Abstract

Modeling road safety development is a complex task, which needs to consider both the quantifiable impact of specific parameters, as well as the underlying trends that cannot always be directly measured. A methodological approach is described in this paper for building structural time-series models for obtaining reliable medium- to long-term forecasts of road traffic fatalities, using data from five countries with different characteristics from all over Europe (Cyprus, Greece, Hungary, Norway, and Switzerland). Two structural time-series models are considered: (i) the local linear trend model and (ii) the latent risk time-series model. Furthermore, a structural decision tree for the selection of the applicable model for each situation (developed within the DiCaTa research project) is outlined. First, the fatality and exposure data used for the development of the models are presented and explained. Then, the modeling process is presented, including the model selection process, the introduction of intervention variables, and the development of mobility scenarios. The forecasts using the developed models appear to be realistic and within acceptable confidence intervals. The proposed methodology is proved to be very efficient for handling different cases of data availability and quality, providing an appropriate framework for the development of structural time-series models in each country. A concluding section providing perspectives and directions for future research is finally presented.

Background & Objectives

- A number of approaches for modeling road safety developments have been proposed.
- During the last decade, the modeling approach of structural-time-series models, such as the latent variables model, has been widely used.
- In this approach, which belongs to the family of unobserved component models, latent variables are decomposed into components which are incorporated into the structural models.

Objectives

- to apply structural time-series models for obtaining reliable medium- to long-term forecasts of fatality risk
- to develop models for the relationship between mobility and risk and examine the effect of mobility on risk
- to develop a structured methodology for the selection of the optimal forecasting model, based on a number of criteria, diagnostics and measures of goodness of fit
- to demonstrate that the developed approach is robust and applicable to different conditions and environments, by applying it to data from the European countries with very different characteristics.

Methodology

Structural time-series models: Local Linear Trend (LLT) and Latent Risk Time-Series (LRT) models

- A basic concept in road safety is that the number of fatalities is a function of the road risk and the level of exposure of road users to this risk. In order to model the evolution of fatality rate, it is required to model the evolution of two parameters: a road safety indicator and an exposure indicator.
- Traffic volume \( \times \) Exposure = Fatalities
- When the logarithm of the Equation is taken (and the error term is explicitly written out) the "measurement equations" of the model can be written as:

\[
\log \text{Traffic volume} \times \log \text{exposure} = \log \text{fatalities} - \text{error term}.
\]

- The latent variables (log exposure) and log (risk) need to be further specified by "state" equations, which, once inserted in the general model, describe the development of the latent variable.

LLT model

- Measurement equations

\[
\begin{align*}
\log \text{Vehicle traffic} & = \log \text{Traffic exposure} + \text{error} \\
\text{State equations} & = \log \text{Traffic growth} + \text{error}
\end{align*}
\]

- LRT model

\[
\begin{align*}
\log \text{Traffic volume} & = \log \text{exposure} + \text{error} \\
\text{State equations} & = \log \text{Traffic growth} + \text{error}
\end{align*}
\]

The Equation now includes the Risk (and not the fatalities)

SUTSE (Seemingly Unrelated Time Series) model

A first step is to develop a methodology and to identify a procedure for developing and applying the two-time-series model.

Methodology (cont.)

Model selection logic

- The family of structural-time-series models leads to a large number of assumptions that distinguish the resulting models into different categories.
- Within the framework of the DiCaTa research project, a decision process and model selection logic has been developed, which leading steps are completed.

1. Investigate exposure: the first step in every modeling effort to assess the quality and characteristics of the underlying data

- Do the available exposure data make sense?
- Can any sudden changes in the level or slope be explained from some real events?

2. Establish whether the two series are statistically related: a SUTSE model is developed and based on the diagnostics, the model may be chosen.

- If one or more of the null-hypotheses regarding the correlation of the disturbances is rejected, the time-series may be related and therefore an LRT can be estimated.
- If, on the other hand, none of the hypotheses can be rejected, there is no evidence that the two series are correlated and therefore an LLT model would be more appropriate.

Model application

Data collection & analysis

- Greece
- Hungary
- Norway
- Switzerland
- Cyprus

Models by country

- Model selection process for Switzerland
- Final models for the other countries

Model application (cont.)

Synthesis & Forecasts

- In Greece, there were approximately 1300 fatalities on 2010, and the forecast for 2030 is 658 fatalities (95% confidence interval: 355-1279 fatalities).
- In Hungary, there were 740 fatalities on 2010, and the forecast for 2030 is 535 fatalities (95% confidence interval: 472-650 fatalities).
- In Switzerland, there were 220 fatalities on 2010, and the forecast for 2030 is 216 fatalities (95% confidence interval: 167-276 fatalities). The number of vehicle-kilometres is expected to increase by 7.5% in 2020, compared to 6.2% in 2010.
- In Norway, there were 212 fatalities on 2010, and the forecast for 2030 is 152 fatalities (95% confidence interval: 53.3-223 fatalities). The number of vehicle-kilometres is expected to increase by 4.2% in 2020, compared to approximately 4.0 in 2006.
- In Cyprus there were 58 fatalities on 2010, and the forecast for 2030 is 37 (95% confidence interval: 13.3-62 fatalities). The fuel consumption is expected to increase up to 5% million t.e. in 2020, compared to 3% million t.e. in 2010.

Provided that the trends will keep on following the developments that they have shown in the past, and no principal change occurs in the main (Business as usual) assumptions.

Mobility scenarios

- Fatality forecasts on the basis of three different scenarios for exposure: the exposure as predicted from the selected LRT model plus one standard deviation.

Overview for the five countries

- Greece
- Hungary
- Norway
- Switzerland
- Cyprus

Conclusions

- The proposed methodology contributes meaningful steps for model selection, starting with SUTSE modeling and proceeding to LRT/LTT full or restricted, on the basis of sound criteria in each case.
- Nevertheless, a good understanding of the road safety and socioeconomic situation in the examined countries was still necessary, not only for understanding the description and forecast of the developments, but also for making decisions in data handling, introduction of interventions variables etc.
- Nevertheless, the estimated models reflect the future situation if the existing policy efforts and the socio-economic context extent to the future, and this may be motivating for devoting additional efforts in outperforming these forecasts.

Key references