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Road safety analysis in Poland using time-series modelling techniques

Keywords

road safety, road accidents and casualties, modelling techniques, time-series analysis, road safety trends.

Abstract

A number of international studies argue that there is a correlation between the number of traffic fatalities and the degree of public activity. The studies use the unemployment rate to support that argument. As unemployment grows miles travelled fall, a factor known to affect road safety. This relationship seems to be true for Poland, as well. The model presented in the paper is intended to prove it. It is a structural time-series local level model with the explanatory variable (the unemployment rate) and some interventions. Because of the dynamic nature of traffic safety developments it lends itself very well to modelling in that way.

1. Introduction

Comparing with other European countries Poland's traffic fatality risk rates still are on very high level reaching about 11killed per 100,000 population. This is the worst position in Europe. This situation shows a strong need of intensified systemic and preventive work in our country, also in the field of research. Today the safest European Union countries reached a level of 6 killed per 100,000 people. This is no doubt a big achievement whose source lies in the number of safety projects and broad methodical research such for example the project COST 329 [3] or SafetyNet [11].

European Commission try to support road safety policy. Road safety will play an important role in the upcoming White Paper on transport policy 2010 – 2020, as lowering the number of road users' casualties is key to improving the overall performance of the transport system and to meet citizens' and companies' needs and expectations. Work like this is aimed at the achievement of a common European goal which is to cut the number of road deaths by half from 2011-2020 [4].

Obviously before such quantitative targets for EU countries could be defined, the actual road safety situation had to be evaluated and its processes understood. The same was done in Poland [5]. The national road safety programme for Poland – GAMBIT 2005 - made it clear how important the monitoring of assumed goals is and how important detailed probability analyses based on the current accident statistics are. This realisation encouraged the author to begin to explore road safety characteristics analyses. The analyses presented in this paper are part of the result of the work. The question to be answered is as follows: is there any relationship between the unemployment rate and the level of traffic safety in Poland?

2. Time series analysis

Because of the nature of road traffic safety, it lends itself very well to modelling using time series. Observations of a series available in moment t, to forecast its future value t+l, is the basis for planning in economics, trade and production control [1]. Effective trend forecasting using historical data requires good quality data and models based on realistic assumptions. In the case of traffic, we assume that any changes in its future state and safety will occur in similar socio-economic conditions, i.e. no unexpected events are taken into account [9].

The time series can be defined as a certain (stochastic) process where the subsequent observations change in time randomly. The observation may be e.g. the number of killed in road fatalities, injured or the total number of accidents over any discrete time, e.g. over a month, quarter or year. This creates the time series, which we then use to build the model. The model, depending on the issue, may consist of several factors: trend, seasonality and random disturbance [6]. Below is an illustration:

Observed series = Trend + Seasonal + Irregular (1)

Trend is the general direction a series will take, a tendency. There are two parts to the trend: level – the actual value of the trend and slope which may or may not to be present. From the perspective of the forecasting procedure, trend is that part of a series which when extrapolated gives the best indication of how the series will behave in the future. Seasonality is that part of the series which when extrapolated is repeated so many times, and for the entire series averages to zero. Random disturbance is the so called "white noise", a sequence of uncorrelated random variables of a constant mean and variation. The structure of series presents Eq. 1.

The three series components: trend, seasonal and irregular are in actual fact unobservable. The advantage of structural series is that they can be isolated and analysed separately. That way we know about how the components behave in time which makes the assessment of the impact of the factors on the series easier. A change of the highway code could substantially distort the random component. The introduction of a speed limit for example or road safety measures will result in its intensification. A regular seasonal diagram implies that certain months have a relative level of safety, for example winter months have a lower number of road deaths than summer and autumn months.

3. An example of application

A number of international studies state that there is a correlation between the number of traffic fatalities and the degree of public activity. The studies use the unemployment rate to support that argument [7]. As unemployment grows miles travelled fall, a factor known to affect road safety. This relationship seems to be true for Poland, as well. The model presented below is intended to prove it. It is a local level model with the explanatory variable (the unemployment rate) and two interventions. The structure of the model can be written as:

LFatalities = Level + Seasonal + ExplVars

+ Interv + Irre-gular (2)

In mathematical formulas:

$$y_t = \mu_t + \gamma_t + \beta_t x_t + \lambda_{t1} w_{t1} + \lambda_{t2} w_{t2} + \varepsilon_t$$

$$\varepsilon_t = N(0, \sigma_\varepsilon^2) \quad (3)$$

$$\mu_{t+1} = \mu_t + \eta_t$$

$$\eta_t = N(0, \sigma_\eta^2) \quad (4)$$

$$\gamma_{t+1} = \gamma_t + \omega_t$$

$$\omega_t = N(0, \sigma_\omega^2) \quad (5)$$

$$\beta_{t+1} = \beta_t + \tau_t$$

$$\tau_t = N(0, \sigma_\tau^2) \quad (6)$$

$$\lambda_{t+1} = \lambda_t + \varsigma_t$$

$$\varsigma_t = N(0, \sigma_\varsigma^2) \quad (7)$$

for $t = 1,...,n$. The state errors τ_t, ω_t and ς_t are fixed on zero. μ_t is the unobserved state in time t, ε_t is the residual, η_t is so called state error [2], [10].

The model was intended to detect the relation between the monthly number of fatalities in Poland in the period 1992-2011 and the unemployment rate within that period. More generally the influence of the economy changes on road safety in the period in Poland was investigated and the level of national economy condition was measured by the rate of unemployment (*Figure1*).

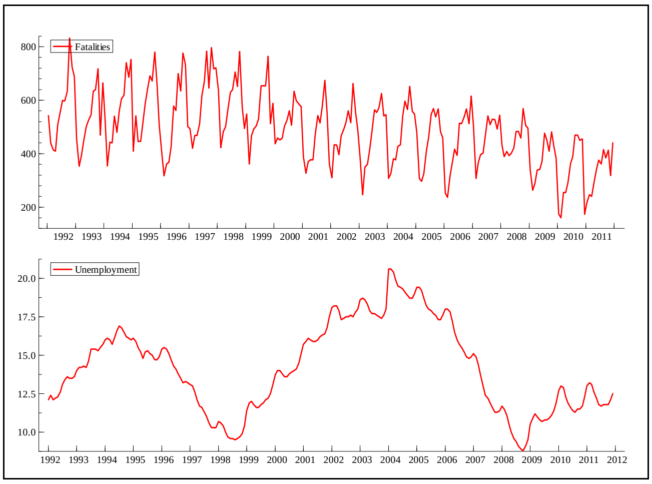

Figure 1. Road fatalities and the unemployment rate in Poland in the period 1992-2011.

Another variables included in the model are interventions variables. There was a sudden economical break observed in Poland in 2001. To investigate the influence of it on the number of fatalities the intervention variables were added to the model. The moments of the interventions were detected by auxiliary residuals analysis (see *Figure 2*). The greatest values of them were observed in December 2001 and 2010 (outlier) and in February 2002 (structural break).

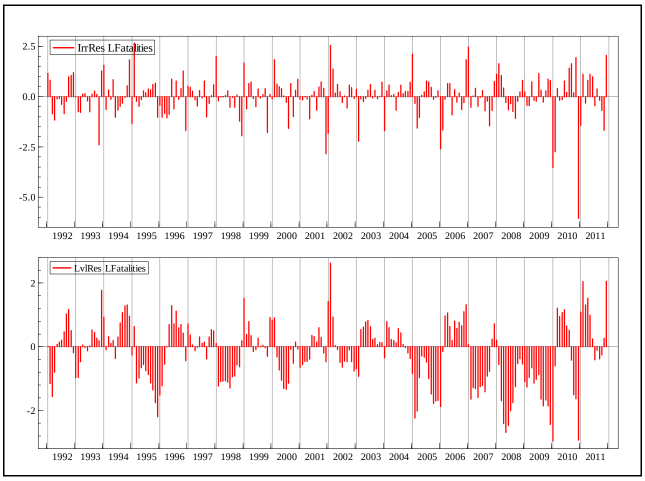

Figure 2. Auxiliary residuals for irregular and level components.

After the estimation procedure subsequent coefficients of explanatory variable (log of unemployment rate) and interventions were achieved (*Table 1*):

Table 1. Coefficients of explanatory variable and interventions.

Variable	Coefficients	R.m.s.e.	t-value
LUnemployment	**-0.3996**	0.1863	-2.1449 [0.0330]
Irr 2001.12	**-0.3292**	0.1147	-2.8696 [0.0045]
Irr 2010.12	**-0.8241**	0.11111	-7.4166 [0.0000]
Lvl 2002. 2	**0.2454**	0.0939	2.6122 [0.0096]

The coefficient β may be interpreted as elasticity - common used in economic analysis [2]. The negative value of β (LUnemployment) indicates a negative relationship between the number of fatalities and the unemployment rate in Poland. Thus the hypothesis on existence of such seems to be true.
The lower unemployment rate is associated with the higher fatalities notes. The value of $\beta = -0.39$ indicates that 1% increase in the unemployment rate resulted in a 0.39% decrease of the number of fatalities.

Concerning interventions since $1 - e^{-0.3292} = 0.2805$, the number of fatalities decreased in December 2001 by 27%. Because this intervention was modelled by the impulse variable it means that the decrease was only for the one moment. The same was in the case of December 2010 when the decrease was even bigger and reached 56%. The third intervention was modelled as structural break in the level of the series. The value of intervention coefficient is 0.2454, which means that the number of fatalities has increased after the intervention by 27%. The explanation of this increase may be the quick return of the economic prosperity after the short downturn in 2001 (*Figure 3*).

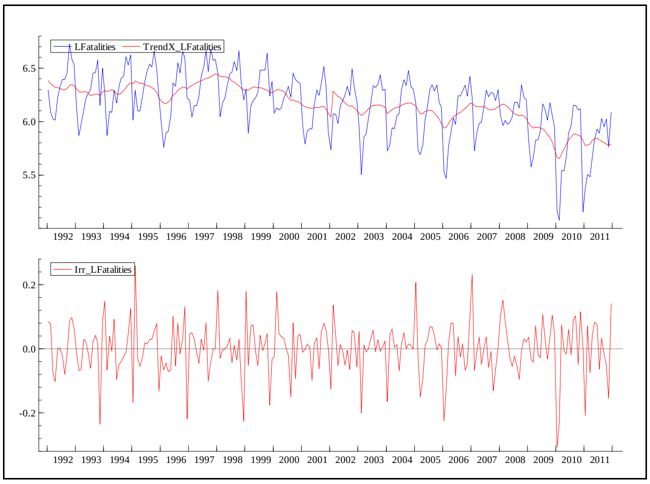

Figure 3. Estimated trend and irregular component for structural time-series model.

4. Conclusion

The GAMBIT 2000 National Road Safety Programme forecast assumes a monotone increase of public mobility in Poland [8]. What we found, however, was that 2001 was when the economic crisis was at its worst. In spring 2001 the government informed the public about Poland's budget deficit. The estimates of the deficit kept changing and ranged between 40 and 80 billion PLN. GAMBIT 2000's estimates of the economic loss caused by road accidents was 12 billion PLN.
Caused by the economic crisis, the falling public activity reduced the demand for transport leading to a reduction in miles travelled. This in turn resulted in fewer accident fatalities. Nevertheless subsequent years with their economic development and a drop in unemployment rate made the traffic risk increased again.
The activity of Polish society has grown, but there was lack of additional prevention measures, no effective safety initiatives. As the result of these missing activities, the number of fatalities does not follow the downward trend. It has established at the level of 5500 in the period 2001-2008. Starting from 2009 we observe slightly bigger decrease.

The conclusion from this analyse shouldn't just state that to diminish road fatalities we need to slow down the economy – that is of course nonsense. But for shore: more fatalities can be expected when the economy is growing and at the same time there is nothing to be done to improve safety.

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