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Safety assesment of the regional Warmia and Mazury road network using time-series analysis

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***Abstract*—Warmia and Mazury still belongs to the areas with the smallest transport accessibility in Europe. Unsatisfactory state of road infrastructure is a major barrier to the development of the regional economy, impacting negatively on the life conditions of the population. Also in terms of road safety Warmia and Mazury is one of the most endangered regions in Poland. The Police statistics show that beside a high pedestrian risk observed in the capital of the region the threat occurs also at the rural area. This indicates the growing role of speed and unforgiving roadside as a cause of accidents. In this article analysis of road safety trends together with short term forecasts of possible future changes are presented based on time series modeling techniques. The results may serve as a tool of road safety management at the regional level.**

***Keywords*—road accidents; road transportation; communication system traffic.**

I. Introduction

Warmia and Mazury is a region of outstanding natural beauty, which at the same time due to the very low accessibility of transport is still of a huge need for development and modernization of the existing road infrastructure, especially the regional road network. This development is a priority for both regional and national road authorities managing road infrastructure, but the implementation of these plans - for not only financial reasons is not an easy task and move on in time [1]. On the one hand, the growing public demand for high-quality transport services and on the other hand the desire to preserve environment make this process very complicated. The proper decisions should be taken quickly since human life is at stake! Unfortunately while the discussion is on progress road users are still being exposed to enormous risk and get injured or die [2], [3].

Even if the long-term road safety trends are quite optimistic the region is still at serious risk due to lack of effective road safety management system and insufficient road network level [1]. The regional decision-makers needs tool for efficient planning, monitoring and evaluation of road safety strategies and countermeasures [4].

The aim of this article is to build a model suitable to forecast and monitor road safety at the regional level in Poland. To do this we will use structural time-series modeling, a technique, which has been successfully applied to many road safety data across Europe and worldwide [5], [6], [7], [8]. This kind of models could be used as a support within the decision-making process in Warmia and Mazury.

While analyzing the Police accidents statistics it is easily seen that the overall accident trend in this region is decreasing although it has at least two periods of the clear development:

- First; between 2000 and 2008 when the average number of accidents was at the level of 2000 and injuries at the level of 2500,
- Second; between 2009 and 2016 when the number of accidents decreased to 1800 and injuries to 2000 (Fig. 1).

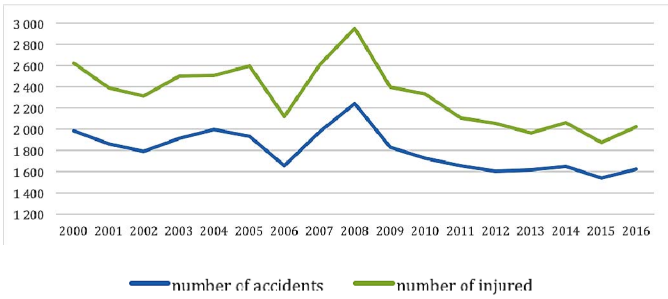

Fig. 1. Changes in the number of traffic accidents and injuries in the period 2000-2016. *(Source: Police Headquarter, 2016)*

When it comes to the most severe accidents the observed improvement was even better:

- Serious injuries decreased from 900 to 500 on average between 2000 and 2016, although 2016 was a year of a sudden significant increase (serious injuries raised by 20 % compering with 2015),

- Fatalities have decreased by about 50 % in the same period, from 300 to 150 on average (Fig. 2).

Big progress was also made in accidents with fatalities where the factor of speed and trees was involved. In the period of 17 years this kind of fatal accidents has decreased by more than 85 %.

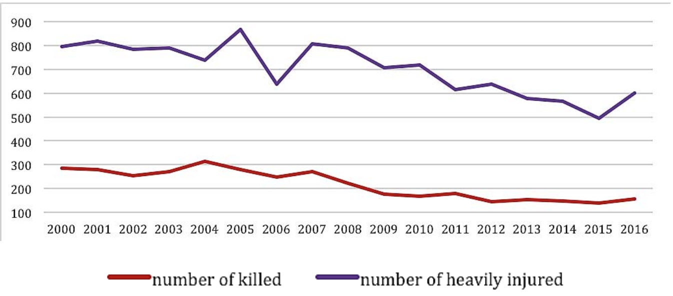

Fig. 2. Changes in the number of traffic fatalities and serious injuries in the period 2000-2016. *(Source: Police Headquarter, 2016)*

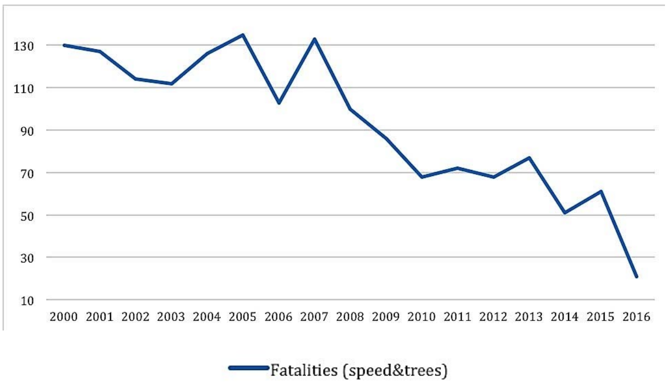

Fig. 3. Changes in the number of traffic fatalities and serious injuries in the period 2000-2016. *(Source: Police Headquarter, 2016)*

To understand the trends and their long term development the analysis of road safety changes in Warmia and Mazury are performed in this article using time-series analysis. The question to be answered is - will the decreasing accidents and fatalities trends continue in the nearest future or there is a risk of reversal? If yes, the message should be announced to the road administrators as soon as it is possible to give them time to undertake proper actions and implement countermeasures [9], [10].

II. Time-Series Modelling

Time-series analysis models serve as one of the main tools for measuring road safety exploring relationships between road accidents/injuries, road traffic exposure and other risk determinants and assessing impacts of road safety interventions. As it can be find in literature a tool appropriate for monitoring of road safety trends, explaining changes in the number of fatalities as well as for forecasting them may be a technique called a structural times series modelling [11], [12]. The application of time-series analyses for road safety purposes began several decades ago, where over time various methods were suggested to handle the data structure and interrelationships.

Because of the nature of road traffic safety, it lends itself very well to modeling 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 [11]. 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. 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 (Equation 1).

$$Y_t = \mu_t + \gamma_t + \varepsilon_t\,,\;\; \varepsilon_t = N(0,\sigma_\varepsilon^2) \qquad (1)$$

$$\mu_t = \mu_{t-1} + \sum_{l=1}^{L} \lambda_l w_{lt} + \eta_t \qquad (2)$$

$$\eta_t = N(0,\sigma_\eta^2) \qquad (3)$$

$$b_t = b_{t-1} + \zeta_t \qquad (4)$$

$$\zeta_t = N(0,\sigma_\zeta^2) \qquad (5)$$

$$\gamma_t = -\sum_{j=1}^{s-1} \gamma_{t-j} + \omega_t \qquad (6)$$

$$\omega_t = N(0,\sigma_\omega^2) \qquad (7)$$

where:

Y_t is the monthly number of fatalities (or and seriously injured),

μ_t and b_t are the level and slope of the local linear trend,

γ_t is the seasonal component written under a dummy form,

ε_t, η_t, ζ_t and ω_{it}, i =1,..,I, are error terms, with variances σ_ε^2, σ_η^2, σ_ζ^2 and $\sigma_{\omega_{it}}^2$ which are not mutually correlated, for $t = 1,\ldots,n$.

III. Warmia and Mazury Accident Data Analysis

The model proposed for Warmia and Mazury in this article is a structural time-series model of periodic (monthly) discrete time series. The modeling data are: monthly number of fatalities (Model 1), monthly number of serious injuries (Model 2) and month number of fatalities were trees and speed factors appeared (Model 3). All of the three models are so called local level and consist of three basic components: the seasonal, the trend and irregular interference (Fig. 4). The seasonal component is fixed (deterministic) while trend and irregular are stochastic. The shape and parameters of this kind of models were discussed in details in [13] and [14].

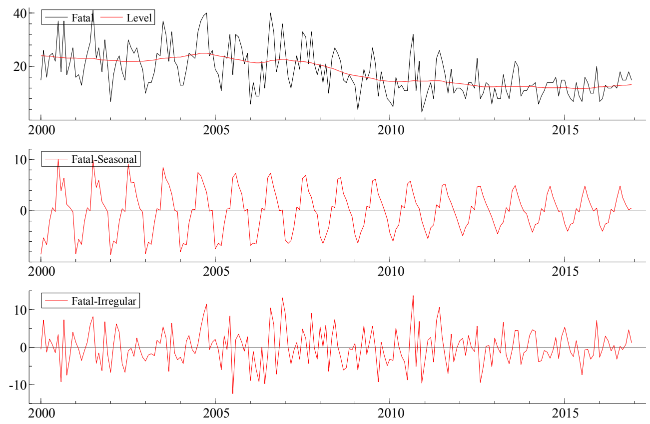

Fig. 4. Structural time-series model for the number of fatalities 2000-2016 (Model 1)

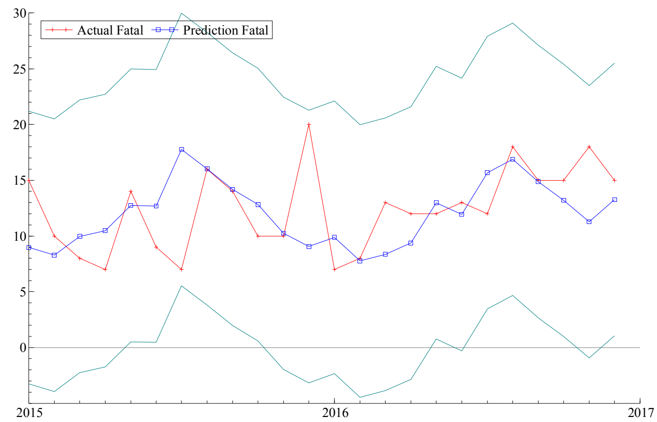

Fig. 5. Prediction of the number of fatalities 2015-2016 based on structural time-series model (Model 1)

After the estimation of the models the results occured to be satified and were chosen as valid for the development of the forecats.

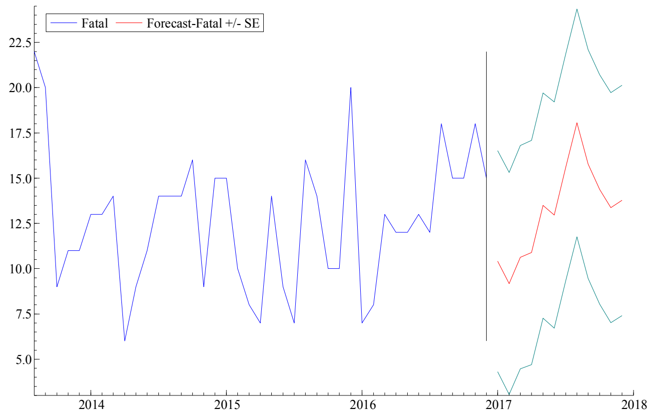

Fig. 6. Forecast of fatalities for the year 2017 based on structural time-series model (based on Model 1)

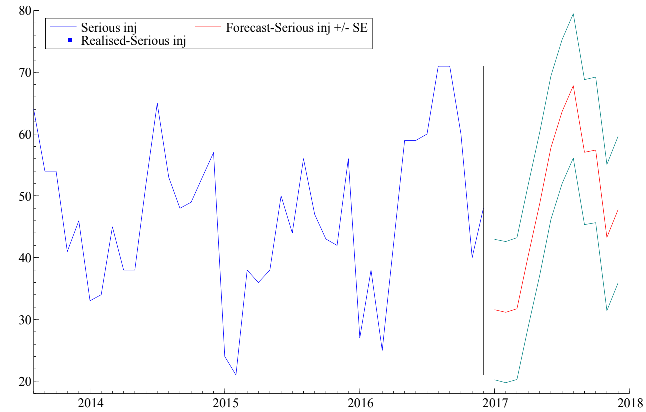

Fig. 7. Forecast of serious injuries for the year 2017 based on structural time-series model (based on Model 2)

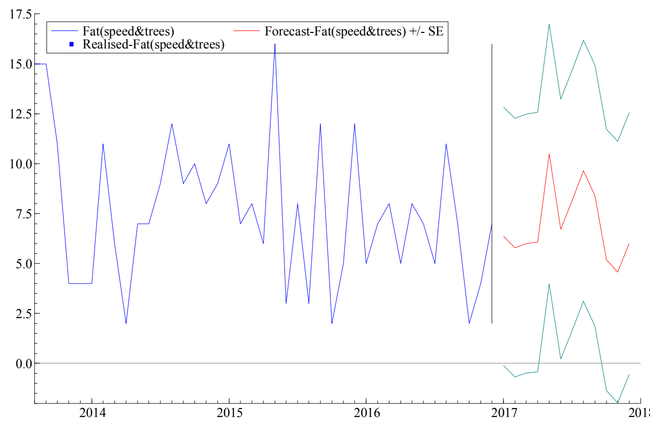

Fig. 8. Forecast of fatalities (speed and trees) for the year 2017 based on structural time-series model (based on Model 3)

One of a crucial motivations and goals of road safety modeling is getting knowledge on future trends development

[15], [16]. Structural time series analysis gives the opportunity to achieve the short-term prognosis of the analyzed variables. For the purpose of the current article a short-term prognosis of fatalities, serious injuries as well fatalities with the impact of speed and trees were performed under the assumption of fixed socio-economic situation within the analyzed period and the graphical results are presented in the above Figures 6-8. The results achieved were compared with the data for 2016 and presented in Table I.

TABLE I. RESULTS OF A FORECASTS OF THE NUMBER OF FATALITIES, SEROIUS INJURIES AND FATALITIES (INVOLVING SPEED AND TREES FACTOR) IN WARMIA-MAZURY REGION (2017)

Month	**Forecast**		
	Fatalities	***Serious injuries***	***Fatalities (speed & trees)***
2017-1	10	32	6
2017-2	9	31	6
2017-3	11	32	6
2017-4	11	40	6
2017-5	13	49	10
2017-6	13	58	7
2017-7	16	64	8
2017-8	18	68	10
2017-9	16	57	8
2017-10	14	57	5
2017-11	13	43	4
2017-12	14	48	6
Sum for 2017	**158**	**579**	**82**
Sum for 2016	158	600	76

The forecats shows that the number of fatalities will stay at the level of 2016's, which is not optimistic signal since the year 2016 was 20% worse then 2015. Such negative trend occurs also for fatalities involving trees and speed factor - here we can expect the increase of the risk. Slightly better situation may be observed for the serious injuries - this number is going to decrease and reach the level of 2014.

IV. CONCLUSION

The analysis performed using structural time-series modeling technique appeared to be suitable to develop a forecast of road safety data for the region of Warmia and Mazury. It showed that to get back on track the regional road administration have to increase efforts and implement more countermeasures. Especially, according to the forecast, the trend of accidents where the factor of speed and trees appeared is going to increase in 2017, which should be a clear sign for the decision-making. Without special actions the overall decreasing accident trend may change its direction into opposite one, which would be a very pessimistic scenario for the whole region.

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References

[1] A. Górska-Pawliczuk and J. Żukowska, Bezpieczne otoczenie drogi jako czynnik zmniejszający ryzyko ciężkich konsekwencji wypadków drogowych, 2015, in Postęp w Inżynierii Bezpieczeństwa, ed. by K. Skibniewska and M. Lutostański, University of Warmia and Mazury in Olsztyn, pp. 267-277 (in Polish).

[2] K. Jamroz, "Strategic Risk Measures in Road Traffic," Journal of Konbin, vol. 13(1), 2010.

[3] J. Wachnicka, "Modeling selected road safety measures at the regional level in Europe," Journal of Polish Safety and Reliability Association. Summer Safety and Reliability Seminars, vol. 3, no. 2, 2012.

[4] R. Elvik and T. Vaa, The Handbook of Road Safety Measures, 2004, Elsevier.

[5] A.C. Harvey, Forecasting structural time series and the Kalman filter, 1989, Cambridge University Press, Cambridge.

[6] R. Rivelott and I. Lopez de Sabando, "ARIMA and Box-Jenkins models for injury accidents in Spain," In COST 329, pp. 159-171, 2004.

[7] P.J. Brockwell and R.A. Davis, Time series: theory and methods, 1986, Springer Verlag, New York.

[8] S. Newstead, A. Delaney, L. Watson and M. Cameron, A model for considering the 'total safety' of the light passenger vehicle fleet. Proceedings, 2004 Road Safety Research, Policing and Education Conference, Perth

[9] W. Kustra, K. Jamroz, and M. Budzynski, "Safety PL- A Support Tool for Road Safety Impact Assessment," Transportation Research Procedia, vol. 14, pp. 3456–3465, 2016, doi: 10.1016/j.trpro.2016.05.308.

[10] U. Brüde, "What is happening to the number of fatalities in road accidents? A model for forecasts and continuous monitoring of development up to the year 2000," Accident Analysis & Prevention, vol. 27, pp. 405–410, 1995.

[11] J.J.F. Commandeur and S.J. Koopman, An introduction to state space time series analysis, Oxford University Press, 2007

[12] E. Hauer, "On the estimation of the expected number of accidents," Accident Analysis and Prevention, 1986, p: 1–12, doi: 10.1016/0001-4575(86)90031-X

[13] R. Bergel-Hayath and J. Żukowska, "Road Safety Trends at National Level in Europe: A Review of Time-series Analysis Performed during the Period 2000-12," Transport Reviews, vol. 35, iss. 5, pp. 650–671, 2015.

[14] R. Bergel and M. Debbarh, Modelling the weather effects on the numbers of injury accidents at an aggregate level in different regions. Chapter 5.3 in Stipdonk H. (Ed.), 2008, pp. 79–85

[15] K. Jamroz, "The impact of road network structure and mobility on the national traffic fatality rate," Procedia - Social and Behavioural Sciences, Vol. 54, 2012, pp. 1370-1377, doi: 10.1016/j.sbspro.2012.09.851.

[16] I. Koßmann and H. Schulze, "The role of safety research in road safety management," Safety Science, 48(9), 2010, pp.1160–1166, http://dx.doi.org/10.1016/j.ssci.2009.12.009.