia***	***SUTSESlovenia1***	***SUTSEbetaSlovenia***
Model description	SUTSE full model	SUTSE fixed levelVKM	SUTSE independent components, beta estimated
Model Criteria			
log likelihood	125.7	105.42	
AIC	-250.97	-210.49	
Variance of the state components			
Level exposure	1.71E-03 nsc	-	
Level risk	8.00E-03 *c	4.44E-03 ns	
Slope exposure	1.55E-03 nsc	2.04E-03 *	
Slope risk	2.75E-04 nsc	4.41E-04 *	
Correlations between the state components			
level-level	0.53		
slope-slope	0.81	0.74	
Observation variance			
Observation variance exposure	1.09E-09 ns	2.33E-04 ns	
Observation variance risk	1.24E-09 ns	1.14E-03 ns	
Interventions			
(Irregular intervention mvkms 1983)		-0.07 *	
(Level break mvkms in 2003)		0.13 *	
(Level break for fatalities in 1980)		-0.21 *	
Beta			0.59 (p=0.06)

Table 1: Model criteria and results for SUTSE models - Slovenia.

3 The LRT Model

The investigation of the SUTSE model does not indicate clearly the presence of a relation between exposure and fatalities in Slovenia. An LRT model could be explored.

3.1 Model selection

Model title	***LRT 1***	***LRT 2***
Model description	LRT for Slovenia – full model	LRT for Slovenia – fixed level exposure
Model Criteria		
log likelihood	106.75	105.13
AIC	-213.07	-209.92
Model Quality		
Box-Ljung test 1 Exposure	3.38	0.15
Box-Ljung test 2 Exposure	4.05	3.51
Box-Ljung test 3 Exposure	4.69	4.62
Box-Ljung test 1 Fatalities	3.82	4.60*
Box-Ljung test 2 Fatalities	6.20*	6.45*
Box-Ljung test 3 Fatalities	6.21	6.46
Heteroscedasticity Test Exposure	0.32	0.21**
Heteroscedasticity Test Fatalities	1.22	1.68
Normality Test standard Residuals Exposure	0.20	0.10
Normality Test standard Residuals Fatalities	1.02	1.67
Normality Test output Aux Res Exposure	0.03	0.43
Normality Test output Aux Res Fatalities	2.17	3.01
Normality Test State Aux Res Level exposure	0.14	1.48
Normality Test State Aux Res Slope exposure	0.12	1.95
Normality Test State Aux Res Level risk	0.69	0.75
Normality Test State Aux Res Slope risk	0.12	0.13
Variance of state components		
Level exposure	9.85E-04 nsc	-
Level risk	2.40E-03 *c	4.12E-03 ns
Slope exposure	1.58E-03 *	2.03E-03 *
Slope risk	2.38E-03 *	1.07E-03 *
Correlations between state components		
level-level	1	
slope-slope	-0.96	-0.9
Observation variance		
Observation variance exposure	1.12E-09 ns	2.36E-04 ns
Observation variance risk	1.52E-09 ns	1.33E-03 ns
Interventions		
(Irregular intervention mvkms 1983)	-0.07 *	-0.07 *
(Level break mvkms in 2003)	0.14 *	0.14 *
(Level break for fatalities in 1980)	-0.24 *	-0.21 *

Two versions of the LRT model were run: the full model, the model with a fixed level for exposure. The residual tests for both model variants do not indicate a violation of the assumptions underlying the Latent Risk model.

The second model has a bigger AIC and is selected. The exposure follows a smooth trend model and the risk a local linear trend model (the risk level variance is not significant). The negative correlation between the slopes is significantly different from 0, but significantly different from 1. There is a negative correlation between exposure an risk, but not to the point to share a common slope.

3.2 Development of the state components

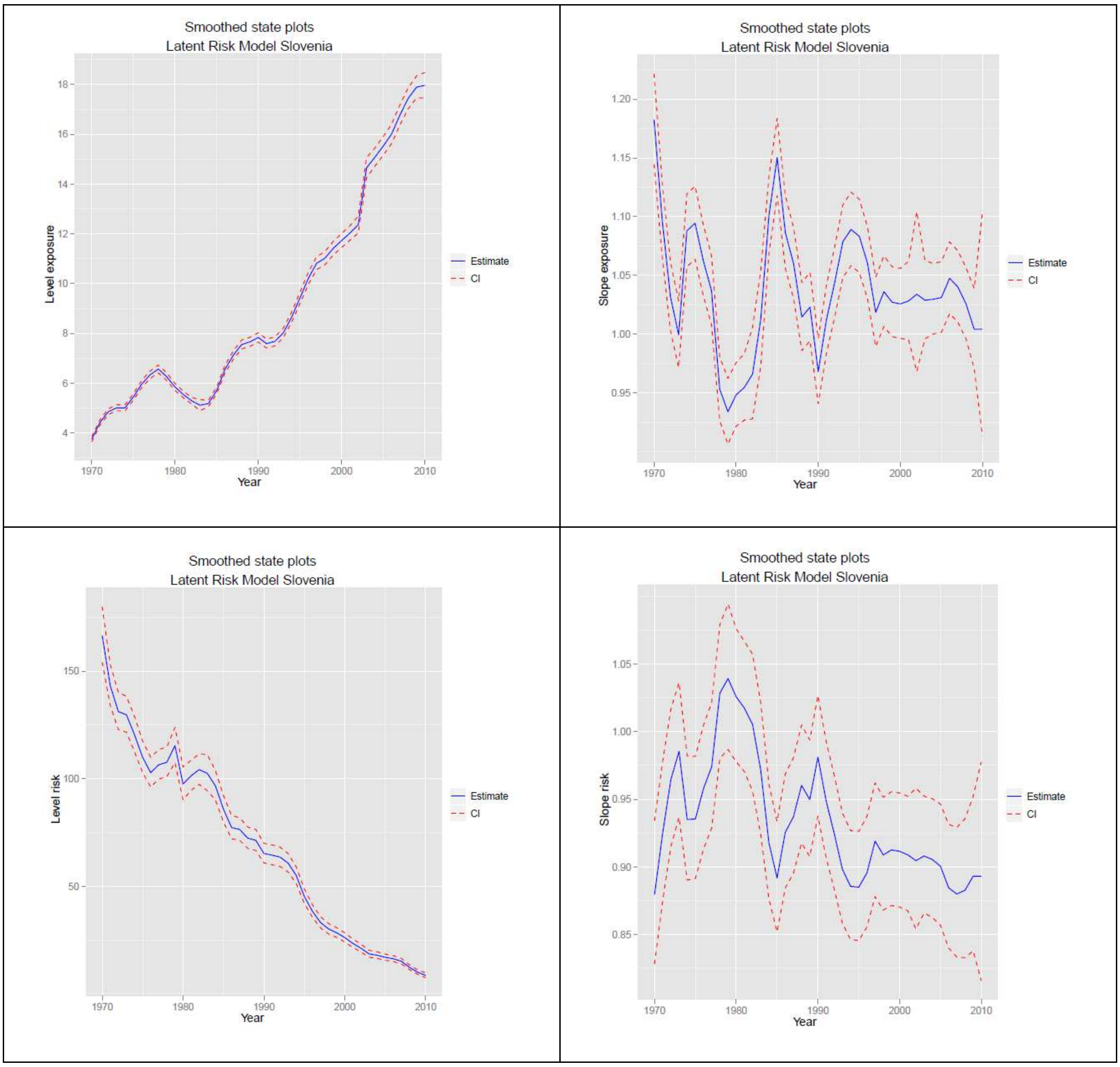


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The evolution of exposure is identical to that observed on the basis of the SUTSE model. The slope is erratic, especially in the 70 and 80s. It stabilizes round 5% in the beginning of the 2000's and then declines a little bit. A 13,6% increase in the level occurred in 2003.

3.2.2 Risk

The risk for fatalities has been reduced in Slovenia from 150 per billion vehicle kilometres in the early 70s to less than 30 per billion vehicle kilometres in the most recent years. This decrease between -5% and -10% is reflected in the negative slope of the risk in the lower left panel of Figure 4. The decrease in the level is -21 % in 1980..

3.3 Quality of the predictions

The quality of the forecasts has not been explored because of the external variations in the last ten years.

4 Forecasts 2011 - 2020

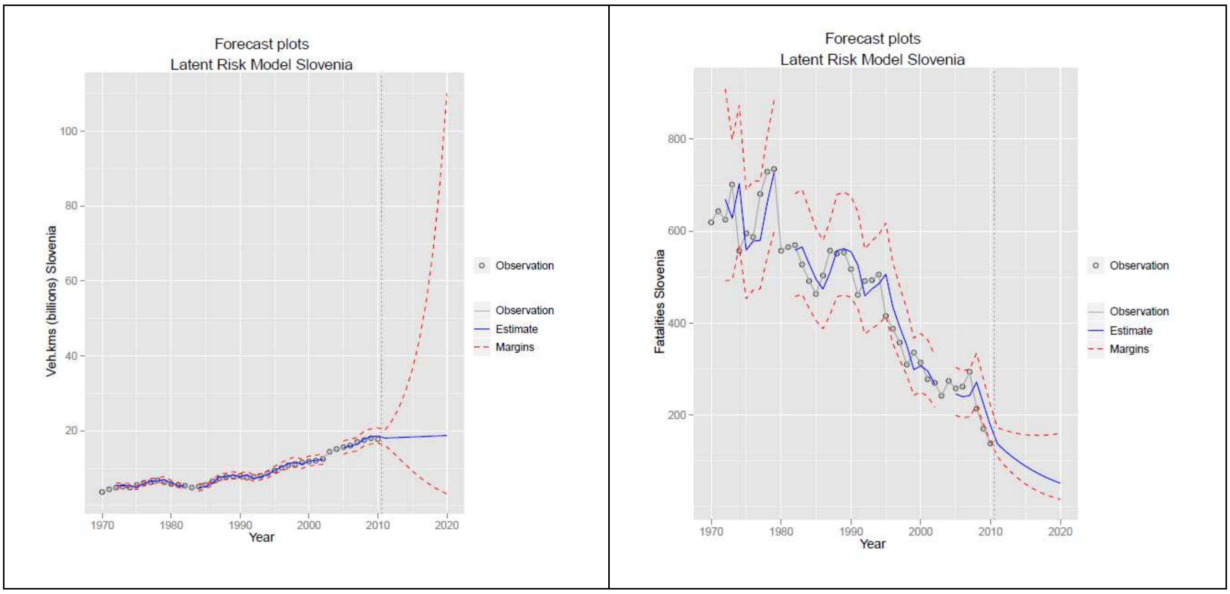


Figure 7: Plot of the vehicle kilometres (right-hand graph) and annual fatality numbers (left-hand graph) for Slovenia forecasted between 2011 and 2020.

The forecasts in Figure 7 and Table 3 provide an indication of the vehicle kilometres and the fatality numbers to be expected between 2011 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Vehicle kilometres (billion)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2011	**18.04**	16.17	20.14	**137**	109	172
2012	**18.12**	14.55	22.56	**123**	91	167
2013	**18.19**	12.76	25.93	**110**	75	163
2014	**18.27**	10.97	30.42	**99**	61	159
2015	**18.34**	9.26	36.33	**89**	50	157
2016	**18.42**	7.69	44.10	**80**	41	156
2017	**18.49**	6.29	54.34	**71**	33	156
2018	**18.57**	5.08	67.89	**64**	26	156
2019	**18.65**	4.05	85.93	**57**	21	158
2020	**18.72**	3.18	110.11	**52**	17	160

Table 3: Slovenia - Forecasts of Latent Risk Model (LRT 2).

5 Scenarios

In Figure 7 it can be seen that there is strong uncertainty about the development of the exposure in France. Given that the exposure influences the prediction of the fatalities it is interesting to demonstrate how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 8 below presents three point-estimates for the number of fatalities that can be expected assuming three different scenarios for exposure.

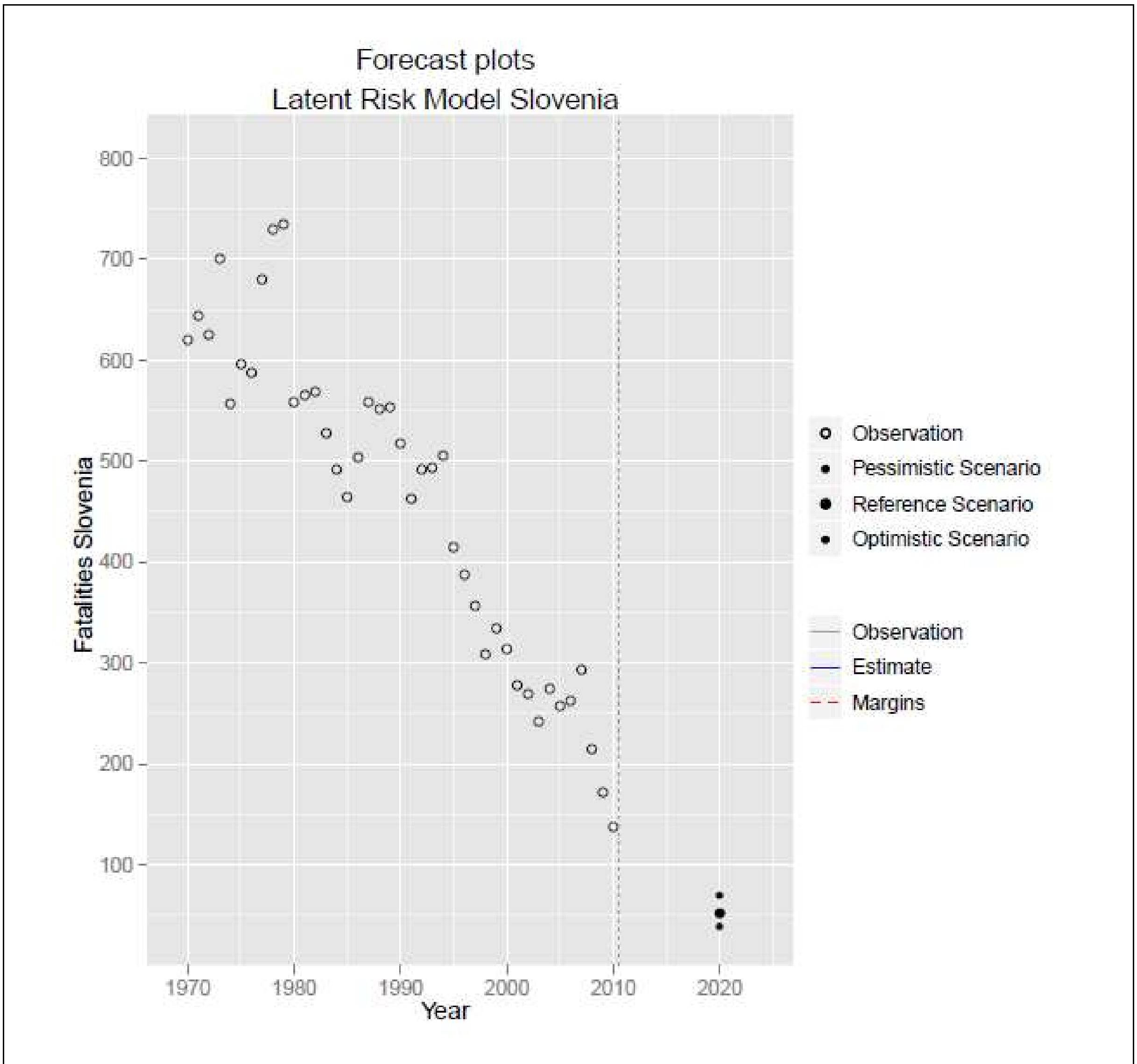


Figure 8: Fatality forecasts Slovenia 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate – 1 SD).

The three mobility scenarios presented here are actually the vehicle kilometres as predicted from the LRT model plus/minus one standard deviation. Assuming that these predictions are correct, and thus ignoring the uncertainty surrounding the forecasts for the exposure, what would be the consequences for the number of fatalities to be expected in 2020?

The full dot in Figure 7 is the expected number of fatalities given that mobility keeps developing as it has before (prediction 18,7 billion veh.km per year). The circles indicate the estimated number of fatalities for an optimistic scenario for exposure (forecast plus one standard deviation: x billion veh.km) and for a pessimistic scenario (forecasted value minus one standard deviation). The prediction that we achieve under these three scenarios are summarized in Table 4.

	Vehicle kilometres (billions)	***Road traffic fatalities***
Situation 2010:	17.83	138
Prediction for 2020 according to mobility scenarios:		
Continuation of development	18.72	52
Stronger growth	46	70
No growth	7.6	39

Table 4: Slovenia - Forecasting scenarios on the basis of the Latent Risk model (LRT 2). Mobility scenarios are based on predicted value from LRT model +/- one standard deviation.

SPAIN

1 Raw data

1.1 Exposure

The selected exposure measure are the vehicle kilometres (in millions) per year (see Figure 1), which are considered from 1975 onwards.

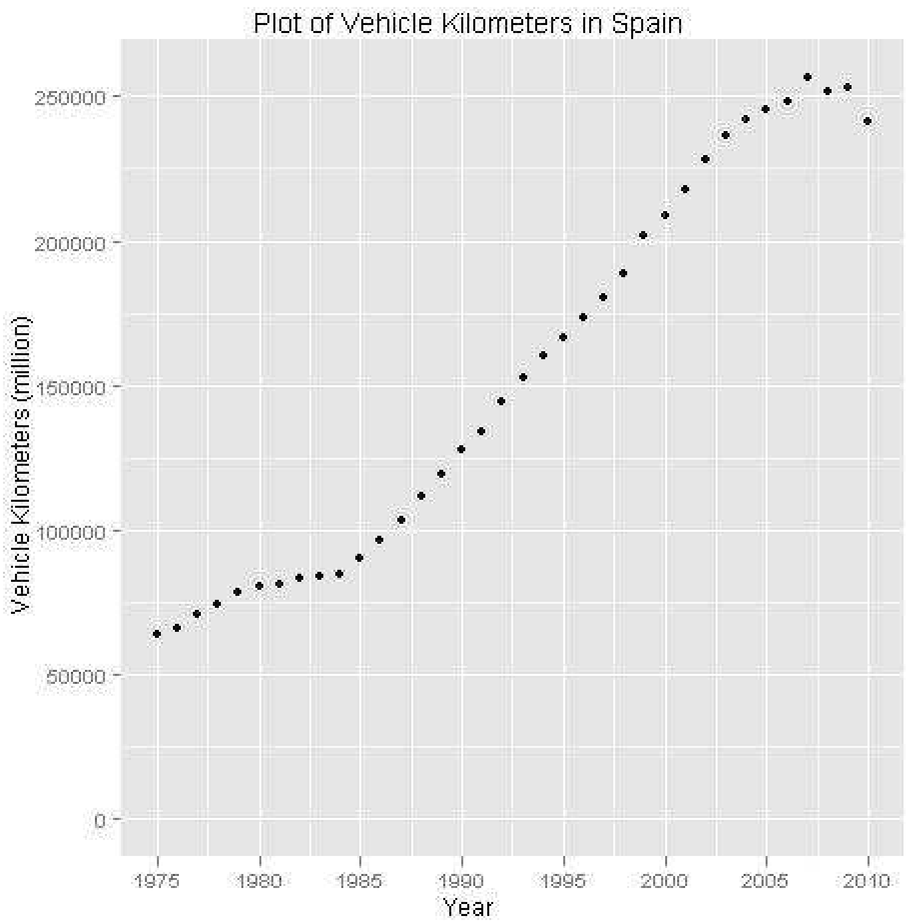


Figure 1: Plot of the annual numbers of vehicle kilometres (in million) for Spain from 1975 to 2010.

The number of vehicle kilometres is estimated and includes only non-urban trips. The quality of estimates is unknown. In 1994 the calculation method changed, but it does not seem to have caused any break in the series.

1.2 Fatalities

Fatalities occurring within 30 days after an accident are included in this analysis. They are plotted in Figure 2.

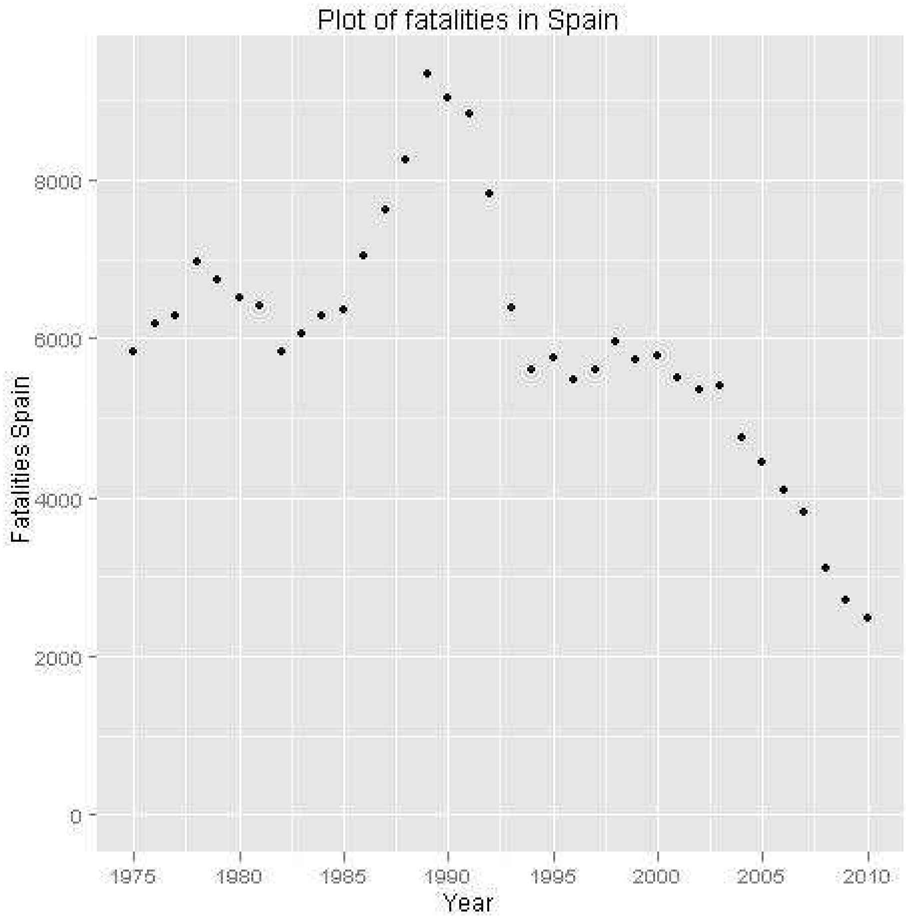


Figure 2: Plot of the annual 30 days traffic fatality counts for Spain from 1975 to 2010.

Generally speaking, annual fatality numbers are characterized by important variation in Spain. However, it is clear that these numbers have been increasing up to 1990 (although with short periods of decrease), and have been decreasing thereafter (although with some periods of stagnation).

The registration of the Spanish traffic fatalities is based upon forms filled in by the police. There have been changes in the registration method in the period of study: In 1993, the 30-days criterion has been adopted to define fatalities at 30 days. However, given that fatalities at 30 days are estimated by correction factors and have been applied retrospectively to all the series, it is unlikely that the series at hand could have been affected by this registration change (as indicated by the absence of a visible break in Figure 2 above).

2 The SUTSE Model

2.1 Development of the state components

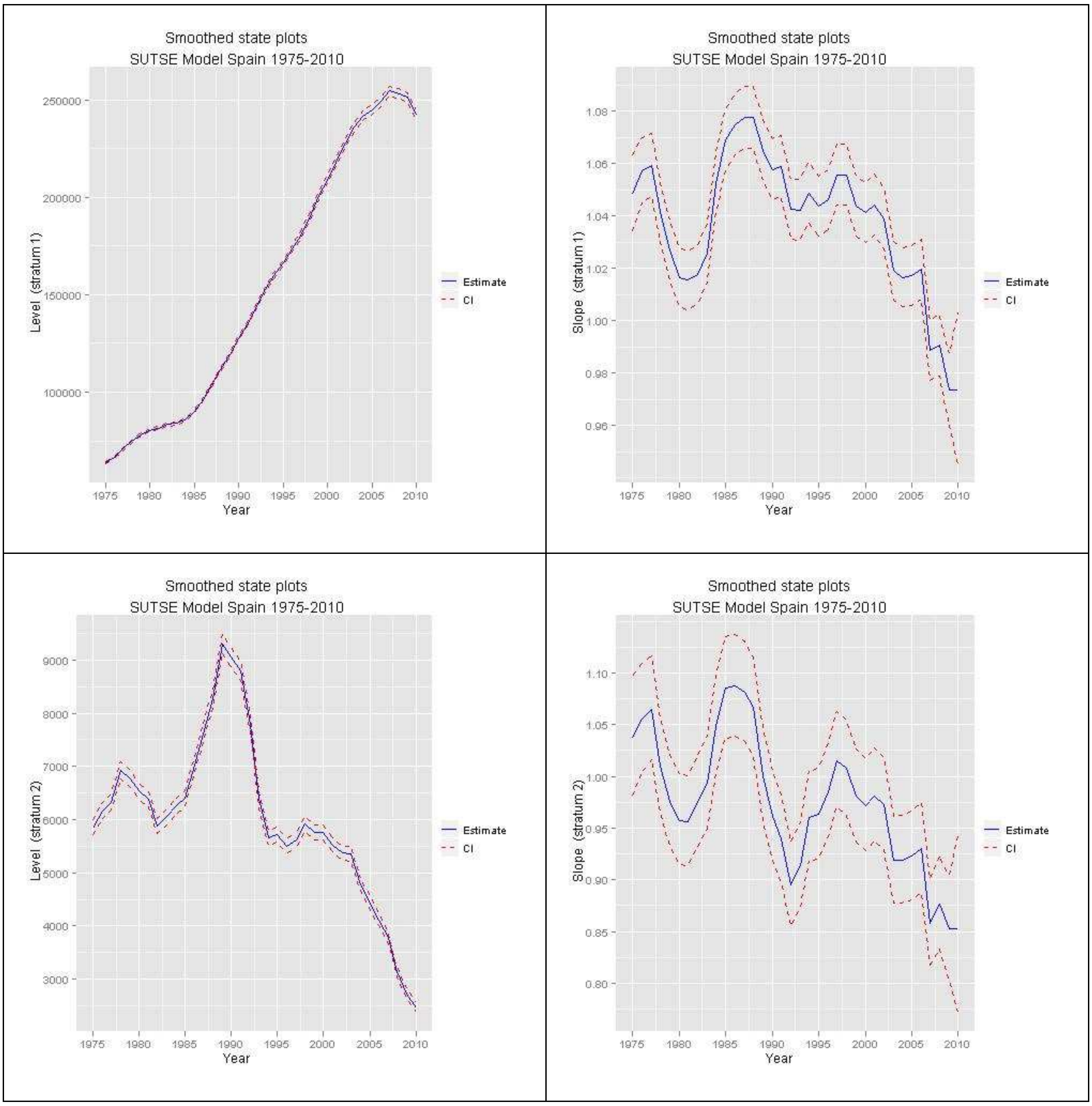


Figure 3: Developments of the state components for the Exposure (upper graphs) and the 30 days - Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The graphs presented in Figure 3 indicate that the slope component varies over time, while the trend does not. The trend increases smoothly, in a seemingly linear way, especially after 1984, probably due to the economic expansion. Vehicle kilometres in Spain increased from 63,834 million in 1975 to 241,131 million in 2010. The slope varies significantly, which means that the increase is not constant throughout the period. In the mid seventies the annual increase was of about 6%, dropping to 1.5% in the beginning of the eighties. Then, it increased again until an annual increase of 8% during the eighties, especially from 1984 on above, probably due to the economic expansion. From the late eighties - early nineties it started to diminish again. Since 2007, probably due to the economic recession, there was a decrease of vehicle kilometres.

2.1.2 Fatalities

As in the case of exposure, the slope is the only component which varies significantly over time for the fatality series.

Overall, the inspection of the trend for the fatalities (Figure 3) leads to very similar conclusions than that of the raw data. The fatalities increased until 1989, from 5,833 fatalities in 1975 to 9,344 in 1989. Since 1989 the fatalities decreased until 2,478 in 2010, with an increase in the later nineties.

The graph for the slope development presented in Figure 3 reveals slope values of above and below 1, corresponding to periods of significant decrease and increase of the annual fatality number. The period with greater rise in the number of road traffic fatalities in Spain was from 1982 to 1989. This period coincides with the country's economic expansion from 1984. The period with the most important reduction in the number of road traffic fatalities in Spain was from 1989 to 1995, which coincides with the economic crisis of 1990. Another period to highlight in the series is 1994-2003 with a steady number of deaths, which coincides with the beginning of a new economical expansion. Finally, from 2004 on, another period of sharp decrease is observed. It corresponds to the moment where road safety has been incorporated as a priority into the Spanish political agenda. Since 2007, there is a sharp reduction in the number of fatalities. It can be related to the implementation of the penalty points system (July 2006), the reform of the penal code that criminalized some road behaviours (December 2008), and the financial crisis that started in 2008.

2.3 Relation between the exposure and fatality series

As discussed in the previous section, there have been a number of events since 1975 that could have affected the number of fatalities and the amount of exposure:

1982-1984: In the mid eighties there was a period of economical expansion. The number of fatalities showed an important increase. We include in the SUTSE model the year 1984 as an intervention on the slope of the exposure (**VS1984**), and the year 1982 as an intervention on the slope of the fatalities (**FS1982**).

1989: After a long period of economical expansion, at the end of the eighties and early nineties there was a period of economic recession. In addition, the road safety law was developed (RDL Ley de Tráfico 1989), which implied among other things an increase of enforcement and of the amount of fines. The year 1989, is the year with the maximum number of fatalities in the series. Since then, there is an inflection and a change in the slope which starts to decrease. The year 1989 is included in the SUTSE model as an intervention on the slope of the fatalities (**FS1989**).

1993-1994: The economical recession started to recover in the mid-nineties. In 1992, new road safety measures were implemented. These measures included the enforcement of helmet use for motorised 2-wheelers and of seat-belt use for the front car seats. The safety of the Spanish vehicle fleet started to improve. The year 1993 is included in the SUTSE model as an intervention on the level of the fatalities (**FL1993**), and 1994 as an intervention on the slope of the fatalities (**FS1994**).

2004: Road safety was included as a priority in the Spanish political agenda. The year 2003 is included in the SUTSE model as an intervention on the slope of the fatalities (**FS2004**).

2007-2008: It was again a period of economic recession. Moreover, the penalty points system was implemented and the penal code was reformed. The year 2007 is included in the SUTSE model as an intervention on the slope of the exposure (**VS2007**) and 2008 as an intervention on the level of the fatalities (**FL2008**).

2008: A reform of the penal code for road safety was done. The year 2008 is included in the SUTSE model as an intervention on the slope of the fatalities.

All these interventions were tested in the SUTSE model and the significant ones were: **VS1984, VS2007, FL1993, FL2008, FS1982, FS1989, FS1994.**

2.3.1 Correlation between the disturbances of the state components

The variance of the levels of the exposure and fatality series are non significant. This indicates that they can be fixed, and cannot be considered significantly correlated (-1; p>0,05). The test for common components is not significant (p>0,05). (See Table1_1 and 1_2)

The slope of the exposure and the slope of the fatalities, show a significant variance, which indicates that they can be considered stochastic. (See Table1_1 and 1_2). In the SUTSE model without interventions the two slopes are not correlated (0.7, p=0.111). However, in the SUTSE model with interventions they are significantly correlated (1, p=0.00064). The test for common components is not significant, which means that this correlation does not significantly deviate from 1 (p=0.50). Therefore, the slopes can be considered as common. (See Table1_1 and 1_2)

2.3.2 Correlation between the irregulars

In the SUTSE model without interventions, the measurement errors for exposure and fatalities are not significantly correlated (-0.19, p=0.879). However, in the SUTSE model with interventions the measurement errors for exposure and fatalities are significantly correlated (-0.80, p=0.004).

2.3.3 Estimation of the relationship by means of a coefficient

A new SUTSE model is estimated to assess the relationship between the two series on the basis of a fixed regression coefficient (SUTSEbeta). It fits the data as well as the current model did (SUTSE full model), where this relationship was estimated on the basis of the covariance between the states disturbances of the two series (see Table 1). In the SUTSE model without interventions, the beta coefficient for the relationship between the latent developments of the two series was no significant (1.403; p=0.171); However, in the SUTSE model with interventions the beta coefficient is equal to 1.725 and is significant (p=0.003). As a consequence, the two series could be considered to be related.

Model title		***SUTSESpain***	***SUTSEbetaSpain***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	161.645	161.271
	AIC	-322.791	-322.098
Variance of the state components			
	Level exposure	6.10E-05 nsc	4.57E-17 ns
	Level risk	1.85E-03 nsc	9.85E-04 ns
	Slope exposure	1.77E-04 *c	1.92E-04 *
	Slope risk	1.67E-03 *c	1.72E-03 *
Correlations between the state components			
	level-level	-1	
	slope-slope	0.7	
Observation variance			
	Observation variance exposure	3.49E-05 ns	5.22E-05 ns
	Observation variance risk	6.24E-06 ns	1.96E-04 ns
Beta			beta= 1.403 (p=**0.171**)

Table 1_1: Overview of the results for SUTSE models – Spain.

Model title		***SUTSESpain with interventions***	***SUTSEbetaSpain with interventions***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	120.342	116.528
	AIC	-240.184	-232.612
Variance of the state components			
	Level exposure	8.55E-15 nsc	2.94E-20 ns

Level risk	2.46E-15 nsc		9.60E-18 ns
Slope exposure	8.21E-05 *c		1.28E-04 *
Slope risk	8.60E-04 *c		1.37E-04 ns
Correlations between the state components			
level-level	-1		
slope-slope	1		
Observation variance			
Observation variance exposure	4.28E-05 *		3.61E-05 *
Observation variance risk	2.99E-04 *		3.97E-04 *
Interventions			
Intervention 1984 slope VKM		0.038*	
Intervention 2007 slope VKM		-0.035*	
Intervention 1982 slope RISK		0.111*	
Intervention 1989 slope RISK		-0.121*	
Intervention 1993 level RISK		-0.134*	
Intervention 1994 slope RISK		0.106*	
Intervention 2008 level RISK		-0.156*	
Beta			1.725 (p=0.003)

Table 1_2: Overview of the results for SUTSE models with interventions– Spain.

3 The LRT Model

The study of the SUTSE model with interventions clearly indicated a relationship between exposure and fatalities in Spain. The correlation between the slope disturbances was significant, and the coefficient (beta) that estimated the relationship between the two series was also significant with p=0.003. It was therefore decided to base the forecasting procedure on the LRT model.

According to the SUTSE model, the slopes can be considered common; therefore the slope component for the risk should be fixed in the LRT model. Moreover, the SUTSE model shows that the level variances and their correlation are not significant and consequently they could be fixed in the model.

Therefore, it was finally decided to base the forecasting procedure on an LRT slope risk and level exposure fixed model with the significant interventions in the SUTSE model.

3.1 Model selection

Model title	***LRT 1***	***LRT 2***	***LRT 3***	***LRT 4***
Model description	LRT for Spain. Full model	LRT for Spain. Full model with interventions	LRT for Spain. Slope risk and level exposure fixed model	LRT for Spain. Slope risk and level exposure fixed model
Model Criteria				
ME10 Fatalities	-951.41	-1282.22	-1558.65	-1558.70
MSE10 Fatalities	1458479.99	2438375.37	3529498.18	3529788.65
log likelihood	161.65	120.89	112.33	103.13
AIC	-322.79	-241.27	-224.39	-205.98
Model Quality				
Box-Ljung test 1 Exposure	1.93	2.76	0.71	1.00
Box-Ljung test 2 Exposure	2.00	2.77	3.05	2.93
Box-Ljung test 3 Exposure	2.01567	3.69447	3.11	2.93
Box-Ljung test 1 Fatalities	0.87864	0.19218	6.77**	2.56
Box-Ljung test 2 Fatalities	3.63453	0.20500	6.80**	3.40
Box-Ljung test 3 Fatalities	5.93744	1.11956	8.49*	3.57
Heteroscedasticity Test Exposure	1.03903	1.42538	1.73	1.67
Heteroscedasticity Test Fatalities	1.16086	1.75	1.28	1.04
Normality standard Residuals Exposure	0.59484	1.23	0.23	0.65
Normality standard Residuals Fatalities	0.53972	0.53	0.42	0.69
Normality Test output Aux Res Exposure	0.23140	1.04	0.85	0.83
Normality Test output Aux Res Fatalities	0.93523	1.53	2.52	1.34
Normality State Aux Res Level exposure	0.11724	0.01	0.24	0.05
Normality State Aux Res Slope exposure	1.06711	0.48	0.30	0.32
Normality Test State Aux Res Level risk	1.71751	0.13	0.72	0.05
Normality Test State Aux Res Slope risk	0.19342	0.36	0.04	0.09
Variance of state components				
Level exposure	6.10E-05 nsc	1.02E-14 nsc	-	-
Level risk	2.59E-03 nsc	1.41E-14 nsc	1.21E-03 *	1.04E-03 *
Slope exposure	1.77E-04 *c	8.31E-05 *c	1.14E-04 *	1.12E-04 *
Slope risk	1.08E-03 *c	3.61E-04 *c	-	-
Correlations between state components				
level-level	-1	-0.81	-0.75	-0.76
slope-slope	0.47	1	1	1
Observation variance				
Observation variance exposure	3.49E-05	4.22E-05 *	3.79E-05 *	3.90E-05 *

Observation variance risk	ns 6.24E-06 ns	3.12E-04 *	2.22E-04 *	2.33E-04 *
Interventions				
Intervention 1984 slope VKM			0.05 *	0.05 *
Intervention 2007 slope VKM			-0.04*	-0.04 *
Intervention 1982 slope RISK			0.05 *	0.05 *
Intervention 1989 slope RISK			-0.14 *	-0.14 *
Intervention 1993 level RISK			-0.14 *	-0.15 *
Intervention 1994 slope RISK			0.06 *	0.07 *
Intervention 2008 level RISK			-0.16 *	-0.12 *
Intervention 2004 slope RISK				-0.04 (p=0.07)

Four versions of the LRT model were run, the full model, the full model with interventions and two restrictive models with a fixed slope for the risk and a fixed level for the exposure. The first restrictive LRT model (LRT3) contains the significant interventions in the SUTSE model, and the other LRT model (LRT4) contains one more intervention.

Table 2 shows that the two full models meet all the assumptions underlying the LRT model. In the restrictive LRT3 model the fatality residuals cannot be considered independent. As a consequence, another LRT with fixed slope risk and level exposure (LRT4) was fitted, which included another intervention for the risk in 2004 (integration of road safety as a priority in the Spanish political agenda). 2004 is characterised by a sharp decrease in the number of deaths and a slowdown in the traffic volume that could have resulted in a risk reduction. The LRT4 model has slightly lower log-likelihood and AIC than the full model with interventions and similar forecasting accuracy (ME10 and MSE10). In this case the fatality residuals can be considered independent, although the 2004 intervention is not strictly significant (p=0.07, p<0.1).

Therefore, it was finally decided to base the forecasting procedure on the LRT4 model.

3.2 Development of the state components

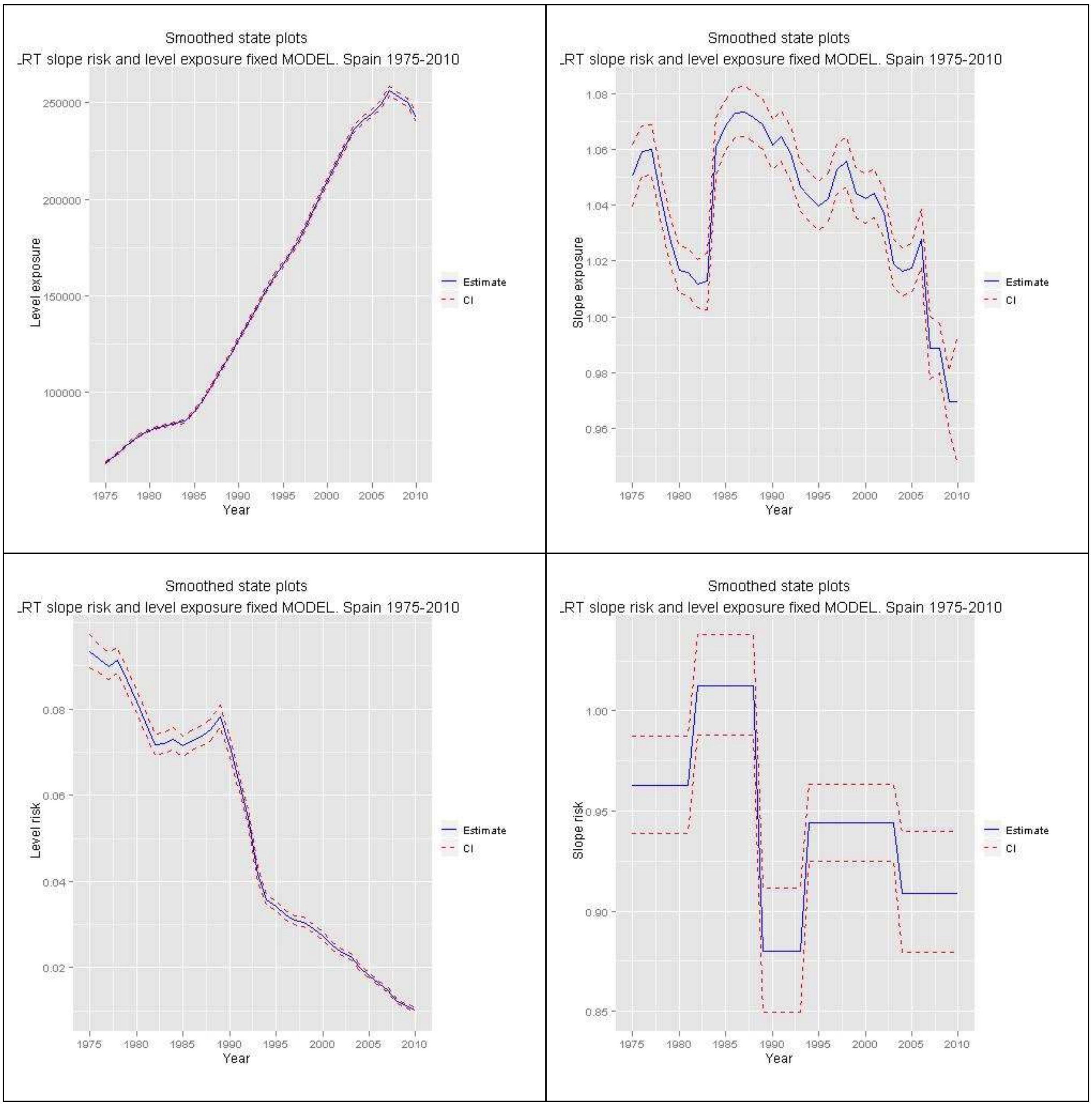


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT4 model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.2.1 Exposure

The level component does not vary significantly over time for the exposure series. The trend increases smoothly, in a seemingly linear trend especially after 1984 and until 2007. The Spanish vehicle kilometres increased from 63,834 million in 1975 to 256,660 million in 2007 and then decrease until 241,131 in 2010.

The slope component for the exposure varies significantly, which means that the increase is not constant throughout the period. In the mid seventies the annual increase was about 6% and later on the increase was smaller until the eighties when it rose again from about 1.5% to 8%. From the late eighties and early nineties, it started to decrease again. Since 2007, there was a reduction of vehicle kilometres.

3.2.2 Risk

Contrary to the exposure, the trend and the slope of the risk vary significantly over time. Five periods can be clearly identified. In general, the risk has been decreasing over the years, except in the period 1982-1988 where the risk increased.

For the first period, from 1975 to 1981, where the number of fatalities and exposure increased, the risk decreased from more than 0.09 fatalities per million vehicle kilometres to around 0.07. This means that this initial increase of the number of fatalities is to be attributed mainly to a stronger increase in traffic volume. As the traffic volume has exceeded the number of fatalities in terms of risk there has been a reduction over the period of around 3.5% yearly.

In contrast, in the second period, from 1982 to 1988, the sharp increase in the number of fatalities has resulted in an increased risk, from around 0.07 fatalities per million vehicle kilometres to around 0.08. This period coincides with the country's economic expansion from 1982-1983, where the increase in traffic volume has been proportionately less than the number of deaths. It resulted in terms of risk in a increase over the period of around 1.5% yearly.

The third remarkable period is from 1989 to 1993, where there was a sharp decrease in the number of fatalities even though the traffic volume continued to rise despite the onset of the crisis of 1990. Therefore there is a strong risk reduction over the period from around 0.08 fatalities per million vehicles kilometres to less than 0.04, that represents a reduction of almost 15% yearly.

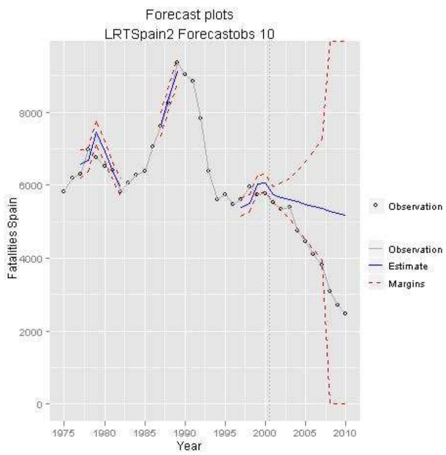
The fourth period to stress is from 1994 to 2003, which coincides with the beginning of a new situation of economical expansion where the number of deaths stabilizes even though the traffic volume continues to rise. It represents a risk reduction from around 0.04 fatalities per million vehicles kilometres to around 0.02, which is a 5% yearly reduction.

Finally, the last period from 2004 to 2010, where road safety is incorporated into the political agenda as a priority, there was a sharp decrease in the number of deaths and a slowdown in the traffic volume resulting in a marked risk reduction from around 0.02 fatalities per million vehicles kilometres to less than 0.01, that represents a reduction of around 10% yearly.

3.3 Quality of the predictions

To assess how well the final model (LRT4 slope risk and level exposure fixed model) can predict, data up to 2000 is used to forecast the fatalities and the exposure between 2001 and 2010. Figure 6 below shows a comparison between the predicted and actually observed values for the fatalities and for the exposure, with de “full model with interventions” (left-hand), and the “fixed slope risk and level exposure model with interventions” (right-hand).

3.3.1 Fatalities



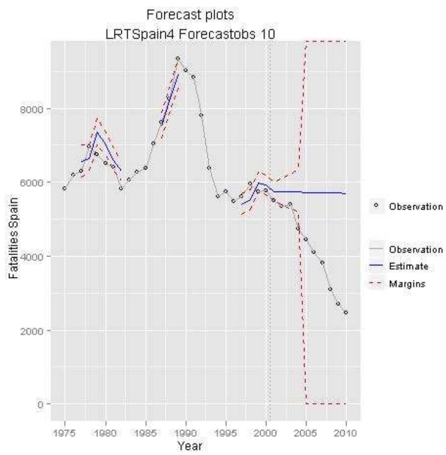
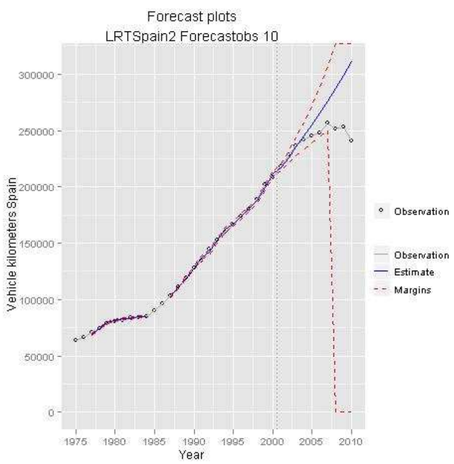


Figure 6: Plots comparing the model predictions (straight line) with the actual observations (“bullets”) for the annual fatality numbers in Spain. “Full model with interventions” (left-hand), “Fixed slope risk and level exposure model with interventions” (right-hand).

3.3.2 Exposure



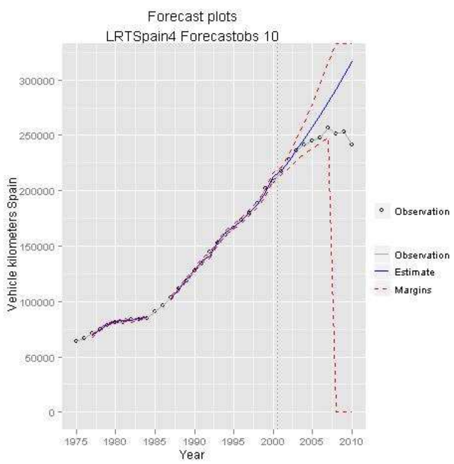


Figure 6: Plots comparing the model predictions (straight line) with the actual observations

("bullets") for the exposure in Spain. "Full model with interventions" (left-hand), and "Fixed slope risk and level exposure model with interventions" (right-hand).

4 Forecasts 2011 – 2020

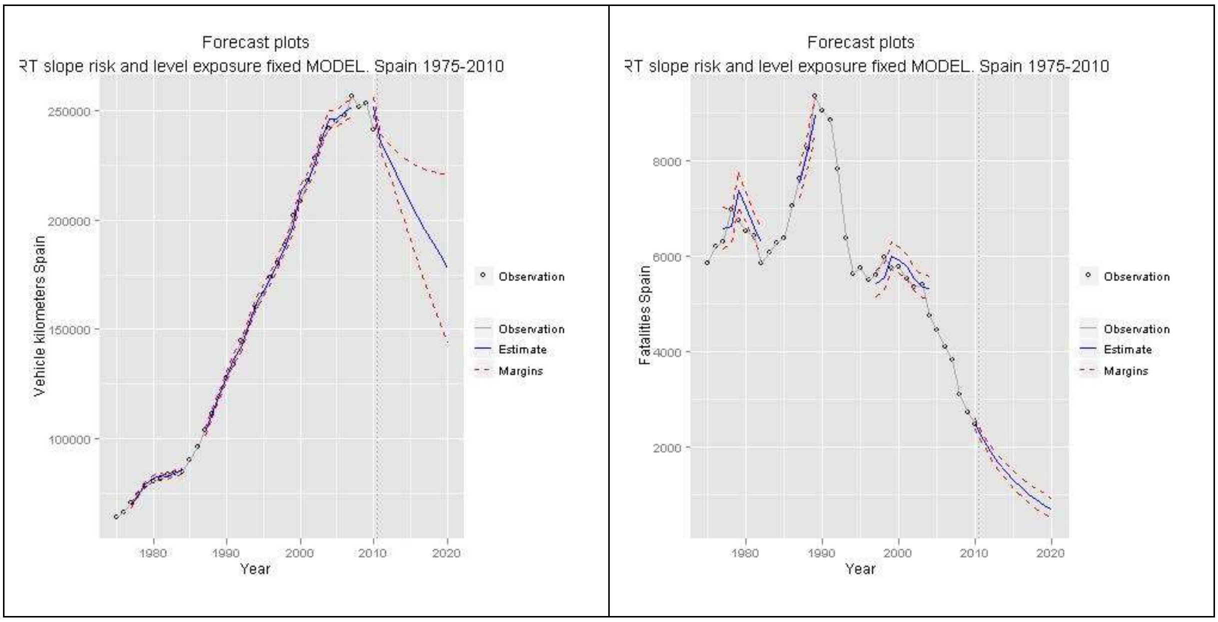


Figure 7: Plot of the vehicle kilometres (right-hand) and annual fatality numbers (left-hand) for Spain forecasted between 2011 and 2020, with the LRT "Fixed slope risk and level exposure model with interventions".

The forecasts in Figure 7 and Table 3 provide an indication of the vehicle kilometres and the fatality numbers to be expected between 2011 and 2020 provided that the trends keep on following throughout these years the developments that they have shown in the past.

	Vehicle kilometres (million)			Fatalities		
Year	Predicted	Confidence Interval		Predicted	Confidence Interval	
2011	**235,282**	228,045	242,748	**2,154**	1,961	2,366
2012	**228,130**	215,549	241,445	**1,899**	1,658	2,174
2013	**221,195**	202,437	241,691	**1,674**	1,398	2,003
2014	**214,471**	189,183	243,140	**1,475**	1,176	1,851
2015	**207,952**	176,046	245,641	**1,300**	986	1,715
2016	**201,631**	163,198	249,115	**1,146**	824	1,594

2017	**195,502**	150,761	253,521	**1,010**	687	1,486
2018	**189,559**	138,820	258,844	**891**	571	1,389
2019	**183,797**	127,436	265,085	**785**	474	1,301
2020	**178,210**	116,649	272,261	**692**	392	1,222

Table 3: Forecasts of The Latent Risk Model with slope risk and level exposure fixed and with interventions (LRT4).

5 Scenarios

In Figure 7 it can be seen that there is strong uncertainty about the development of the exposure in Spain. Given that the exposure influences the prediction of the fatalities it is interesting to see how much of the possible variation indicated by the confidence interval around the fatalities is due to the variation in exposure. Figure 8 below shows three point-estimates for the number of fatalities with the *LRT slope risk and level exposure fixed model with interventions* that can be expected assuming three different scenarios for exposure.

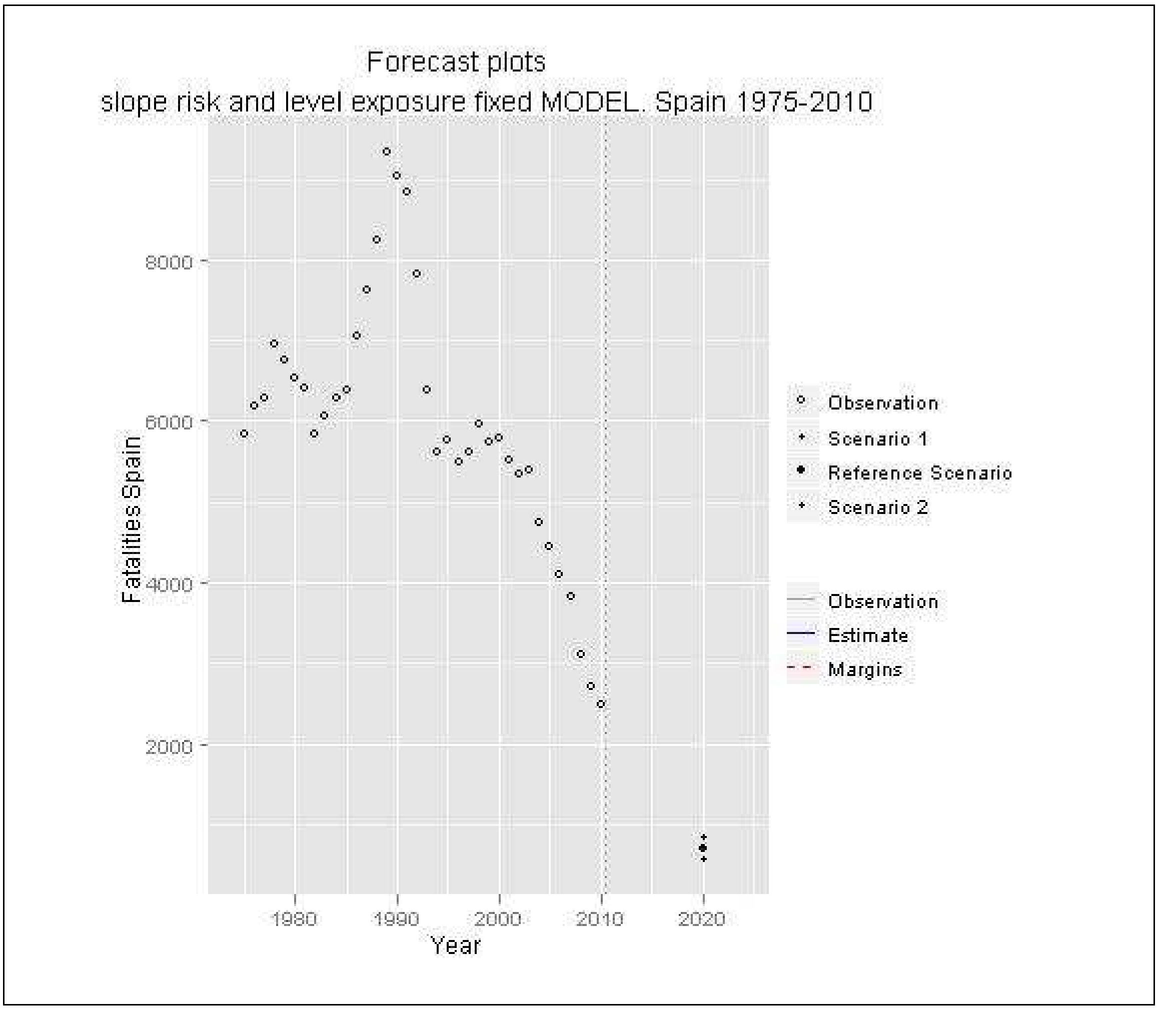


Figure 8: Fatality forecasts Spain 2020 under 3 mobility scenarios. ● Continuation of development (as estimated by LRT4 model). ◦ Stronger growth (LRT4 estimate + 1 SD). ◦ No growth (LRT4 estimate – 1 SD).

The three mobility scenarios presented here are actually the vehicle kilometres as predicted from the LRT slope risk and level exposure fixed model with interventions plus/minus one standard deviation. The full dot in Figure 8 is the expected number of fatalities in 2020 given that mobility keeps developing as it has before (Reference scenario -- further stagnation: forecast= 178,210 million veh-km). The circles indicate the estimated number of fatalities for an optimistic scenario for exposure (Scenario 1 -- growth: forecast plus one standard deviation= 220,943 million veh-km) and for a pessimistic scenario (Scenario 2: forecast minus one standard deviation = 143,743 million veh-km). The prediction that we achieve under these three scenarios are summarized in Table 4.

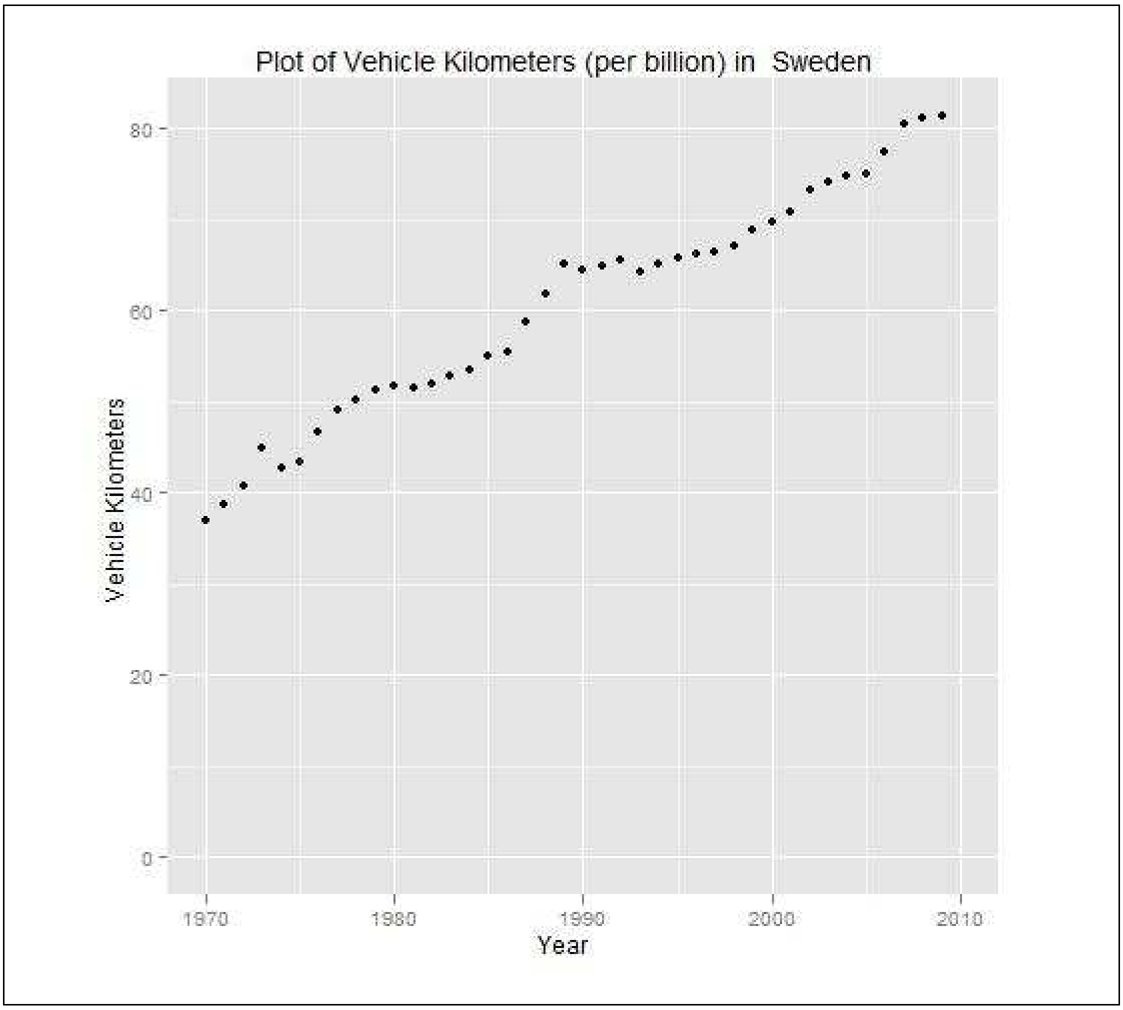
	Vehicle kilometres (millions)	***Road traffic fatalities***
Situation 2010:	241,131	2,478
Prediction for 2020 according to mobility scenarios:		
Further stagnation	178,210	692
Growth	220,943	847
Reduction	143,743	566

Table 4: Forecasting scenarios on the basis of the Latent Risk model with level risk and level exposure fixed and with interventions (LRT 4). Mobility scenarios are based on predicted value from LRT4 model +/- one standard deviation.

SWEDEN

1 Raw data:

1.1 Exposure:



Figur.1: Plot of the annual number of vehicle kilometres (in billion) for Sweden from 1970 to 2009.

As exposure measure we consider the number of motor vehicle kilometres. Yearly data are obtained from IRTAD and shown for the period 1970 to 2009.

The plot shows a gradual increase over the years. In the years 1973, 1976 and 1987-1989 there was a larger increase in vehicle kilometres.

1.2 Fatalities:

The plot below shows the number of fatalities in Sweden from 1970 to 2010. Data are from CARE and IRTAD.

In general, there is a decrease in the number of fatalities between 1970 and 1982, followed by a stagnation in the period 1983-1992. Afterwards, the general trend was decreasing, yet there was a peak in the number of fatalities in 2000 and 2007.

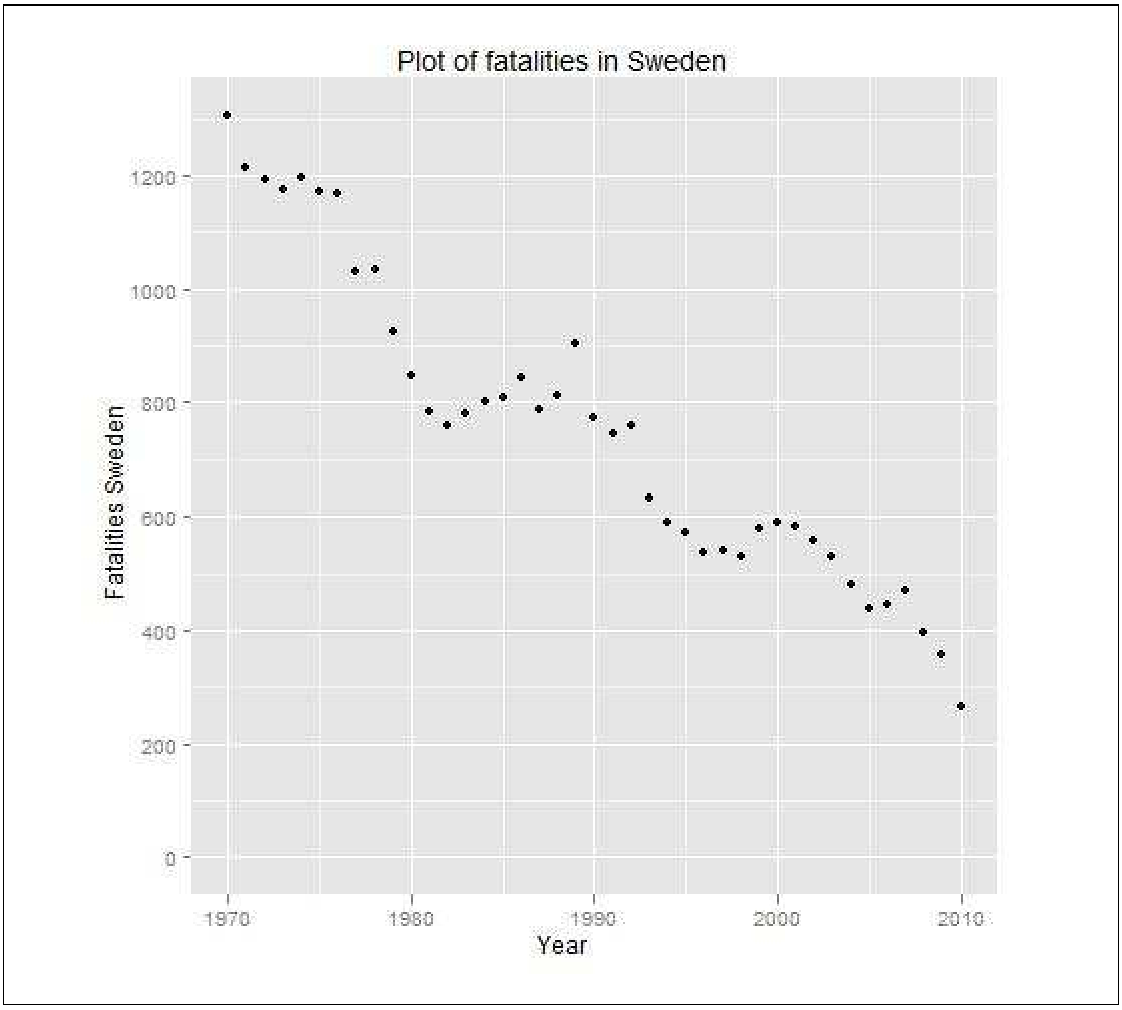


Figure 2: Plot of the annual fatality counts for Sweden from 1970 to 2010.

2 The SUTSE Model:

2.1 Development of the state components:

The figure below presents the varying level and slope estimation results of the SUTSE model: in particular the smoothed state plots for the exposure (top) and fatality (bottom) variables. The left subfigure in each row shows the level estimate for the corresponding variable and the right subfigure shows the slope estimate. Confidence intervals are also presented in these figures.

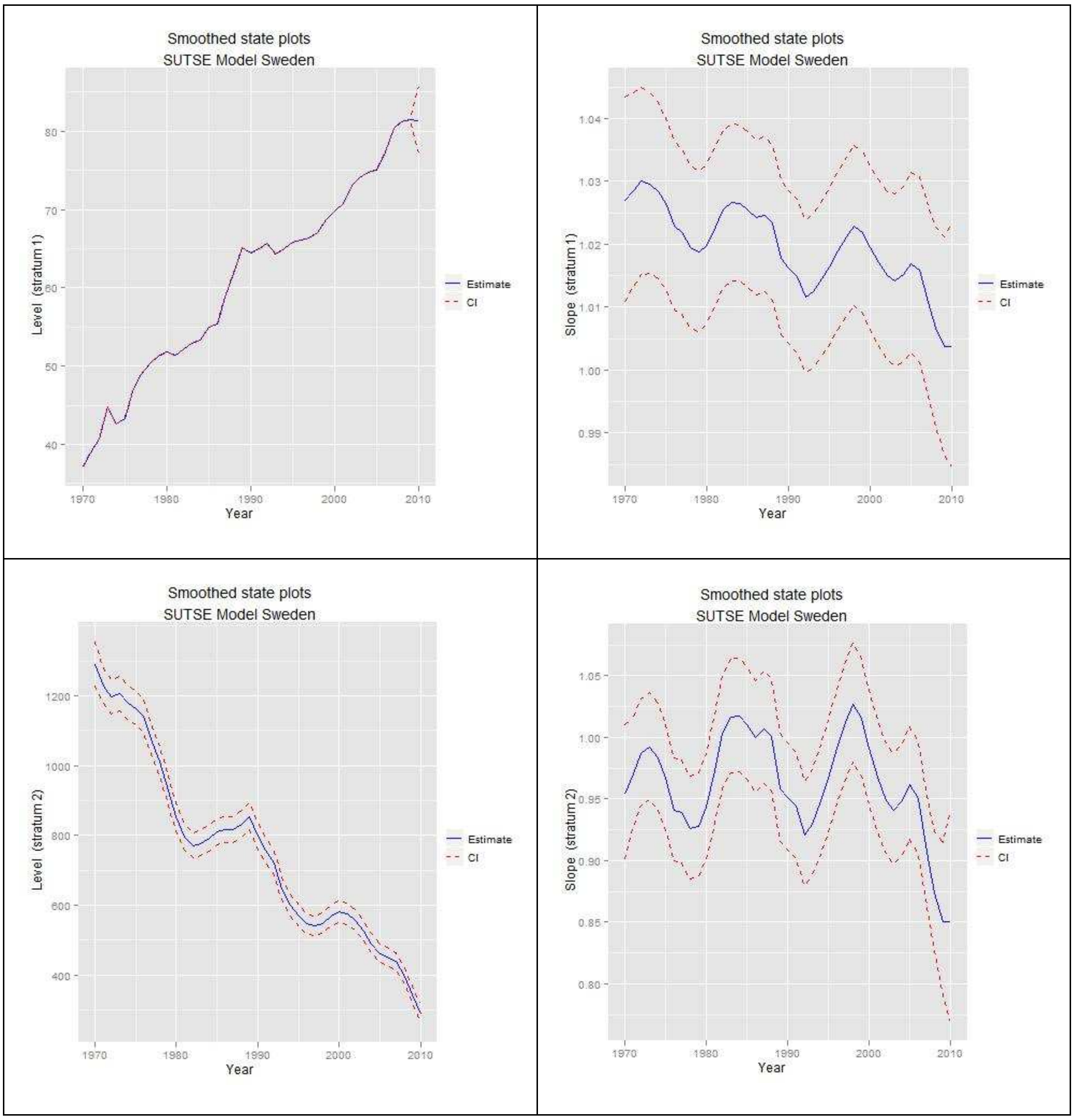


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend in the number of vehicle kilometres in Sweden increased from 37 billion in 1970 to more than 80 billion by 2009. Since all slope values (see top right subfigure in Figure 3) exceed 1, the number of vehicle kilometres has systematically increased from one year to another. The size of the annual increases decreases over the years and tends towards zero in the latest years.

2.1.2 Fatalities

The trend in the number of fatalities decreased from 1300 to 300 in the period 1975-2010. During the 1980s and late 1990s, the trend increased. Similar to the slope evolution regarding exposure, fluctuations can be seen. The majority of the values are smaller than 1, thereby indicating a decrease in the annual fatality numbers over most of the time period studied. Between 2006 and 2010 the slope further decreased instead of going up again.

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components

The correlation between the two levels is estimated as 0.34 and the correlation between the two slopes as 0.85. Both correlations are not significant (p=0.32 respectively 0.57).

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 0.00 which is not significant (p=1).

2.2.3 Estimation of the relationship by means of a coefficient

A SUTSE model where the relationship between the 2 series is estimated on the basis of a fixed regression coefficient fits the data equally well as the current model, where this relationship is estimated on the basis of the covariance between the state disturbances of the two series (see Table 1). The beta coefficient for the relationship between the latent developments of the two series is equal to 0.58 and is not significant (p=0.22).

2.2.4 Conclusion

It can be concluded that the fatalities and vehicle kilometres series are not related and therefore further modeling can be made using the LLT model (instead of the LRT).

Model title		***SUTSE Sweden1***	***SUTSEbetaSweden1***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	169.86	169.59
	AIC	-339.29	-338.79
Hyperparameters			
	Level exposure	6.29E-04 *c	6.48E-04 *
	Level fatalities	6.57E-04 nsc	9.25E-04 ns
	Slope exposure	1.98E-05 nsc	5.75E-06 ns
	Slope fatalities	1.24E-03 nsc	9.50E-04 ns
Correlations			
	level-level	0.34	
	slope-slope	0.85	
Observation variances			
	Observation variance exposure	1.03E-09 ns	2.26E-09 ns
	Observation variance fatalities	1.76E-09 ns	1.84E-09 ns
Beta		/	0.58 (p= 0.22)

Table 1: Model criteria and results for SUTSE models – Sweden.

3 The LLT/LRT Model:

3.1 Model selection:

Given that no relationship could be identified between exposure and fatalities on the basis of the data at hand, a Local Linear Trend model was fit to model the fatalities.

In the full model (LLTSweden1), both level and slope appeared to be non-significant. Therefore, a second respectively third LLT model was run, i.e. LLTSweden2 with a fixed slope and LLTSweden3 with a fixed level. Given the fact that in both cases, the remaining component appeared to be significant, no further models were run.

We select a more parsimonious model over the full model. Moreover, given the smaller prediction errors (ME10 and MSE10), LLTSweden2 is selected as the forecasting model. The very low 2010 value influences its violation of the assumption concerning the normality of the residuals.

Model title	***LLT Sweden1***	***LLT Sweden2***	***LLT Sweden3***
Model description	Full Model	Fixed slope	Fixed level
Model Criteria			
ME10	-275.02	-47.13	-275.02
MSE10	103811.79	5339.34	103811.79
log likelihood	64.63	63.71	64.59
AIC	-129.12	-127.31	-129.09
Model Quality			
Box-Ljung test 1	0.33	3.40	0.21
Box-Ljung test 2	2.45	3.50	0.35
Box-Ljung test 3	3.81	4.35	2.42
Heteroscedasticity Test	1.49	1.43	1.48
Normality Test standard Residuals	2.42	2.96	2.45
Normality Test output Aux Res	2.28	9.70**	2.42
Normality Test State Aux Res Level	0.06	2.47	0.07
Normality Test State Aux Res Slope	1.28	0.05	1.67
Variance of state components			
Level	4.74E-04 ns	4.06E-03 *	-
Slope	1.32E-03 ns	-	1.57E-03 *
Observation variance			
Observation variance	1.00E-09 ns	1.00E-09 ns	6.99E-06 ns
Interventions			

Table 2: Overview of the results for the LLT models – Sweden.

3.2 Development of the state components:

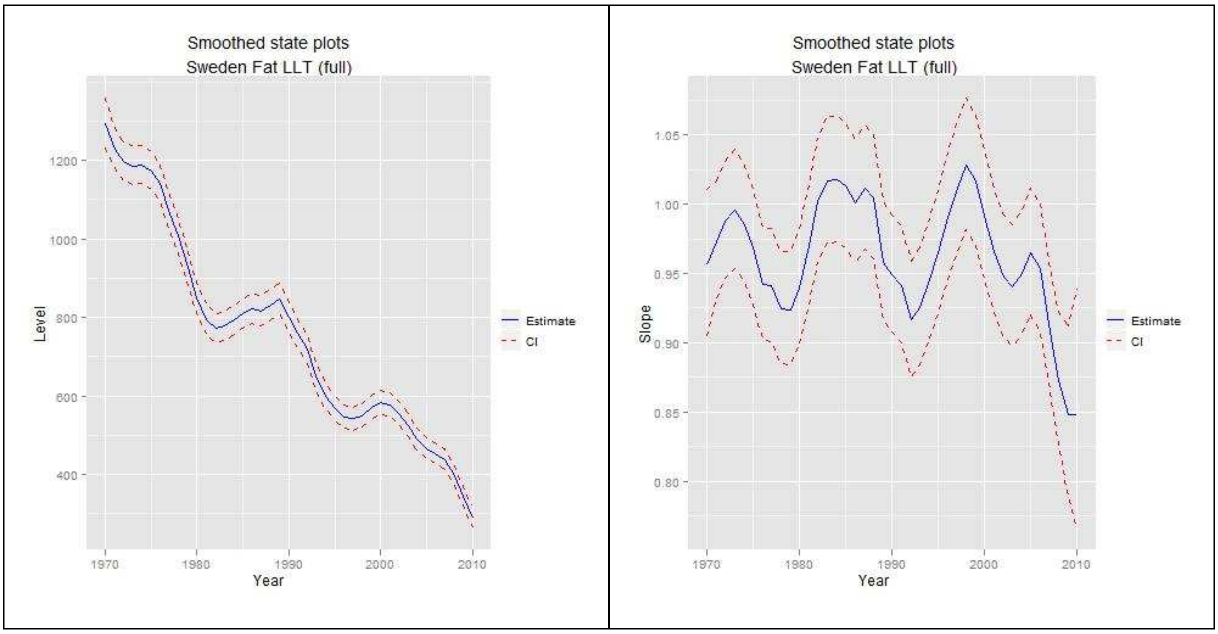


Figure 4: Developments of the state components for the fatalities, as estimated on the basis of the full LLT model.

3.2.1 Fatalities

The trend in the number of fatalities decreased from 1300 to 300 in the period 1975-2010. During the 1980s and late 1990s, the trend increased. The right-hand figure shows fluctuations. The majority of the values are smaller than 1, thereby indicating a decrease in the annual fatality numbers over most of the time period studied (of on average 3.6% per year). Between 2006 and 2010 the slope further decreased instead of going up again.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series. It can be seen that the actual values lie within the prediction margins except the 2009 and 2010 value.

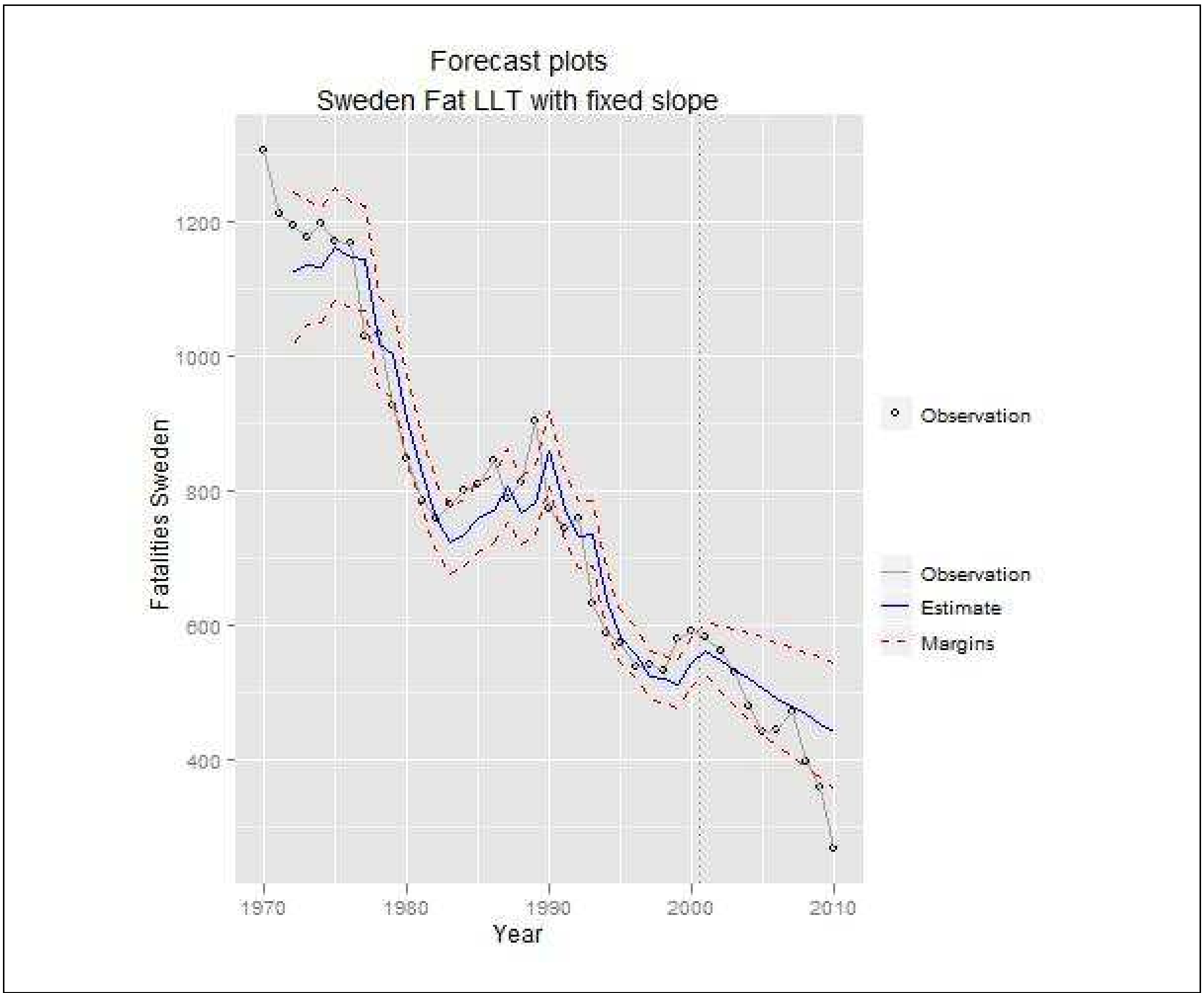


Figure 5: Plot comparing the model predictions (straight line) with the actual observations (“bullets”) for the annual fatality numbers in Sweden for the LLTSweden2 model.

4 Forecasts 2011 – 2020:

The forecasts obtained from the model provide an indication of the fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past.*

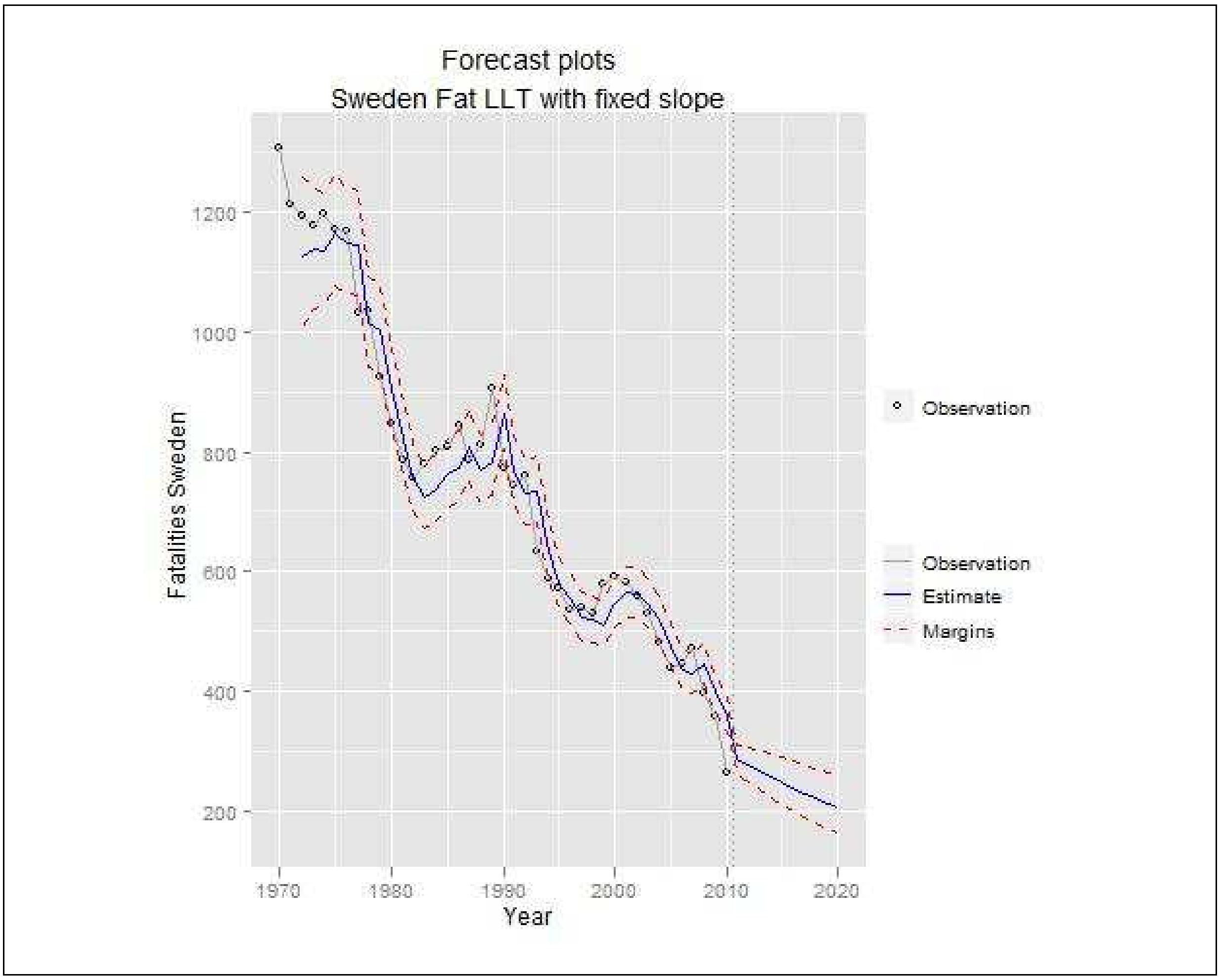


Figure 6: Plot of the annual fatality numbers for Sweden and the forecast for 2020 (based on the Local Linear Trend Model LLTSweden2).

	Fatalities		
Year	Predicted	Confidence Interval	
2011	**287**	245	337
2012	**277**	225	340
2013	**267**	208	341
2014	**257**	194	341
2015	**248**	181	339
2016	**239**	169	337
2017	**230**	158	335
2018	**222**	148	332
2019	**214**	139	329
2020	**206**	130	326

Table 3: Forecasts of the Local Linear Trend Model LLTSweden2

SWITZERLAND

1 Raw data

1.1 Exposure

The selected exposure measure is the vehicle kilometres (in millions) travelled (see Figure 1), which are considered from 1975 onwards.

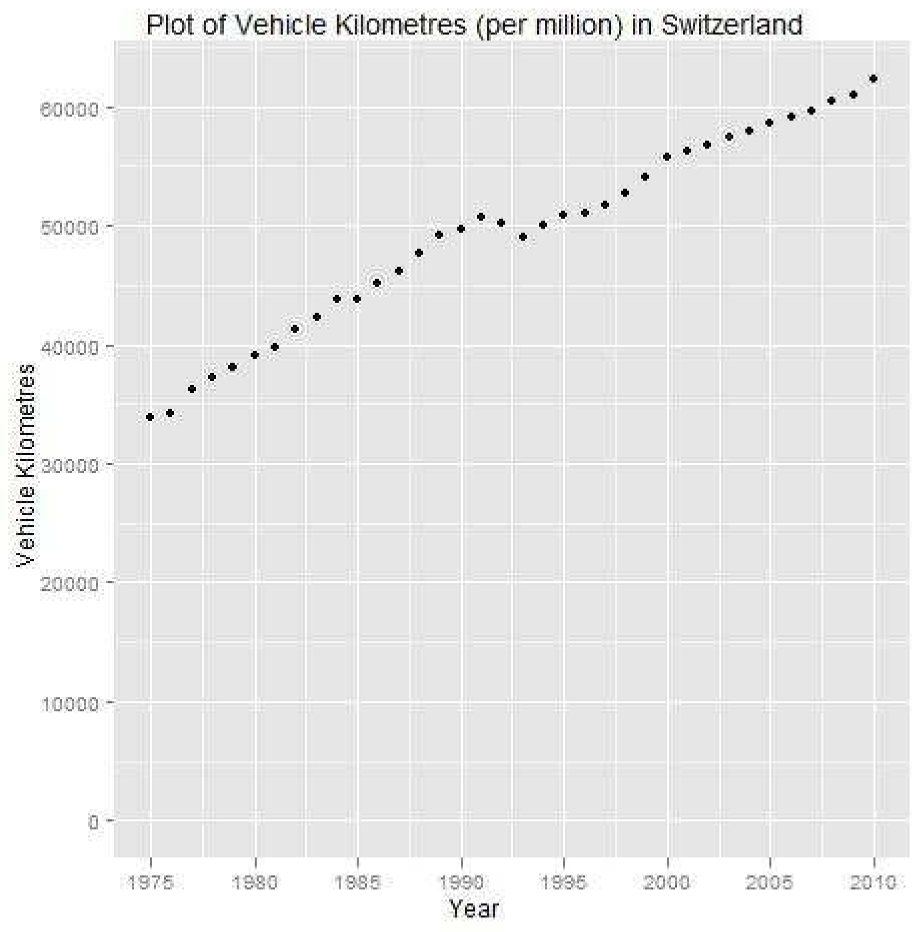


Figure 1: Plot of the annual numbers of vehicle kilometres (in million) for Switzerland from 1975 to 2010.

Between 1975 and 2010 the vehicle kilometres in Switzerland presents a constantly increasing trend, interrupted by a small drop on 1993. The mobility in that country does not appear to be affected by the global recession.

1.2 Fatalities

In Figure 2, the Swiss road accident fatalities are plotted. The fatality figures present a constantly decreasing trend throughout the period 1975 - 2010, with three visible drops on 1976, 1985 and 2004, and a visible small rise on 1990. The drop on 1985 is more striking, however according to national sources no intervention was involved, such as a change in registration, introduction of measures or other socioeconomic event. It was decided to treat this value in the fatality series as an outlier.

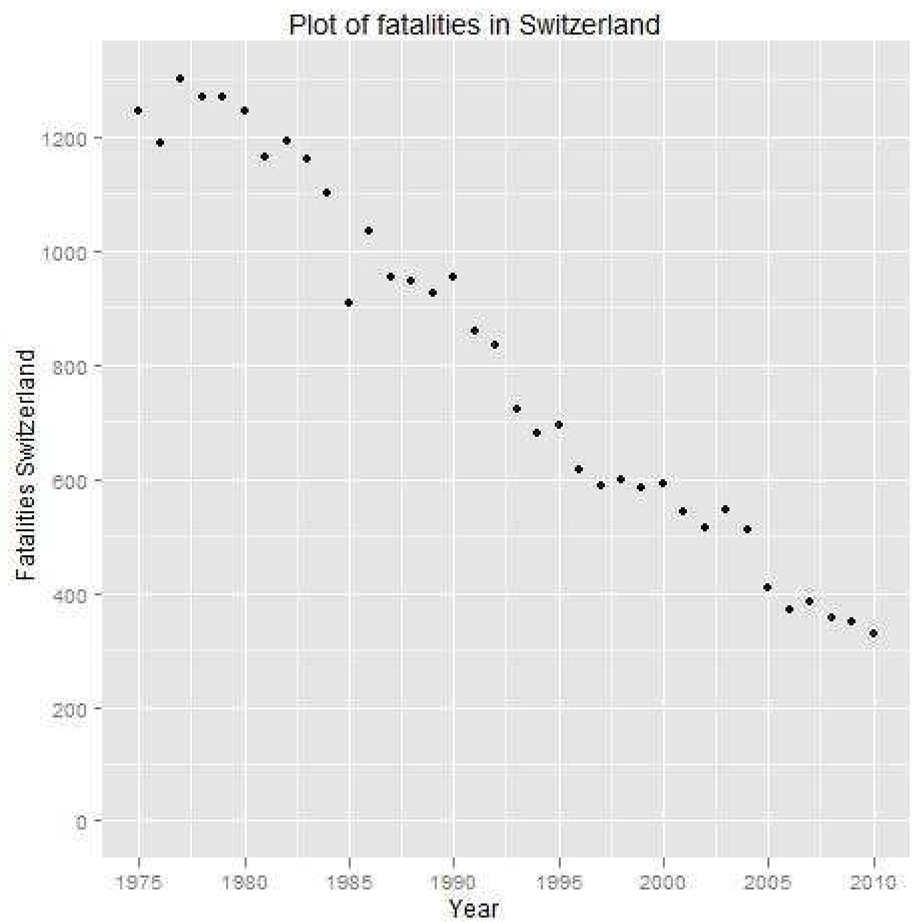


Figure 2: Plot of the annual fatality counts for Switzerland from 1975 to 2010.

2 The SUTSE Model

2.1 Development of the state components

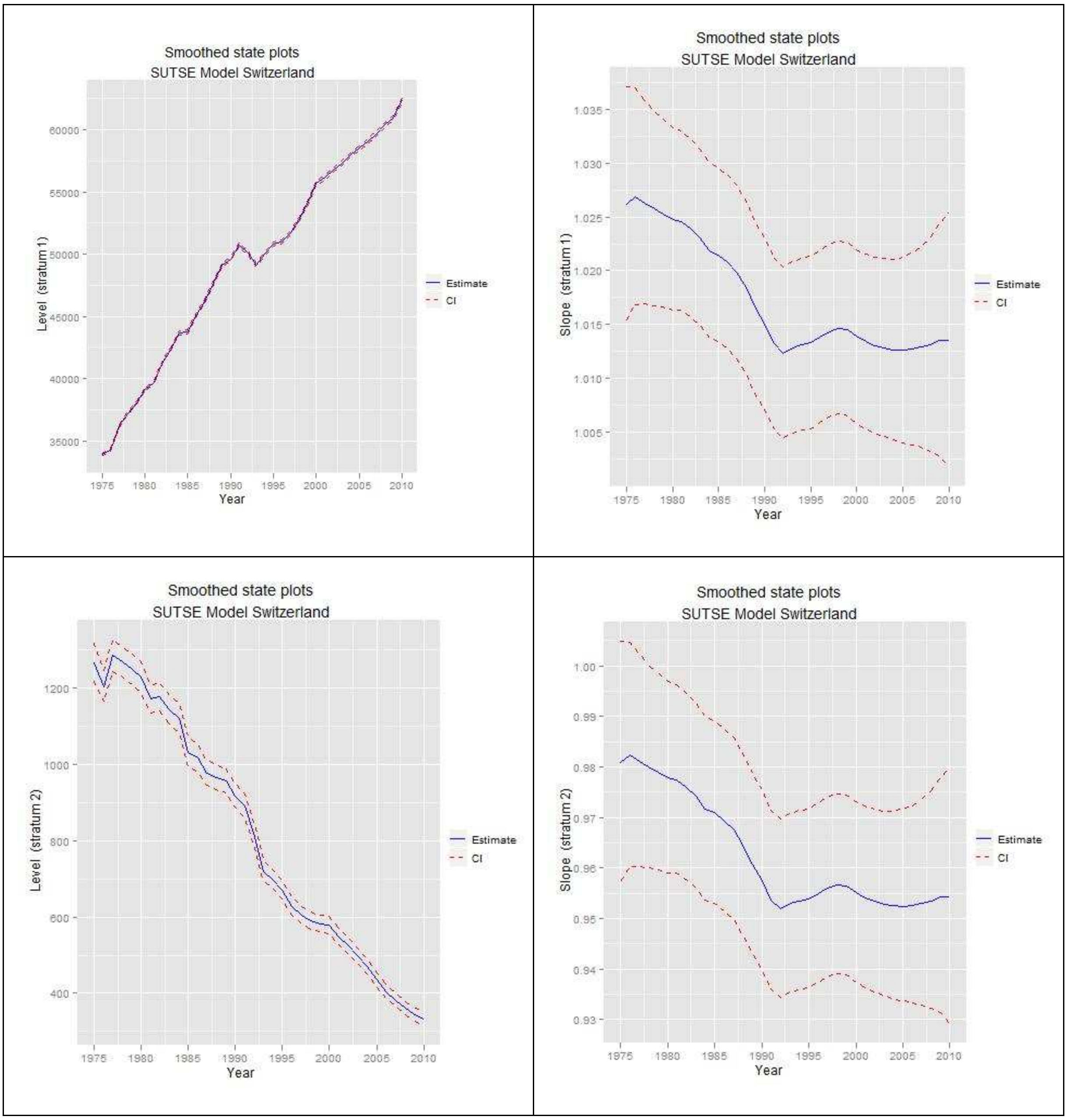


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the right-hand graphs, the slope developments in the left-hand graphs.

2.1.1 Exposure

The exposure rises constantly, in a seemingly linear way, and only the slope component appears to vary significantly. All the values of the slope component are higher than 1, suggesting that vehicle kilometres in Switzerland were constantly increasing, with a slightly slower rate as from 1993.

2.1.2 Fatalities

Both the level and the slope components vary significantly, with fatalities presenting a constant decreasing trend. The fatalities ranged between 1243 on 1975 (peaking at 1302 on 1977) to 327 on 2010. The slope component presents a very similar picture to the exposure slope component, suggesting that the two components may be related or even common.

2.2 Relation between the exposure and fatality series

2.2.1 Correlation between the disturbances of the state components

The level and the slope components of both the fatalities and the exposure are non significant. The correlation between the two levels is 0.84 and marginally significant at 95% ($p=0.095$). The correlation between the two slopes is equal to 1 and non significant ($p=0.156$) at 95%; it is however significant at approximately 85%, suggesting that the two components may be related to some extent.

2.2.2 Correlation between the irregulars

The measurement errors for exposure and fatalities are correlated at 0.07 which is not significant ($p=0.904$).

2.2.3 Estimation of the relationship by means of a coefficient

The relation between exposure and fatalities estimated by the beta coefficient in a restricted SUTSE/LRT model is 2.21 and is highly significant ($p<0.001$) at 99% suggesting that the two series are strongly related.

The fit of the restricted SUTSE/LRT model is identical to the fit of the full SUTSE model, indicating that the relation between fatalities and exposure does not vary over time.

Model title	***SUTSESwitzerland1***	***SUTSEbetaSwitzerland1***
Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria		
log likelihood	181.56	181.56
AIC	-362.62	-362.68
Variance of the state components		
Level exposure	1.61E-04 nsc	1.62E-04 *
Level risk	1.14E-03 nsc	3.44E-04 ns
Slope exposure	6.46E-06 nsc	6.43E-06 *
Slope risk	3.15E-05 nsc	1.12E-17 ns
Correlations between the state components		
level-level	0.84	
slope-slope	1	
Observation variance		
Observation variance exposure	2.95E-06 ns	2.82E-06 ns
Observation variance risk	4.18E-06 ns	4.08E-06 ns
Beta		2.21

Table 1: Overview of the results for SUTSE models – Switzerland

3 The LRT Model

The investigation of the SUTSE model clearly indicates a relation between exposure and fatalities in Switzerland. Moreover, from the data exploration, it appears obvious that the two series are related (for instance, the fatalities present a constant decreasing trend while the exposure presents a constant increasing trend, the developments of the slope components of both the fatalities and the exposure are very similar etc.) For these reasons, LRT models are examined for Switzerland.

3.1 Model selection

Model title	***LRT 1***	***LRT 4***	***LRT 5***

Model description	LRT for Switzerland - full model	LRT for Switzerland - restricted model	LRT for Switzerland - restricted model with intervention
Model Criteria			
ME10 Fatalities	-60.37	-53.74	-49.18
MSE10 Fatalities	5568.27	4795.50	4351.26
log likelihood	181.56	176.75	170.71
AIC	-362.62	-353.23	-341.15
Model Quality			
Box-Ljung test 1 Exposure	0.23	1.22	1.36
Box-Ljung test 2 Exposure	0.80	2.41	5.03
Box-Ljung test 3 Exposure	0.85	3.3	5.84
Box-Ljung test 1 Fatalities	2.17	2.86	2.64
Box-Ljung test 2 Fatalities	2.55	3.16	2.66
Box-Ljung test 3 Fatalities	3.11	3.77	3.36
Heteroscedasticity Test Exposure	0.39	0.45	0.81
Heteroscedasticity Test Fatalities	2.69	3.03	2.81
Normality Test standard Residuals Exposure	6*	1.32	3.3
Normality Test standard Residuals Fatalities	0.02	0.31	0.53
Normality Test output Aux Res Exposure	0.044	0.46	3.53
Normality Test output Aux Res Fatalities	1.25	1.59	1.83
Normality Test State Aux Res Level exposure	3.38	3.08	0.04
Normality Test State Aux Res Slope exposure	1.3	0.71	0.18
Normality Test State Aux Res Level risk	3.57	8.38*	7.70*
Normality Test State Aux Res Slope risk	0.07	3.92E-05	3.37E-05
Variance of state components			
Level exposure	1.61E-04 nsc	-	-
Level risk	5.84E-04 nsc	7.66E-04 *	7.79E-04 *
Slope exposure	6.46E-06 nsc	4.15E-05 *	6.84E-06 *
Slope risk	9.41E-06 nsc	-	-
Correlations between state components			
level-level	0.64		
slope-slope	1		
Observation variance			
Observation variance exposure	2.95E-06 ns	5.95E-05 *	7.32E-05 *
Observation variance risk	4.18E-06 ns	2.99E-04 ns	2.47E-04 ns
Interventions			
(1993 exposure level)			-0.05 *

Three versions of the LRT model are presented: a full model, a restricted model (fixed level exposure and fixed slope risk), and a restricted model with interventions.
The full LRT model (LRT 1) suggests that both the level and slope of both components are non significant. All components are also indicated to be common, suggesting that it might be

wise to start fixing “half” of the related components (i.e. the slopes). Moreover, the covariances between components are significant in the full LRT model, and the correlation between them is close to one.

Initially, a restricted model with fixed slope of the risk was fitted (LRT2 – not presented here), in which the remaining three components were still non significant. Two alternatives were then examined: in the first one, both slopes (exposure and risk) were fixed; the output of this model (LRT3 – not presented here) was still problematic, as the covariance between the two levels was very significant and the smoothed output plots reflected a deterministic exposure level. The second option was a model with a fixed slope risk and a fixed level exposure (LRT4); this was proved to be a better option, as the remaining components were significant and the output was satisfactory overall.

Concerning the possible interventions, no information was available for specific road safety interventions or other socioeconomic events, it was therefore attempted to describe the most important changes reflected in the data series itself.

A change in exposure level on 1993 was considered as intervention variable, in LRT5 model. This variable was significant at 99% (p-value lower than 0.001). This model presents significantly improved fit compared to the full model (the difference in log-likelihood is equal to 12) and the prediction errors for fatalities are improved compared to the full model.

Consequently, this model (LRT5) is selected as the best performing model for Swiss fatality risk.

3.2 Development of the state components:

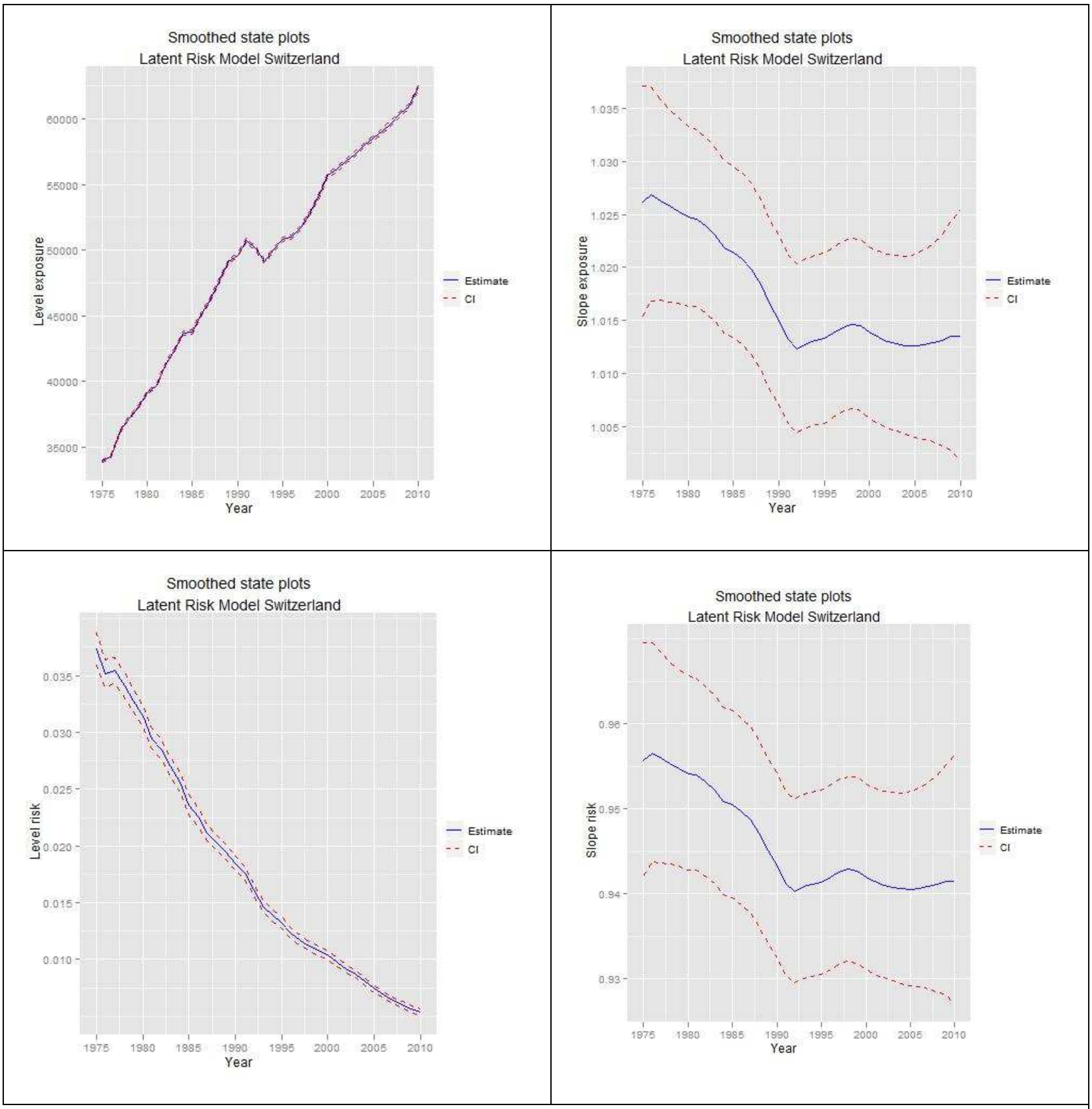


Figure 4: Developments of the state components for the exposure (above) and the risk (below), as estimated on the basis of the LRT1 model. The trend (level) developments are represented in the right-hand graphs, the slope developments in the left-hand graphs.

3.2.1 Exposure:

In the full model LRT1, only the slope components of the exposure series varies significantly over time.

The various values taken by the slope over the series are plotted in the right part of Figure 4. Each slope value indicates the percent change in the vehicle kilometres that has taken place from one year to the other.

Concerning the exposure slope, all the values exceed 1, which means that the number of vehicle kilometres has systematically increased from one year to the other. Changes in slope are observed on 1992 and on 2003.

The level appears to be deterministic, starting from around 33 billion vehicle kilometres in 1975, increasing smoothly, in a seemingly linear way and reaching a peak of 62 billion on 2010, with only a small drop on 1993.

3.2.2 Risk:

Similar to the exposure series, the trend for risk does not appear to be stochastic, while the slope does.

The level for the risk (i.e., the fatalities per million vehicle kilometres) decreases smoothly.

The plot of the risk slope values over the years varies significantly, in a much similar way to the slope of the exposure.

3.3 Quality of the predictions:

In order to evaluate the ability of the model (LRT5) to correctly predict the fatality numbers, it has been used to forecast these numbers for three different periods: 2006-2010, 2003-2010 and 1990-2010. Figure 5 below shows a plot of the predicted and observed values for the whole series, for the first (4 observations) and second (7 observations) forecasting period. The results of the third option (10 observations) are quite similar to those of the second one (7 observations).

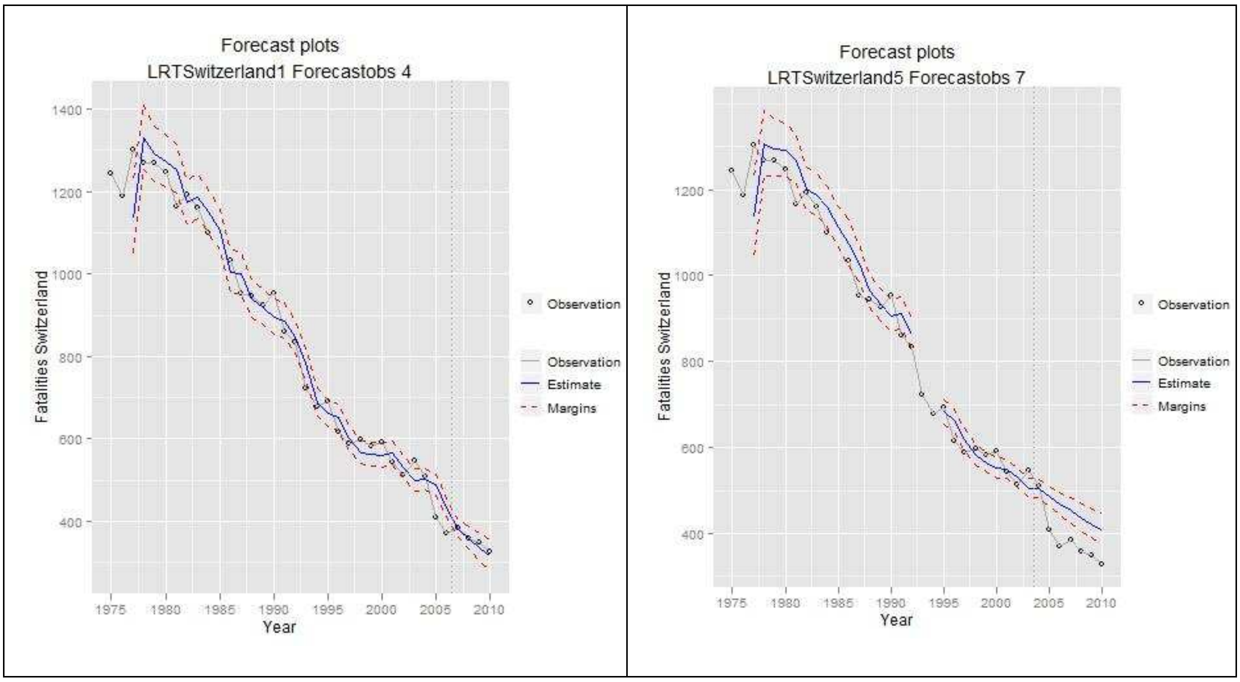


Figure 5: Plots comparing the model predictions (straight line) with the actual observations (“bullets”) for the annual fatality numbers in Switzerland for the LRT5 model with 4 forecasting observations (left-hand graph) and 7 forecasting observations (right-hand graph).

It is revealed that, only the first forecasting models (with 4 observations) appears to accurately predict the last part of the series. In case of 4 observations, the predictions are much closer to the actual values, due to the fact that the 2003 small drop in fatalities is included in the observation period, and not in the forecasting period. This is not the case in the second and third forecasting model (7 and 10 observations), resulting in overestimation of the last part of the series.

4 Forecasts 2010 - 2020:

The forecasts obtained from the model provide an indication of the vehicle kilometres and fatality numbers to be expected between 2010 and 2020 provided that, throughout these years, the trends keep on following the developments that they have shown in the past. Under this assumption, the number of vehicle kilometres is expected to decrease up to 70.8 billion in 2020, compared to 62.3 in 2010.

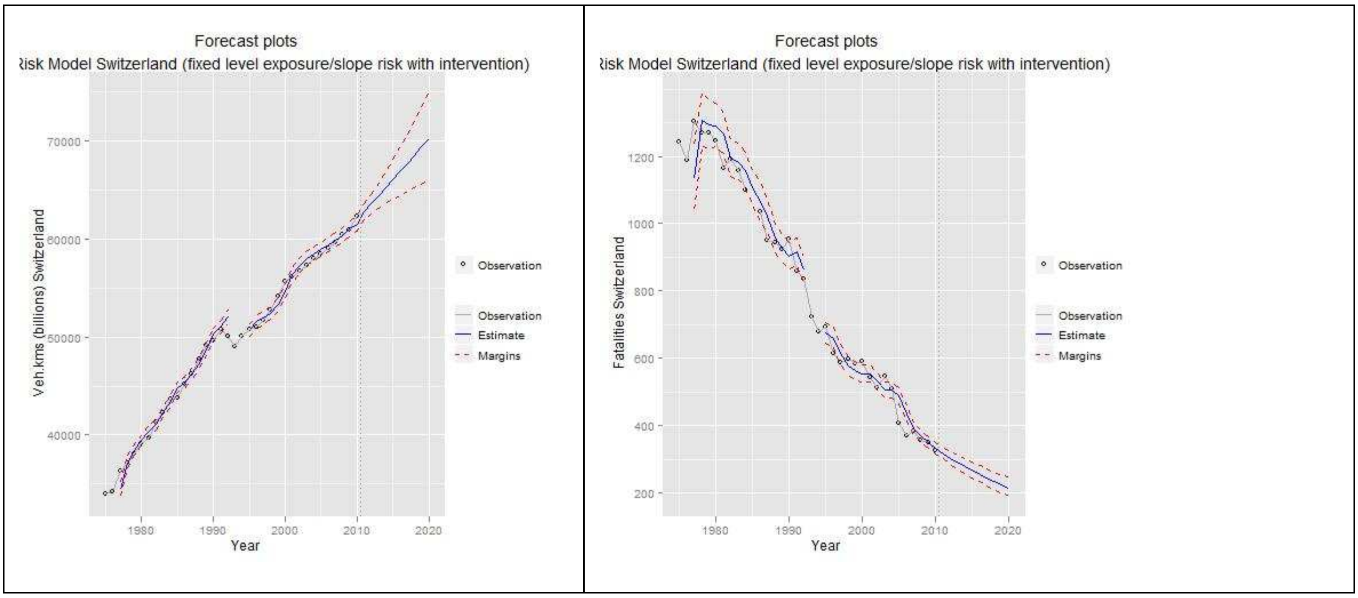


Figure 6: Plot of the vehicle fleet (left-hand graph) and annual fatality numbers (right-hand graph) for Switzerland forecasted between 2010 and 2020 (LRT 5).

Still assuming that past developments will extend into the future, the fatality numbers for Switzerland should keep on decreasing after 2010. The predicted value for 2020 is 216 fatalities, whereas 329 fatalities were recorded on 2010. Table 3 provides the details of the values forecasted for exposure and fatalities for all years from 2010 up to 2020.

	Vehicle kilometres (billions) Switzerland			Fatalities Switzerland		
Year	Forecast	Lower (2.50%)	Upper (97.50%)	Forecast	Lower (2.50%)	Upper (97.50%)
2011	**62.8**	61.2	64.4	**317**	288	350
2012	**63.6**	61.6	65.6	**304**	271	342
2013	**64.4**	61.9	66.9	**291**	255	333
2014	**65.2**	62.1	68.4	**279**	240	324
2015	**66.0**	62.2	70.1	**267**	226	316
2016	**66.8**	62.2	71.8	**256**	213	308
2017	**67.7**	62.2	73.6	**245**	201	300
2018	**68.5**	62.2	75.5	**235**	189	292
2019	**69.4**	62.1	77.6	**225**	178	285
2020	**70.3**	61.9	79.8	**216**	167	278

Table 3: Forecasts of the Latent Risk Model (LRT5)

5 Exposure Scenarios

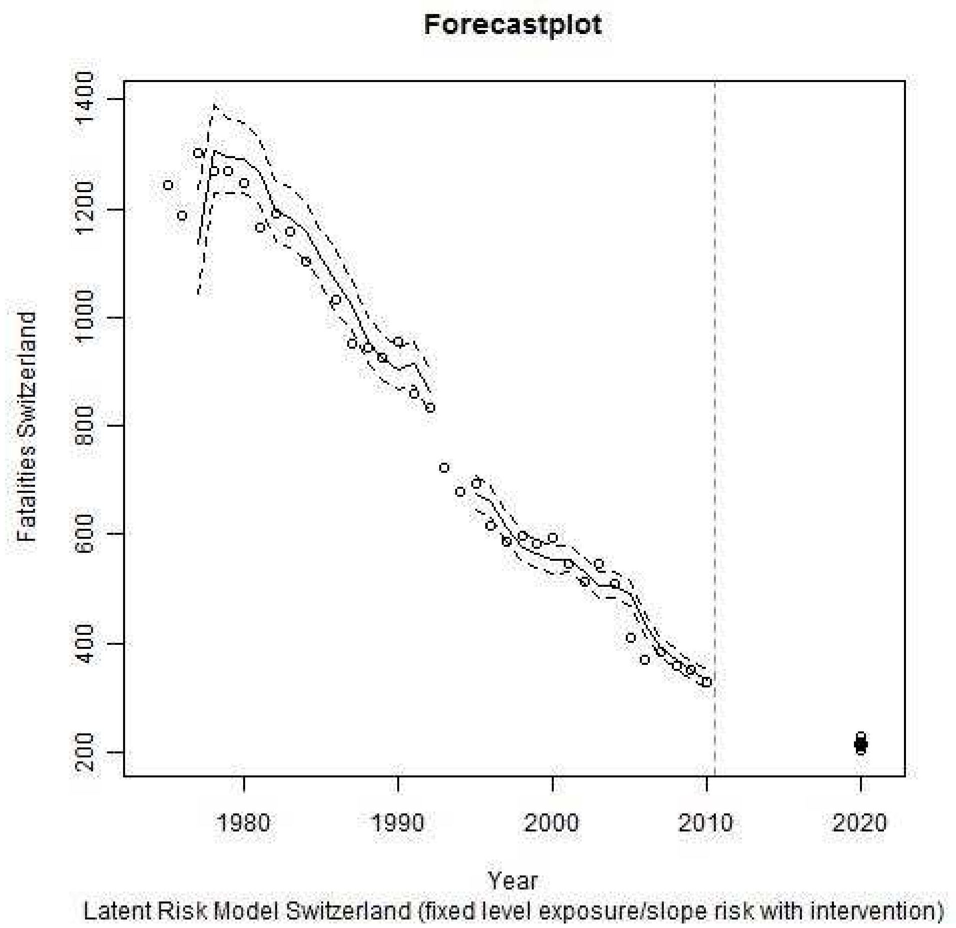


Figure 7: Fatality forecasts Switzerland 2020 under 3 exposure scenarios. ●Continuation of development (as estimated by LRT5 model). ◦ Stronger growth (LRT estimate + 1 SD). ◦ No growth (LRT estimate - 1 SD).

Three scenarios for the development of exposure are considered, which correspond to the number of vehicle kilometres predicted by the model (LRT5) for that year, plus/minus one standard deviation[20]. The values for the exposure scenarios and the estimated number of fatalities under each of them are provided in Table 4, and plotted in Figure 7.

[20] The upper and lower scenarios now include 68% of the cases, assuming a normal distribution.

	Vehicle kilometres (billions)	*Road traffic fatalities*
Situation 2010:	62,3	327
Prediction for 2020 according to mobility scenarios:		
Continuation of development	70.3	216
Stronger development	74.9	230
Decrease	65.9	202

Table 4: Forecasting scenarios on the basis of the Latent Risk model with level risk and level exposure fixed and with interventions (LRT5). Mobility scenarios are based on predicted value from LRT5 model +/- one standard deviation.

The predicted number of vehicle-kilometres for 2020 is 70 billion, a scenario under which one would expect 216 fatalities. The estimated fatality numbers assuming an increase in vehicle kilometres growth (forecast plus one standard deviation: 74.9 billion), is equal to 230, whereas the respective fatality numbers for a decrease in vehicle kilometres (forecast minus one standard deviation: 65.9 billion) is equal to 202.

UK

1 Raw data

1.1 Exposure

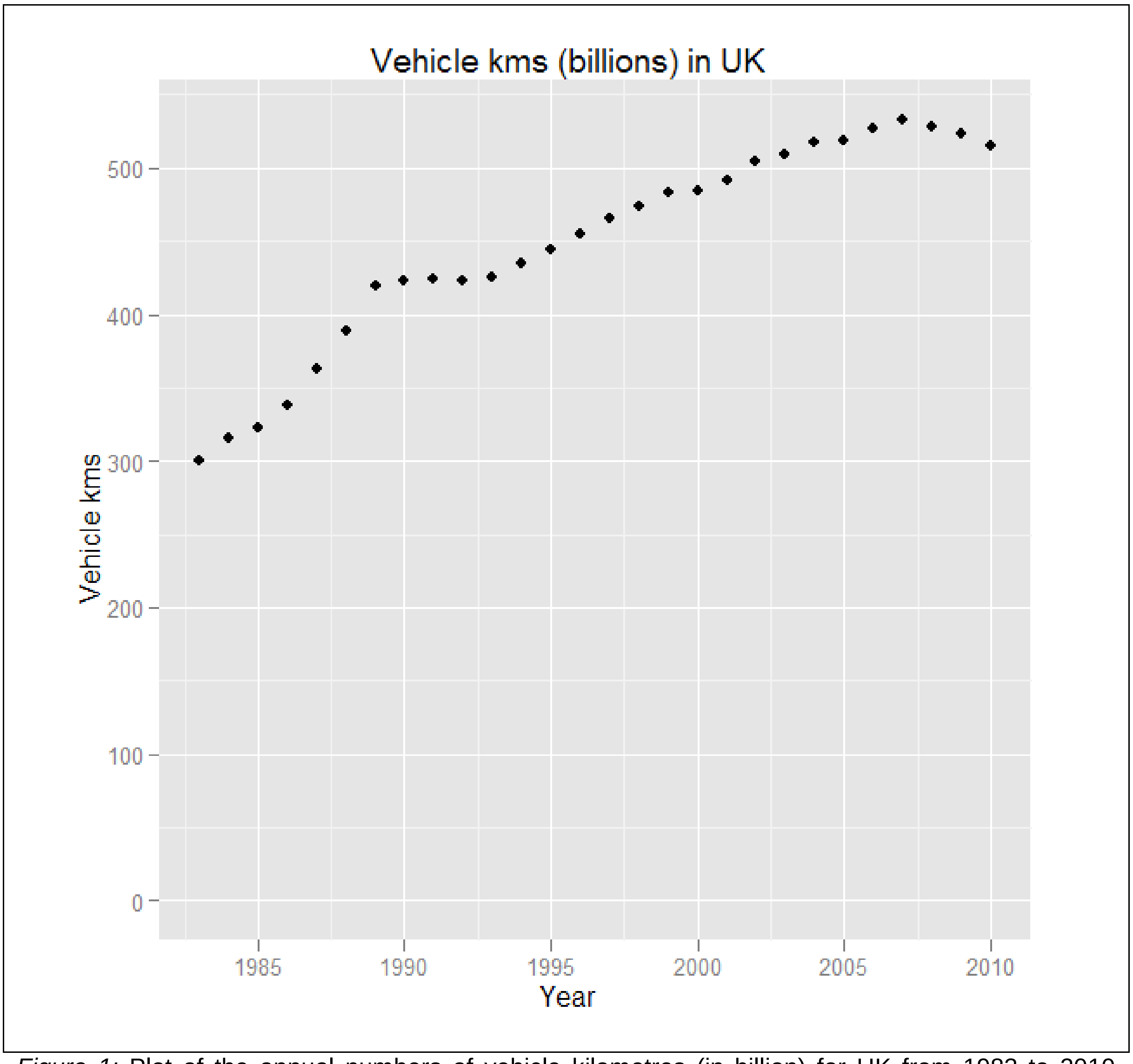


Figure 1: Plot of the annual numbers of vehicle kilometres (in billion) for UK from 1983 to 2010 (estimates for Northern Ireland have been included for 1983-1991).

Annual vehicle kilometres (traffic volume) are available for Great Britain and Northern Ireland separately, added together to give UK. The traffic and fatality data are available for Great Britain from 1947 but for Northern Ireland the traffic data are only available from 1991.

The annual volume of car traffic for GB is measured by the National Road Traffic Survey (NRTS). The road traffic estimates are calculated by combining data collected by some 180 Automatic Traffic Counters (ATCs) and manual counts at approximately ten thousand sites per annum.

Initially models of fatalities were fitted to the UK data using data from 1991. However, better fitting models can be developed using a longer time series. 1983 was chosen as a start year. This has the advantage of minimising any effects of the compulsory wearing of seatbelts law introduced at the start of 1983 and minimising the number of traffic data that would need to be imputed for Northern Ireland (8 years) in the modelling process.

Overall, vehicle kilometres in the UK increased from 1983 to 2007 with a flat period in the early 1990s but have started to fall in recent years.

1.2 Fatalities:

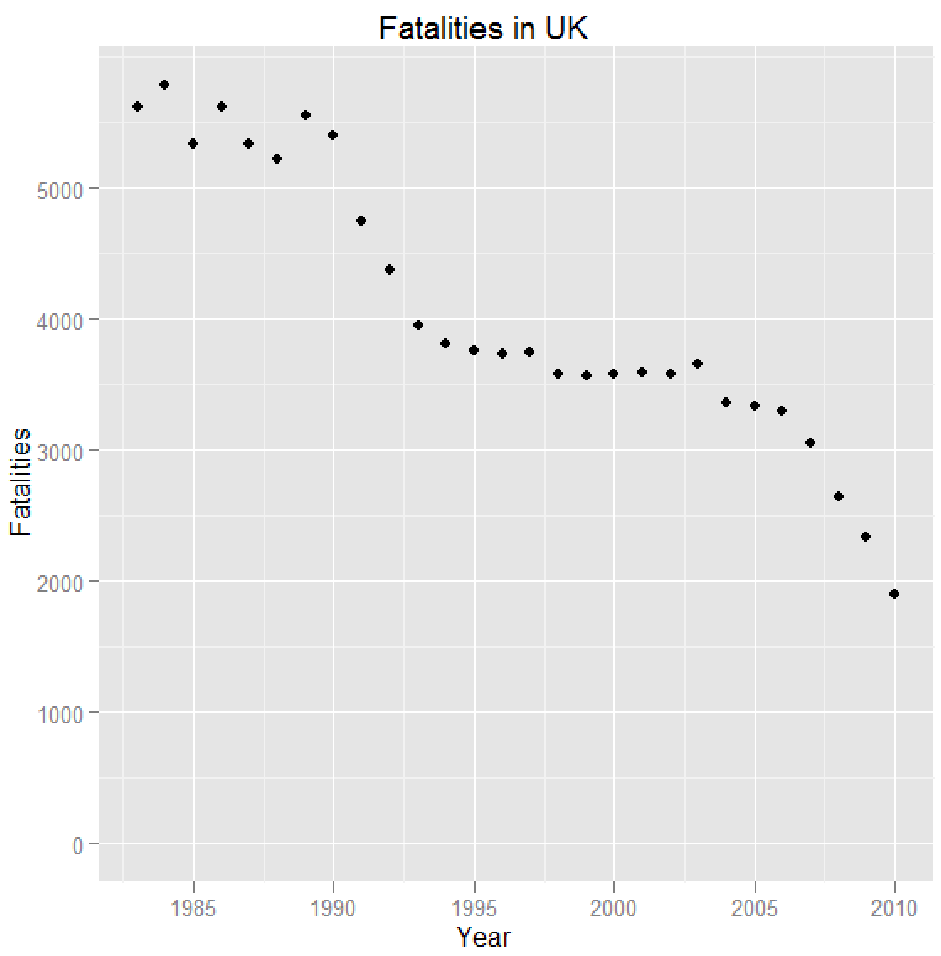


Figure 2: Plot of the annual fatality counts for UK from 1983 to 2010.

The data used in the modelling are the annual numbers of fatalities for Great Britain and Northern Ireland, added together to give UK.

The data come from national databases. The details of road accidents and casualties come from the national STATS19 database. Since 1949, police throughout Great Britain have recorded details of road accidents that involve personal injury using a single reporting system that is reviewed and updated regularly. The information about road accident casualties for Northern Ireland comes from the database of T1 accident reports compiled by the Police Service of Northern Ireland. Very few, if any, fatal accidents do not become known to the police.

The number of people killed has varied fairly erratically, with periods of slow decline in 1983-1990 and 1994-2007 separated by a period of more rapid decline between 1990 and 1993 and 2006 to 2010 The number of fatalities observed in 2010 (1905) is around 3 times lower than in 1983 (5,616).

2 The SUTSE Model:

2.1 Development of the state components:

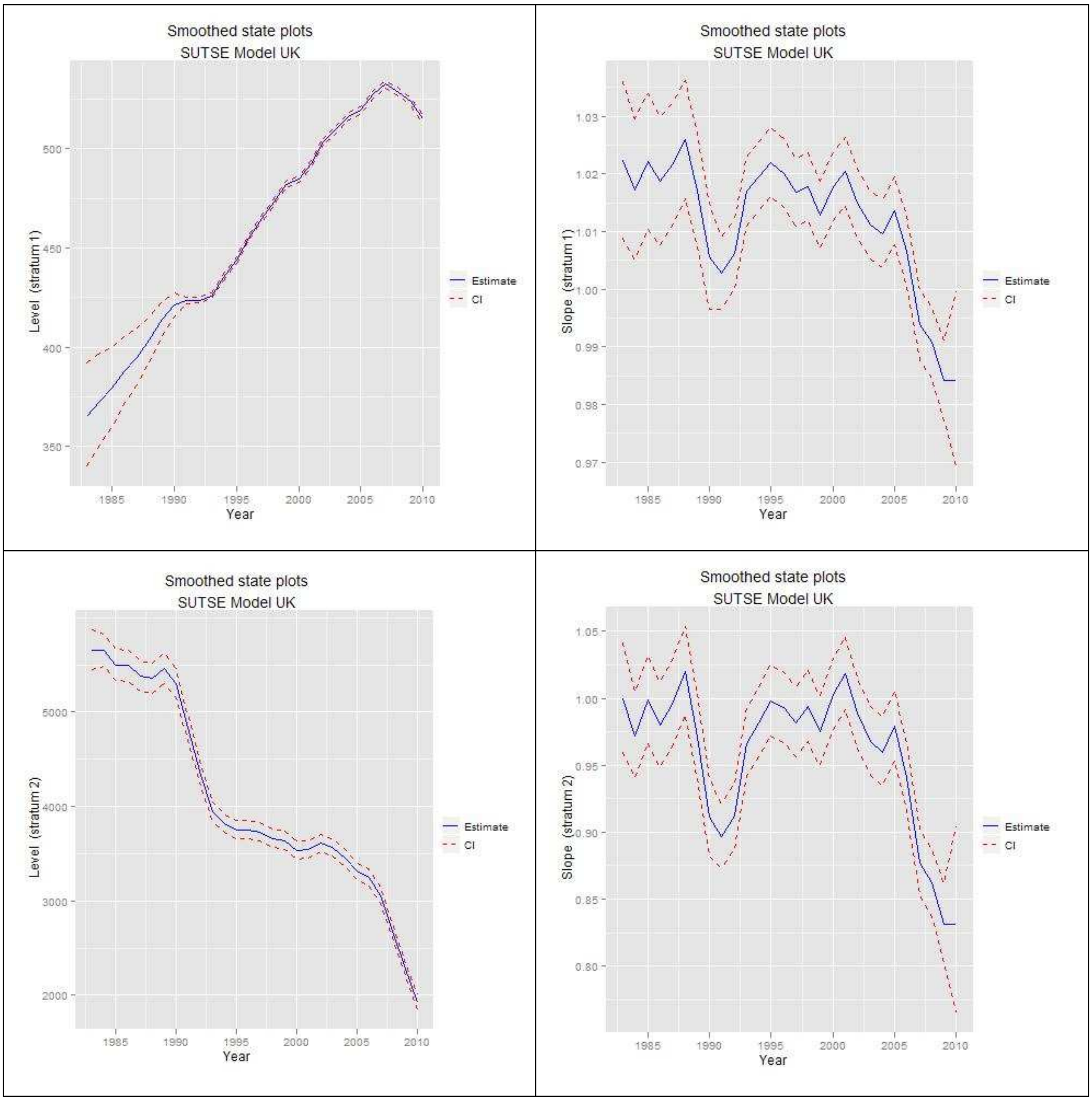


Figure 3: Developments of the state components for the Exposure (upper graphs) and the Fatalities (lower graphs), as estimated on the basis of the SUTSE model. The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

2.1.1 Exposure

The trend for exposure is estimated around 300 billion kilometres at the start of the series and around 515 billion kilometres at the end. The trend increases relatively smoothly, with the exception of a flat period in the early 1990s and falls from 2007.

The development of the slope is plotted in the top right of Figure 1. The slope shows the flat period in the early 1990s and the falls seen since 2008.

For exposure, the slope component is the only one to vary significantly over time (Table 1).

2.1.2 Risk

Figure 1 shows how the fatality risk per billion vehicles KM has developed in the UK between 1983 and 2010. It can be seen that overall the UK fatality risk has been declining for many years. The effects of the two recessions (periods of economic decline) in the early 1990s and from 2008 appear to have influenced the gradient of the risk curve (the slope), with it declining more steeply during these periods.

For risk, the slope component is the only one to vary significantly over time (Table 1).

2.2 Relation between the exposure and fatality series:

2.2.1 Correlation between the disturbances of the state components:

The correlation between the level disturbances of the two series is 1 and this correlation is not significant ($p=0.93$). The correlation between the slope disturbances of the two series is 0.97 and is significant ($p=0.003$) which could indicate the possibility of a common slope component. However when intervention terms are put into the model (to reflect the slope changes seen in the exposure and fatalities series) the correlation between the slope components is not significant.

2.2.2 Correlation between the irregulars:

The measurement errors for exposure and risk are correlated at -0.76 and this correlation is not significantly different from zero ($p=0.37$).

2.2.3 Estimation of the relationship by means of a coefficient:

An LRT/SUTSE model was fitted where the relationship between the 2 series was estimated on the basis of a fixed regression coefficient beta (= 4.83). This coefficient is significantly different from zero ($p=0.001$); i.e. implying that exposure and fatalities are correlated.

2.2.4 Compare the log-likelihoods of SUTSE model and LRT/SUTSE model

The values are very similar (111.1 compared to 111.0).

2.2.5 Conclusion

The fatality and exposure series are related and as such an LRT model should be fitted.

Model title		***SUTSEUK1***	***SUTSEbetaUK1***
	Model description	SUTSE full model	SUTSE independent components, beta estimated
Model Criteria			
	log likelihood	111.14	111.03
	AIC	-221.63	-221.5
Hyperparameters			
	Level exposure	1.99E-05 nsc	3.42E-17 ns
	Level risk	4.50E-06 nsc	1.17E-15 ns
	Slope exposure	4.94E-05 *c	6.04E-05 *
	Slope risk	1.48E-03 *c	1.62E-04 ns
Correlations			
	level-level	1	
	slope-slope	0.97	
Observation variances			
	Observation variance exposure	6.19E-06 ns	1.11E-05 *
	Observation variance risk	2.37E-04 ns	2.21E-04 ns
Beta			4.83* (p= 0.001)

Table 1: Model criteria and results for SUTSE models - UK.

3 The LRT Model:

3.1 Model selection:

In the previous section, a relationship could be identified between exposure and fatalities. Therefore several versions of the Latent Risk Model were fitted using interventions for the changes in slope in the exposure and risk curves seen in the initial investigation.

Initially a full LRT model was fitted using no interventions. It became immediately clear that without modelling the two slope changes in the 1991-1993 and from 2008, the forecasted number of fatalities could not be considered plausible (too low). The recent trends are not expected to continue until 2020 and this assumption needs to be taken into account in the modelling. This is further confirmed by the fact that the number of fatalities recorded in the UK in 2011 (1960 fatalities)- which is not used in the present analysis - is larger than the one recorded in 2010 (1905).

A simple forecasting option would be to forecast 2020 using data up to 2007 only and to treat the later years as missing (estimate 2,266 in 2020). However, this approach is not ideal either as it discards known information, and is likely to overestimate the future numbers as it does not take account of any recent falls in the series. Given the uncertainty surrounding the forecasts, the decision was made to report both the results of a model in which no intervention is used to model the recession effects in the last years of the series with one in which the impact of the economic crisis is modeled by introducing interventions.

Concretely, the approach taken in the latter case was to use intervention terms to model the change in slope for the fatality and the exposure series (in the early 1990s and around 2007). It is assumed that these slope changes are an effect of two economic recessions in the UK. A major challenge in this approach was ‘predicting’ the end of the current economic recession. A study of the GDP figures lead to the assumptions that an intervention was needed for the years 1991-1992 (returning to ‘normal’ in 1993) and from 2008 to 2011 (returning to ‘normal’ in 2012). The fatality series appears to lag behind GDP, because although falls in GDP were seen in 1990Q2 the fatality risk did not fall until 1991. It was of interest to test the sensitivity to the forecasts if it was assumed the slope returned to ‘normal’ in 2010 and 2011.

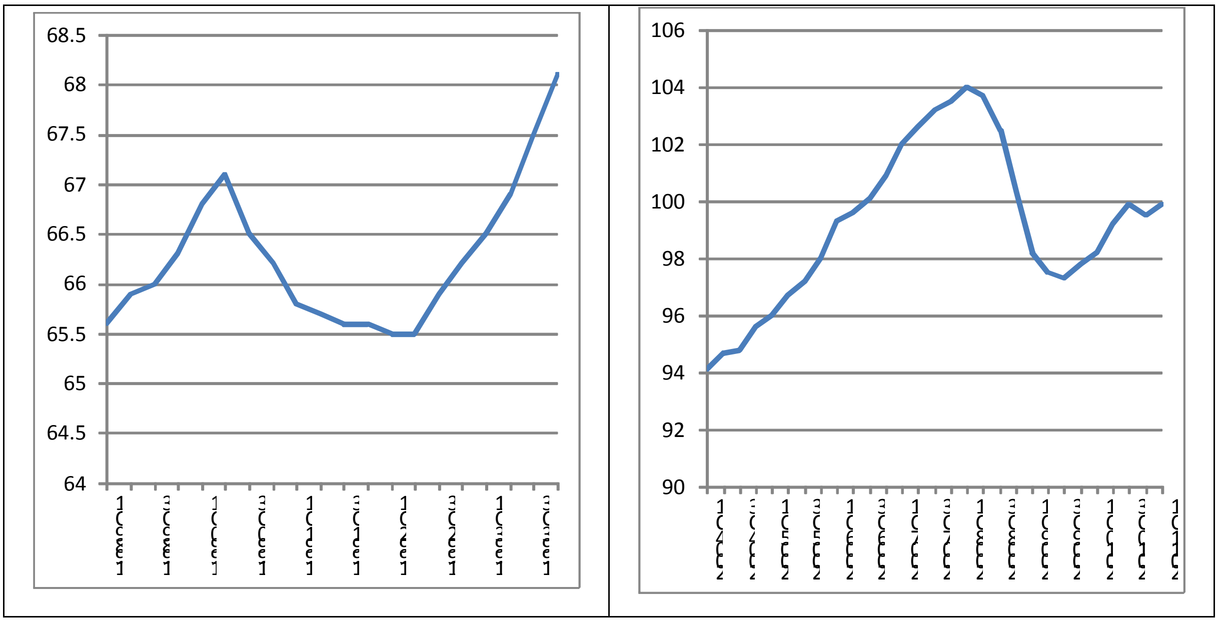


Figure 4: Plot of quarterly GDP 1989-1994 (left-hand graph) and 2004-2011 (right-hand graph) for UK.

All four interventions were significant. However, the addition of these interventions caused the heteroscedasticity tests to fail. The main reason for this is that the series is more erratic prior to 1990 compared to the later series.

Another possibility was to assume that the “erratic” behaviour of the slope prior to 1990 is part of its “normal” dynamic, and to assume that they would continue in the future. As explained already, this results in very optimistic, and actually very uncertain forecasts compared to those obtained from the model where the important reduction at the end of the series is modeled by means of interventions (and consequently are explained and are not assumed to maintain in the future).

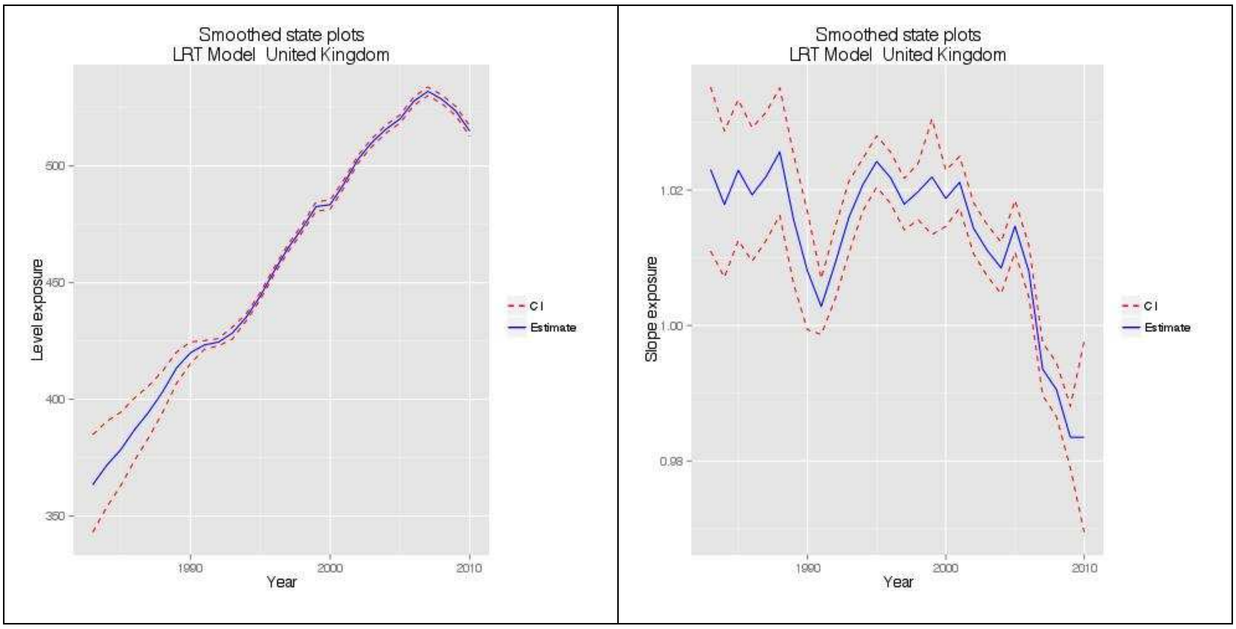
The full LRT model (with no intervention terms) suggested that the random component of the level should be fixed for both exposure and fatalities. One potential intervention was identified on the exposure level in 2000, but its influence on the forecast is minimal.

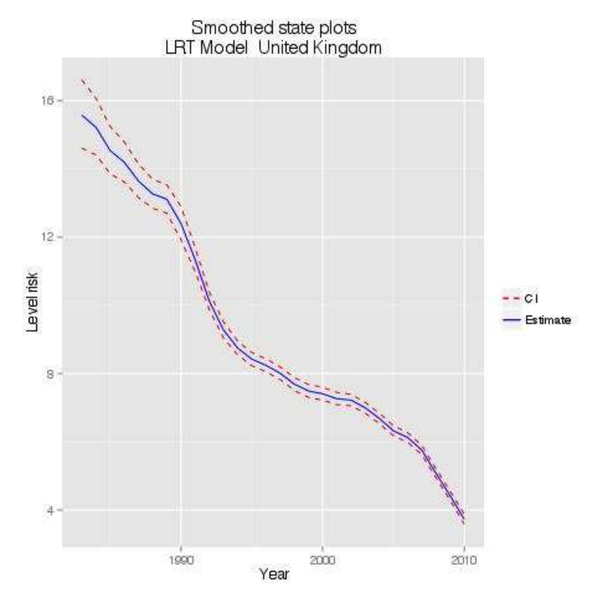
Model title	***LRT 1***	***LRT2***	***LRT3***
Model description	LRT full model With no interventions	LRT full model with interventions	LRT model with interventions and fixed levels for exposure and fat-risk
Model Criteria			
Log-likelihood	111.14	103,351	96,235
AIC	-221.63	-206,06	-192,041
Model Quality			
Box-Ljung test 1 Exposure	1.13	2,10	2,04
Box-Ljung test 2 Exposure	1.58	2,11	2,05
Box-Ljung test 3 Exposure	3.17	2,85	2,12
Box-Ljung test 1 Fatalities	1.23	1,46	1,04
Box-Ljung test 2 Fatalities	1.34	1,47	1,26
Box-Ljung test 3 Fatalities	1.66	1,76	1,26
Heteroscedasticity Test Exposure	0.87	0,93	1,20
Heteroscedasticity Test Fatalities	5.28	7.02*	4,31
Normality Test standard Residuals Exposure	0.04	0,43	0,11
Normality Test standard Residuals Fatalities	1.29	3,19	2,08
Normality Test output Aux Res Exposure	0.57	0,89	0,72
Normality Test output Aux Res Fatalities	0.41	0,20	0,27
Normality Test State Aux Res Level exposure	1.22	0,69	1,55
Normality Test State Aux Res Slope exposure	0.39	0,60	0,44

Normality Test State Aux Res Level risk	1.59	1,55	1,24
Normality Test State Aux Res Slope risk	0.22	0,46	0,42
Variance of state components			
Level exposure	1.99E-05 nsc	2.13E-06 nsc	-
Level risk	5.48E-06 nsc	2.22E-05 nsc	-
Slope exposure	4.94E-05 *c	5.78E-05 *c	4.80E-05 *
Slope risk	1.00E-03 *c	1.07E-03 *c	9.24E-04 *
Correlations between state components			
level-level	-1	1	-
slope-slope	0.95	0,96	0,96
Observation variance			
Observation variance exposure	6.19E-06 ns	1.75E-05 ns	7.64E-06 *
Observation variance risk	2.37E-04 ns	2.95E-04 ns	2.05E-04 *
Interventions			
(Break level exposure in 2000)	None	-0.02 *	-0.02 *

Table 2: Overview of the results for UK.

3.2 Development of the state components:





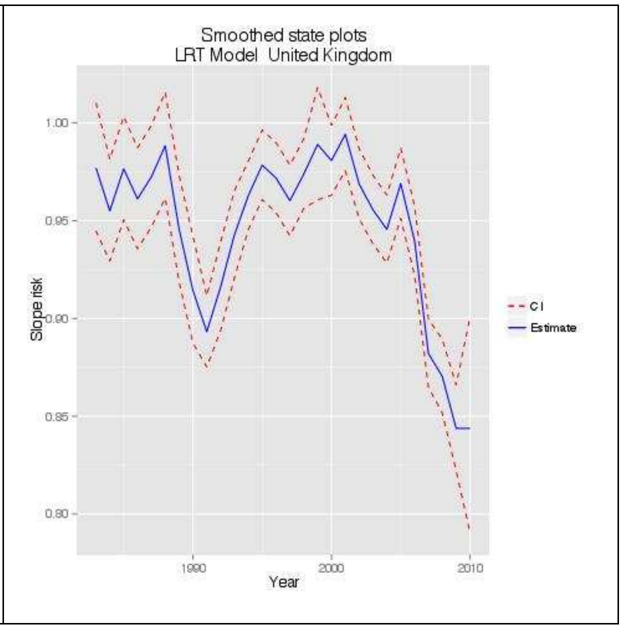


Figure 5: Developments of the state components for the exposure (above) and the risk (below), estimated using the LRT model (with interventions). The trend (level) developments are represented in the left-hand graphs, the slope developments in the right-hand graphs.

3.3 Quality of the predictions:

To evaluate the ability of the model to correctly predict the fatality numbers, it has been used to forecast these numbers for the years 2001 to 2010. For those years, it is then possible to compare the actual values with the forecasted ones. Figure 5 below shows a plot of the predicted and observed values for the whole series. This plot clearly demonstrates that the model was unable to predict the sharp falls seen in the later years. This reinforces the need to use an intervention term when forecasting to 2020. Is should be noted that it would have been *miraculous* had the model been able to forecast the occurrence of the recession in 2001 (that is, using traffic volume and fatality data recorded up to 2001), let alone the strength of the effects it seems to have had on exposure and risk. In general, this result points out the limitations of (long term) forecasting: forecasts assume the continuation of the past trends modelled and cannot predict or take into account such unexpected events as the recession.

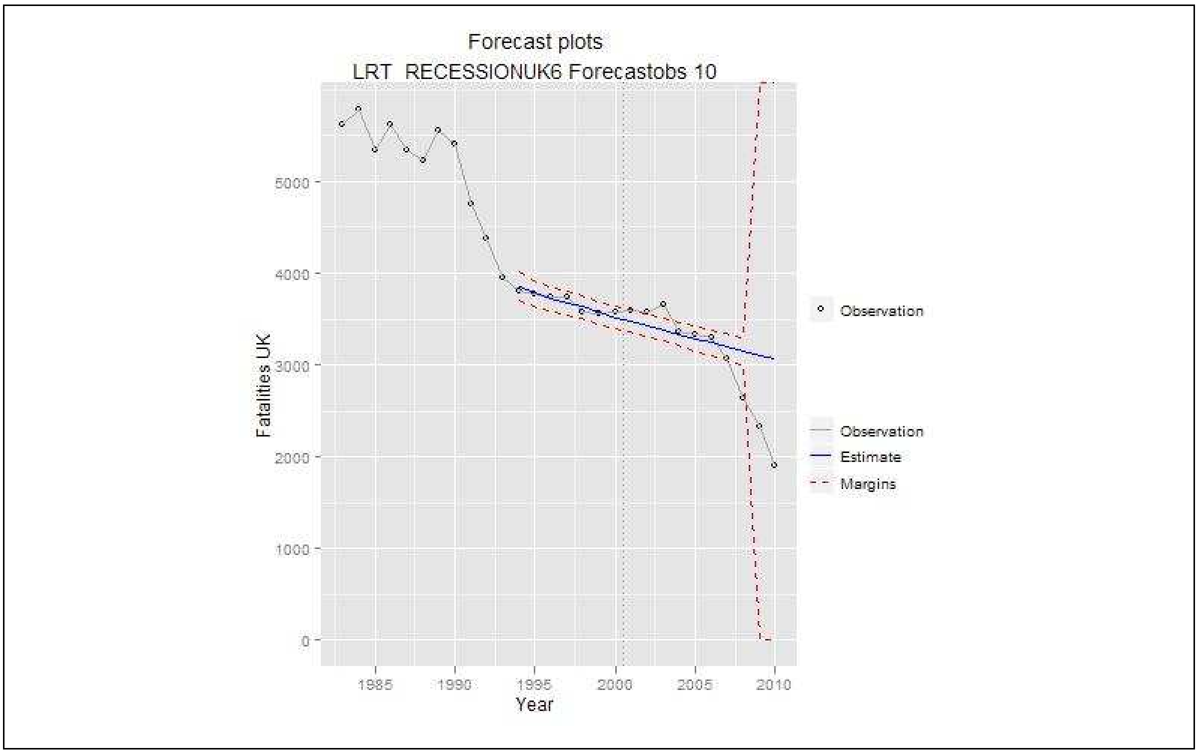
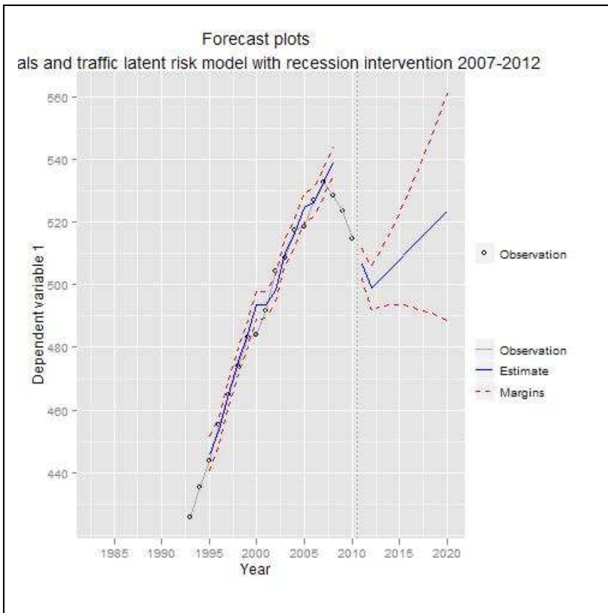


Figure 6: Plot comparing the model predictions (straight line) with the actual observations ("bullets") for the annual fatality numbers in the UK for the full LRT model (LRT2).

4. Forecasts 2011 – 2020:

Two forecasts results are presented in the case of UK. First, those based on the model where the stronger decrease in fatality numbers at the end of the series is modelled by means of interventions (Figure 7 and Table 3). These forecasts provide an indication of the vehicle kilometres and fatality numbers to be expected between 2011 and 2020 *provided that, throughout these years, the trends keep on following the developments that they have shown in the past and the change in slope seen in 2008-2010 returns to the trend seen prior to 2008 in 2012.* Under this assumption, the annual number of fatalities is estimated to 979.

Second, forecasts are provided for the same period on the basis of the model where no intervention is defined to model the stronger decrease observed at the end of the series. These are consequently considered to be part of the random variation in the slope, and are consequently a lot more optimistic, since on this basis 297 fatalities are predicted for 2020 (Figure 8 and Table 4). This is of course a large difference. Given that we still do not have the necessary distance to evaluate the nature of the changes that occurred around 2008 – and that we consequently do not know which of both statistical approaches is to be privileged – the more conservative (i.e., the less optimistic forecasts) will be made available in the forecast factsheet for UK.



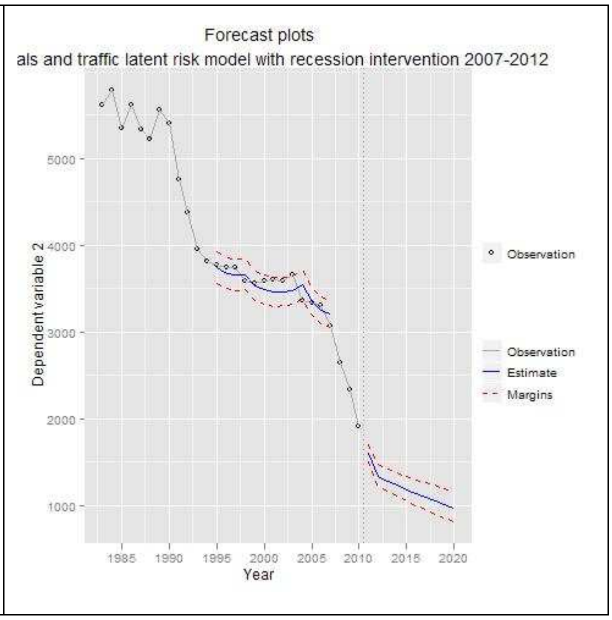


Figure 7: Plot of the vehicle kilometres (left-hand graph) and annual fatality numbers (right-hand graph) for UK forecasted between 2010 and 2020 (full LRT with recession intervention).

	Vehicle kilometres (billion)				Fatalities		
Year	Predicted	Confidence Interval		Year	Predicted	Confidence Interval	
2011	**507**	497	517	2011	**1605**	1415	1820
2012	**499**	485	513	2012	**1344**	1113	1622
2013	**502**	485	519	2013	**1292**	1053	1584
2014	**505**	483	528	2014	**1242**	994	1551
2015	**508**	480	538	2015	**1193**	935	1522
2016	**511**	476	549	2016	**1147**	879	1497
2017	**514**	472	560	2017	**1102**	824	1474
2018	**517**	467	573	2018	**1059**	772	1454
2019	**521**	462	586	2019	**1018**	722	1437
2020	**524**	457	600	2020	**979**	674	1422

Table 3: Forecasts of the Latent Risk Model (full LRT with recession intervention).

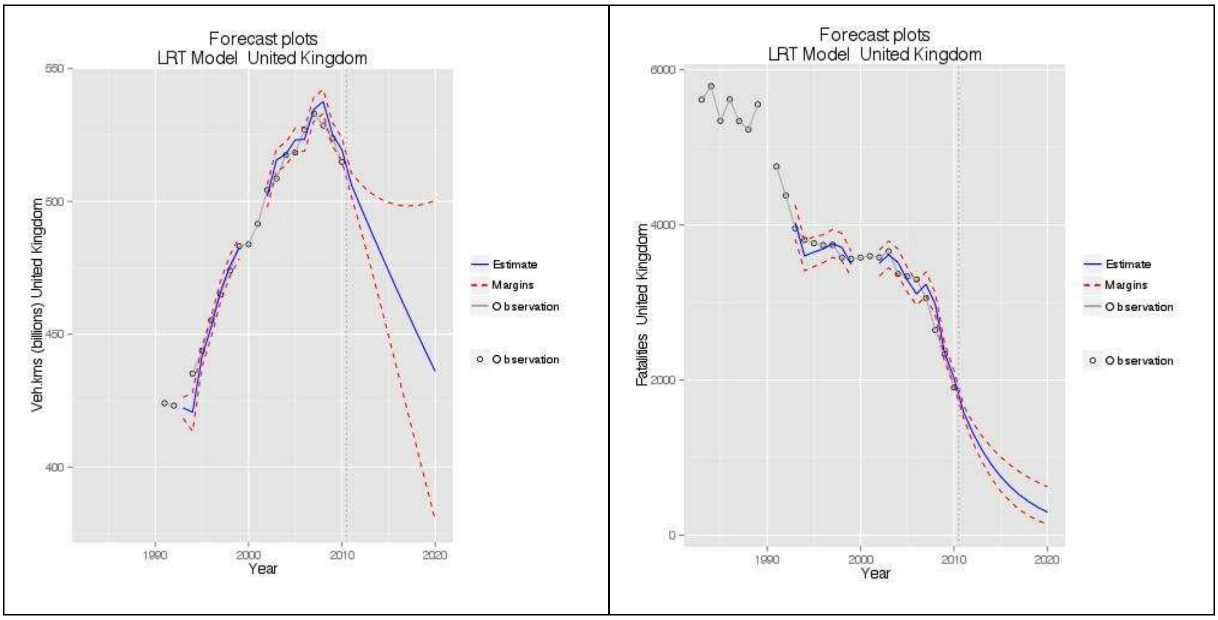


Figure 8: Plot of the vehicle kilometres (left-hand graph) and annual fatality numbers (right-hand graph) for UK forecasted between 2010 and 2020 (50% confidence interval) on the basis of the LRT model *without* recession interventions.

	Vehicle kilometres (billion)				Fatalities		
Year	Predicted	Confidence Interval		Year	Predicted	Confidence Interval	
2011	506	498	515	2011	1594	1443	1760
2012	498	482	515	2012	1323	1097	1595
2013	490	464	517	2013	1098	816	1477
2014	482	446	521	2014	911	596	1392
2015	474	427	526	2015	756	429	1332
2016	466	408	532	2016	627	304	1292
2017	458	389	540	2017	521	214	1269
2018	451	370	550	2018	432	148	1260
2019	443	351	560	2019	358	102	1265
2020	436	333	572	2020	297	69	1283

Table 4: Forecasts of the Latent Risk Model (95% confidence intervals).

The forecasts obtained from the model provide an indication of the vehicle kilometres and fatality numbers to be expected between 2011 and 2020 *assuming that recent fluctuations are to continue, which yields a forecast for 2020 of 297 fatalities. This figure is extremely low, and considered unlikely. Note, however, that it is not very different from what would be expected from the fatality data alone starting in 2006. Due to the erratic behaviour of the slope components, the confidence interval of the forecasts is quite substantial. This uncertainty is reduced when interventions are used, which explain (part of) the variation in the development of the slope, and thus reduce its random nature. This improved confidence is however conditional on the correctness of the additional assumption underlying the interventions (in the case of the above-described model: that the recession effect will be fully relieved in 2012). Therefore it can be misleading.*

5 Scenarios

Clearly the forecast for 2020 is dependent on the assumption of when the recession intervention ends. The forecast of 979 assumes that the economic downturn ceases by 2012. Figure 4 shows how GDP developed throughout the period and the following table gives forecasts using the assumptions that the risk slope returns to 'normal' in 2010, 2011 and 2013. The predictions for 2020 vary between 853 and 1289.

Recession scenarios	***Vehicle kilometres (billions)***	***Road traffic fatalities***
Situation in 2010:	514.9	1905
Prediction for 2020 according to recession assumptions		
• Recession ends 2012	524	979
• Recession ends 2011	536	1123
• Recession ends 2010	547	1289
• Recession end 2013	513	853

Table 4: Forecasting scenarios of the Latent Risk model according to different recession assumptions.

In addition to the uncertainty over the recession intervention there is also large uncertainty around the development of the vehicle kilometres. Clearly this also depends on the recession assumptions (as demonstrated in table 4). However, it is also interesting to look at predictions for the fatalities based on three scenarios for the development of exposure, which correspond to the number of vehicle kilometres predicted by the model for that year, plus/minus one standard deviation[21]. The values for the exposure scenarios and the estimated number of fatalities under each of them are provided in Table 5, and plotted in Figure 8. In all cases, it was assumed the recession ended in 2012.

[21] The upper and lower scenarios now include 68% of the cases, assuming a normal distribution.

APPENDIX B: COUNTRY FORECASTS 2020 -- FACTSHEETS

For each country there is a factsheet containing the most important forecasting results for this country.

These factsheets are meant to give a relatively non-technical description of the development of the fatalities (and the mobility if available) in each country. If known, the (possible) reasons for the developments are shortly described. The forecasts given are based on the assumption that the present development continues as observed before. For those countries that have an exposure measure of the necessary quality (see Chapter 2), the development of the fatality *risk*, (i.e. the number of fatalities per unit of mobility) is presented and for the forecasts, three scenarios are presented, each based on a different assumptions for the development of mobility in the next 20 years.

In these factsheets, no reason is given for the choice of the forecasting models. For this, the interested reader is referred to the Appendix, where a technical description of the forecasting model for each country is given. The use or non-use of exposure is argued in the appendix on the basis of a SUTSE analyses (see also explanations about this in Chapter 2) and different forecasting models are compared according to various quality criteria. While the factsheets presented in the present chapter do not require a statistical background, the background documents presented in the appendix will be difficult to understand without knowledge about statistical principals underlying latent state modeling as for example given in D4.2.

Please find the forecast factsheets as pdf files in attachment with the generic name:

DaCoTA_forecast_factsheet_<country>.pdf