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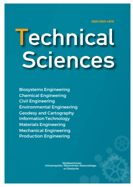

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IMPACT OF INFORMATION ON THE NUMBER OF TRAFFIC ACCIDENTS ON THE OUTCOME OF THE FORECAST

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Keywords: forecasting, traffic accident, number of time series elements, mean absolute percentage error MAPE.

Abstract

Every year, more and more vehicles appear on the world's roads. This leads to increased traffic on the roads. Road accidents have become a rapidly growing threat. The main problem in forecasting and analyzing data on the number of traffic accidents is the small size of the dataset that can be used for analysis in this regard. And on the other hand, road accidents cause, globally, millions of deaths and injuries annually is their density in time and space.

The purpose of the article is to assess the impact of information on the number of traffic accidents on the outcome of the forecast. Based on the study, it can be concluded that a smaller number of input data, historical data on the number of accidents, instead of 32 years, 7 years, makes the determination of the forecast of the number of accidents for subsequent years, is at a satisfactory level, the average absolute percentage error of MAPE less than 7%. The article concludes with the determination of the forecast for future years. It is worth noting that the prevailing pandemic distorts the results obtained.

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Introduction

Road accidents have been and continue to be a significant social problem for every country. Their causes depend on many factors, which include weather conditions, the state of intoxicated drivers, the speed of the car. etc. According to the World Health Organization (*The Global Status on Road Safety* 2018), every year more than 1.35 million people die in road accidents, and millions more suffer serious injuries and long-term negative health consequences. For this reason, road accidents also generate economic losses. The number of traffic accidents is decreasing year by year. This has also happened in recent years, primarily due to the COVID-19 pandemic. However, the number of road accidents on Polish roads is very high (Fig. 1), with an average of 62 road accidents every day, in which 6 people are killed and 72 injured.

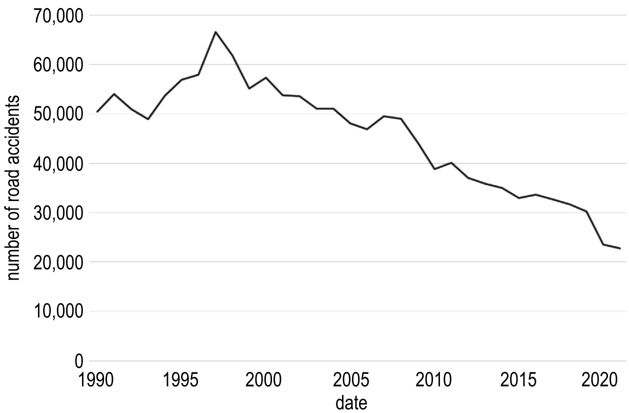

Fig.1. Number of road accidents in Poland from 1990 to 2021
Source: based on Statystyka – Portal polskiej Policji (2022).

This causes an increase in medical costs, the need for repairs to vehicles and road infrastructure, and a negative impact on the environment (e.g., through leaks of fuel and operating fluids). Therefore, various measures are being taken to prevent traffic accidents and reduce their number. One such measure is forecasting the number of traffic accidents using known forecasting methods. Here it should also be taken into account that the number of vehicles on Polish roads is increasing (Fig. 2). The problem of traffic safety has been addressed in the following articles (Bartuska et al. 2016, Čubranić-Dobrodolac et al. 2020, Gorzelanczyk, Bazela 2021, Gorzelanczyk, Huk 2022, Gorzelanczyk, Tylicki 2023, Gorzelanczyk et al. 2020, 2022a, 2022b, 2022c, 2022d, Gorzelanczyk 2023a, 2023b, 2023c, 2023d).

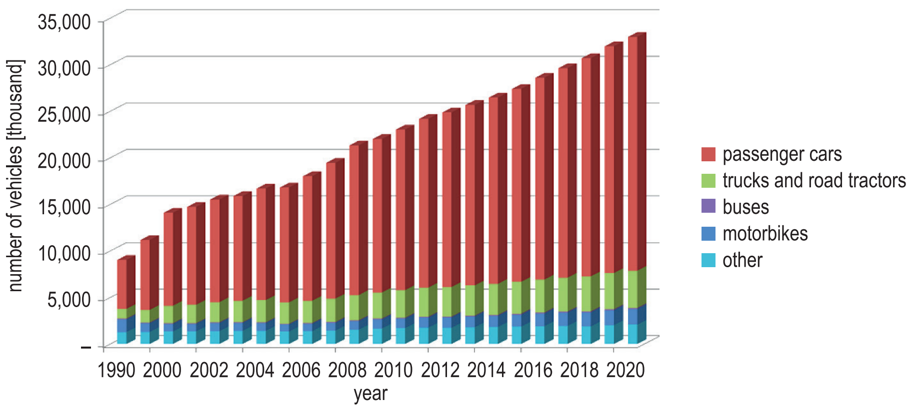

Fig. 2. Number of registered vehicles in Poland in 1999-2020
Source: based on Bank Danych Lokalnych (2022), *Pojazdy samochodowe i motorowery zarejestrowane w Polsce* (2023).

Various methods for forecasting the number of accidents can be found in articles. The most commonly used methods for forecasting the number of traffic accidents are time series methods (HELGASON 2016, LAVRENZ et al. 2018) which have the disadvantages of not being able to assess the quality of the forecast based on expired forecasts and frequent autocorrelation of the residual component (*Prognozowanie na podstawie szeregów czasowych* 2022). PROCHAZKA and CAMAJ (2017) and PROCHÁZKA et al. (2017) used the multiple seasonality model for forecasting, and SUNNY et al. (2018) used the Holt-Winters exponential smoothing method. Its limitations include the inability to introduce exogenous variables into the model (DUDEK 2013, SZMUKSTA-ZAWADZKA, ZAWADZKI 2009).

A vector autoregression model has also been used to forecast the number of traffic accidents, the drawback of which is the need to have a large number of observations of variables in order to correctly estimate their parameters (WÓJCIK 2014), as well as the autoregression models of MONEDERO et al. (2021) for analyzing the number of fatalities (MONEDERO et al. 2021) and the curve--fit regression models of AL-MADANI (2018). These, in turn, require only simple linear relationships (MAMCZUK 2020), and an order of autoregression (assuming the series is already stationary) (PIŁATOWSKA 2012).

BISWAS et al. (2019) used Random Forest regression to predict the number of traffic accidents. In this case, the data contains groups of correlated features of similar significance to the original data, smaller groups are favored over larger ones (*Las losowy* 2022), and there is instability in the method and spike prediction (FIJOREK et al. 2010). CHUDY-LASKOWSKA and PISULA (2014) used an autoregressive quadratic trend model, a univariate periodic trend model and an exponential equalization model for the forecasting issue at hand. A moving average model can also be used to forecast the number of traffic accidents, which has the disadvantages of low forecast accuracy, loss of data in the sequence, and lack of consideration of trends and seasonal effects (KASHPRUK 2010). PROCHOZKA and CAMEJ (2017) used the GARMA method, in which certain constraints are imposed in the parameter space to guarantee the stationarity of the process. Very often, the ARMA model for a stationary process or ARIMA or SARIMA for a non-stationary process is used for forecasting (PROCHAZKA, CAMAJ 2017, SUNNY at al. 2018, DUTTA et al. 2020, KARLAFTIS, VLAHOGIANNI 2009). There is great flexibility in the models in question, but this is also a disadvantage, as good model identification requires researchers to have more experience than, for example, regression analysis (ŁOBEJKO 2015). Another disadvantage is the linear nature of the ARIMA model (DUDEK 2013).

Based on the presented literature analysis, it can be concluded that the problem of forecasting the number of traffic accidents has been considered by many researchers, but none of the analyzed researchers have studied how the number of historical inputs affects the quality of prediction of the number of traffic accidents? For this reason, the author addressed this issue. In this case, it is important to remember that the data on the number of traffic accidents is seasonal, and not all forecasting methods work well for this type of forecasting.

Materials and methods

The purpose of the article is to answer the question: how the number of historical inputs affects the quality of prediction of the number of traffic accidents. For this purpose, the author analyzed the annual number of road accidents in Poland from 1990-2021 from the statistics of the Police (Statystyka – Portal polskiej Policji 2022). Taking into account the above review of methods, the author used the following forecasting methods in his research to determine the forecast horizon of the number of road accidents:

- adaptive methods:
  - 2-point moving average method,
  - 3-point moving average method,
  - 4-point moving average method,
  - exponential smoothing no trend seasonal component: none,
  - exponential smoothing no trend seasonal component: additive,
  - exponential smoothing no trend seasonal component: multiplicative,
  - exponential smoothing of the seasonal component of the linear trend: none – HOLTA,
  - exponential smoothing of linear trend seasonal component: additive,
  - exponential smoothing of the linear trend seasonal component: multiplicative – WINTERSA,
  - exponential smoothing of the exponential seasonal component: none,

  - exponential smoothing exponential seasonal component: additive,
  - exponential smoothing exponential seasonal component: multiplicative,
  - exponential smoothing seasonal component of trend fading: none,
  - exponential smoothing fading trend seasonal component: additive,
  - exponential smoothing of seasonal trend decay component: multiplicative;
- neural network methods, assuming the following factors:
  - random sample size teaching 70%, testing 15% and validation 15%,
  - random sample size teaching 80%, testing 10% and validation 10%;
- regression methods:
  - exponential trend model,
  - linear trend model,
  - logarithmic trend model,
  - trend model polynomial of 2nd degree,
  - trend model polynomial of 3rd degree,
  - trend model polynomial of 4th degree,
  - trend model polynomial of 5th degree,
  - trend model polynomial of 6th degree,
  - trend model of power.

As we can see, there are many forecasting methods. Their results of forecasting the number of accidents are even more. The author selected only a part of them. For this reason, for further analysis, on the basis of previous detailed studies (JURKOVIC et al. 2022), the author chose an adaptive method – with exponential smoothing of the seasonal component of the linear trend: none – HOLTA, for which, for the assumed data (Tab. 1, 2), the average absolute percentage error MAPE (4), of the forecast of the number of traffic accidents was the smallest. The following forecast errors, determined from equations (1-5), were used to calculate measures of analytical forecast excellence:

- ME – mean error

$$\mathrm{ME} = \frac{1}{n}\sum_{i=1}^{n}\left(\mathrm{lwd}(t_i) - \mathrm{lwd}(t_p)\right) \tag{1}$$

- MAE – mean absolute error

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|\mathrm{lwd}(t_i) - \mathrm{lwd}(t_p)\right| \tag{2}$$

- MPE – mean percentage error

$$\mathrm{MPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{\mathrm{lwd}(t_i) - \mathrm{lwd}(t_p)}{\mathrm{lwd}(t_i)} \tag{3}$$

- MAPE – mean absolute percentage error

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\text{lwd}(t_i) - \text{lwd}(t_p)}{\text{lwd}(t_i)}\right| \tag{4}$$

- RMSE – root mean square error

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\text{lwd}(t_i) - \text{lwd}(t_p)\right)^2} \tag{5}$$

where:

n – number of observations,
$\text{lwd}(t_i)$ – number of traffic accidents over time t_i,
$\text{lwd}(t_i)$ – forecasts number of traffic accidents over time t_i.

Table 1

Number of road accidents in Poland from 1990 to 2021

Year	Number of road accidents	Year	Number of road accidents
1990	50,432	2006	46,876
1991	54,038	2007	49,536
1992	50,990	2008	49,054
1993	48,901	2009	44,196
1994	53,647	2010	38,832
1995	56,904	2011	40,065
1996	57,911	2012	37,046
1997	66,586	2013	35,847
1998	61,855	2014	34,970
1999	55,106	2015	32,967
2000	57,331	2016	33,664
2001	53,799	2017	32,760
2002	53,559	2018	31,674
2003	51,078	2019	30,288
2004	51,069	2020	23,540
2005	48,100	2021	22,816

Source: based on Statystyka – Portal polskiej Policji (2022).

Using the data presented in Table 1, for the assumed forecasting method (HOLTA), the author examined how reducing the number of inputs, historical data from 32 (years 1990-2021) to 4 years (2019-2021), affected the value of the average absolute percentage error MAPE (1) of the forecast for the following years. Based on previous research, the author concluded that the forecast of the number of traffic accidents for the next 6 years using annual data can be successfully applied. The research was conducted on the basis of police statistics (Statystyka – Portal polskiej Policji 2022) on the number of traffic accidents in 1990-2021 using Statistica software.

Results

On the basis of the study, with predetermined input conditions, the average absolute percentage error of MAPE was determined (Tab. 2). The last time frame studied was 2017-2021 (5 years). The inability to perform the study for another year, was due to the fact, too little data to perform the study. Considering the number of accidents in the analyzed time interval, taking into account the average absolute percentage error (Fig. 3), a forecast of the number of traffic accidents for the next 6 years was determined (Tab. 3). For analysis, on the basis of previous detailed studies (JURKOVIC et al. 2022), the author chose an adaptive method – with exponential smoothing of the seasonal component of the linear trend: none – HOLTA.

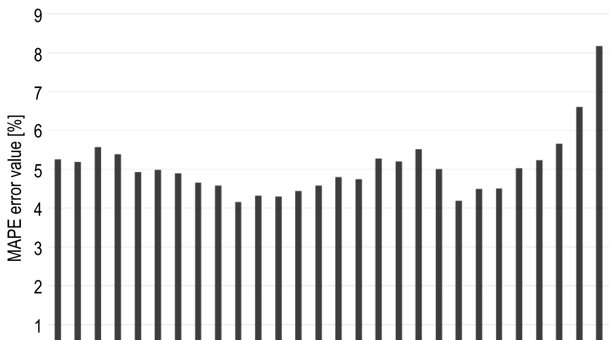

Fig. 3. MAPE error values for the analyzed time periods

Table 2

MAPE road accident number forecast error values

Police data		Number of years analyzed	ME	MAE [%]	SSE	MPE	MAPE [%]
Initial data	Final data						
1990	2021	32	2.90	2,371.41	11,225,553.95	0.98	5.26
1991	2021	31	137.48	2,405.70	10,823,929.82	0.50	5.20
1992	2021	30	210.74	4,083.84	86,881,932.68	0.81	5.57
1993	2021	29	126.00	2,459.43	11,213,728.75	1.11	5.39
1994	2021	28	51.53	2,185.23	10,119,430.54	0.99	4.94
1995	2021	27	72.49	2,110.23	8,963,641.45	1.08	4.99
1996	2021	26	96.36	2,004.91	6,755,718.23	0.74	4.90
1997	2021	25	227.15	1,920.69	7,255,704.63	0.10	4.66
1998	2021	24	353.03	1,834.28	5,818,092.42	0.21	4.58
1999	2021	23	4.84	1,637.08	4,948,975.20	0.58	4.16
2000	2021	22	58.11	1,687.22	5,229,621.52	0.42	4.33
2001	2021	21	1.20	1,636.67	4,989,296.28	0.59	4.30
2002	2021	20	44.17	1,674.77	5,289,451.52	0.49	4.44
2003	2021	19	14.76	1,710.84	5,481,746.85	0.66	4.59
2004	2021	18	13.35	1,780.47	6,167,433.87	0.63	4.80
2005	2021	17	19.17	1,712.56	5,583,080.49	0.68	4.75
2006	2021	16	1,129.50	1,896.53	5,898,166.07	2.62	5.28
2007	2021	15	49.67	1,836.01	6,017,103.96	0.47	5.20
2008	2021	14	127.48	1,955.91	8,282,719.54	0.43	5.52
2009	2021	13	132.37	1,662.21	5,875,982.22	0.38	5.00
2010	2021	12	79.23	1,282.69	3,926,128.00	0.48	4.20
2011	2021	11	17.38	1,356.57	5,035,837.48	0.88	4.50
2012	2021	10	22.13	1,299.56	4,380,978.23	0.74	4.50
2013	2021	9	159.78	1,450.60	4,910,592.12	0.35	5.03
2014	2021	8	70.15	1,473.28	5,518,752.46	0.70	5.24
2015	2021	7	3.40	1,557.80	5,646,988.68	0.95	5.66
2016	2021	6	33.08	1,812.88	7,213,260.99	1.24	6.61
2017	2021	5	138.91	2,207.56	10,027,996.76	1.80	8.17

Table 3

Forecasting number of road accidents for 2022-2027

Police data		Number of years analyzed	2022	2023	2024	2025	2026	2027
Initial data	Final data							
1990	2021	32	22,355.63	21,464.79	20,573.95	19,683.11	18,792.27	17,901.43
1991	2021	31	21,808.07	20,767.33	19,726.60	18,685.87	17,645.13	16,604.40
1992	2021	30	21,041.99	19,298.38	17,554.77	15,811.16	14,067.56	12,323.95
1993	2021	29	21,925.23	20,993.62	20,062.01	19,130.41	18,198.80	17,267.19
1994	2021	28	22,000.45	20,858.56	19,716.67	18,574.79	17,432.90	16,291.01
1995	2021	27	22,960.23	21,649.16	20,338.08	19,027.00	17,715.93	16,404.85
1996	2021	26	24,399.79	22,995.99	21,592.19	20,188.39	18,784.59	17,380.79
1997	2021	25	21,692.52	20,030.33	18,368.13	16,705.94	15,043.75	13,381.56
1998	2021	24	21,721.83	20,080.81	18,439.79	16,798.77	15,157.75	13,516.73
1999	2021	23	21,346.36	19,876.90	18,407.45	16,938.00	15,468.54	13,999.09
2000	2021	22	21,216.26	19,616.45	18,016.65	16,416.84	14,817.04	13,217.23
2001	2021	21	21,266.32	19,716.29	18,166.27	16,616.24	15,066.22	13,516.19
2002	2021	20	21,227.98	19,639.50	18,051.03	16,462.55	14,874.08	13,285.60
2003	2021	19	21,233.46	19,650.84	18,068.23	16,485.61	14,903.00	13,320.38
2004	2021	18	21,168.65	19,520.85	17,873.05	16,225.25	14,577.45	12,929.66
2005	2021	17	21,223.88	19,631.35	18,038.83	16,446.30	14,853.78	13,261.25
2006	2021	16	22,377.64	20,835.48	19,293.32	17,751.16	16,209.01	14,666.85
2007	2021	15	20,971.51	19,127.10	17,282.69	15,438.27	13,593.86	11,749.45
2008	2021	14	20,977.09	19,137.56	17,298.02	15,458.49	13,618.96	11,779.43
2009	2021	13	21,146.62	19,477.24	17,807.86	16,138.48	14,469.09	12,799.71
2010	2021	12	21,377.22	19,938.55	18,499.88	17,061.21	15,622.54	14,183.87
2011	2021	11	21,070.03	19,323.97	17,577.90	15,831.84	14,085.77	12,339.71
2012	2021	10	21,249.72	19,683.85	18,117.98	16,552.11	14,986.24	13,420.37
2013	2021	9	21,247.76	19,682.29	18,116.83	16,551.37	14,985.90	13,420.44
2014	2021	8	21,124.90	19,433.98	17,743.07	16,052.16	14,361.25	12,670.33
2015	2021	7	21,126.18	19,436.01	17,745.84	16,055.67	14,365.50	12,675.33
2016	2021	6	20,611.53	18,406.33	16,201.14	13,995.94	11,790.74	9,585.55
2017	2021	5	20,114.20	17,412.69	14,711.19	12,009.68	9,308.17	6,606.67

Summary and conclusions

The article attempts to answer: How the number of historical inputs affects the quality of prediction of the number of traffic accidents? For this purpose, the author analyzed the annual number of road accidents in Poland from 1990-2021 from the statistics of the Police and determined the value of the average absolute error MAPE percentage error in forecasting the number of accidents in Poland during the forecasting method used. Based on the study, it can be concluded that using annual static data on the number of road accidents in the dependency to forecast the number of accidents is enough to use data from 7 years (2015-2021), for which the value of the forecast error will be less than 7%. Regardless of whether we use data from 32 years or 7 years, the value of the analyzed error does not exceed 7%. A smaller number of input data, only increases the value of analyzed errors, and too little data makes it impossible to carry out the forecast. However, when determining the forecast for subsequent years, it should be borne in mind that despite the small value of the average absolute percentage error of MAPE, the result of the forecast, depending on the input data, can change, in the sixth year of the forecast, by nearly 50%. It should be remembered, however, that the prevailing pandemic, reduced the number of accidents on the roads, but also affected the presented forecasts, as confirmed in other works by the author (Jurkovic et al. 2022, Gorzelanczyk 2022, Gorzelanczyk et al. 2022e).

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