Journal of KONBiN 1 (13) 2010
ISSN 1895-8281

DOI 10.2478/v10040-008-0150-3

ANALYSIS OF FACTORS INFLUENCING THE DENSITY OF FATALITIES ON NATIONAL ROADS IN POLAND

ANALIZA CZYNNIKÓW WPŁYWAJĄCYCH NA GĘSTOŚĆ OFIAR ŚMIERTELNYCH NA DROGACH KRAJOWYCH W POLSCE

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Abstract. *In Poland 20% of the total number of accidents occur on the national roads, which constitute 7% of the length of all roads. In the case of fatalities this share is significantly higher as it constitutes up to 36% of the total casualties. In accordance with the EU Directive (Journal of Laws EU L. 319/59) the level of road traffic safety should be raised by targeting investment on the most dangerous road sections. Finding the dependence between road and traffic factors and the number of accidents and casualties of road accidents may be helpful in predicting safety levels and selecting road traffic safety improvement measures. The paper presents the experience of other countries and preliminary tests results of the impact of the selected factors on the density and the number of road accident fatalities on the national roads in Poland.*

Key words: *national roads, road traffic safety, impact factors, road accident fatalities*

Streszczenie. *W Polsce na drogach krajowych, które stanowią 7 % długości wszystkich dróg dochodzi do ponad 20% ogółu wypadków. W przypadku ofiar śmiertelnych udział ten jest znacznie wyższy, bo stanowi aż 36% ogółu ofiar. Zgodnie z Unijną Dyrektywą (Dz.U. UE L.319/ 59) poziom bezpieczeństwa ruchu drogowego powinien zostać podniesiony poprzez inwestycje na najbardziej niebezpiecznych odcinkach dróg. Znalezienie zależności pomiędzy czynnikami drogowo-ruchowymi a liczbą wypadków i ofiar wypadków drogowych może być pomocna przy prognozowaniu poziomu bezpieczeństwa i wyborze środków poprawy brd. W referacie przedstawiono doświadczenia innych krajów i wstępne wyniki badań wpływu wybranych czynników na gęstość i liczbę ofiar śmiertelnych wypadków drogowych na drogach krajowych w Polsce.*

Słowa kluczowe: *drogi krajowe, bezpieczeństwo ruchu drogowego, czynniki wpływu, ofiary śmiertelne wypadków.*

1. Introduction

In accordance with the EU Directive requirements, the assessments of the impact on road safety should demonstrate, on a strategic level, what is the impact of different planned variants of an infrastructure project on road safety and play a decisive role in plotting the routes of roads. The safety level of existing roads should be raised by investment in specific road sections with the highest concentration of accidents or highest accident reduction potential [1].

Creating prediction models of accidents and casualties will be one of the elements to determine the impact of the individual road and traffic factors on road safety levels on the existing and newly built roads. In accordance with Article Eight of the Directive, setting guidelines and models to define the existing and predicted level of road traffic safety on selected road sections is within the obligations of road management.

In Poland national roads of the length of 18.520 km constitute 7% of the length of all the hard roads in Poland. This paper sets out the results of analyses of the level of road traffic safety on national roads managed by the General Director for National Roads and Motorways (all express roads and motorways and the other national roads outside grodzki poviat). In the years 2006 to 2008 more than 29 thousand accidents occurred on these roads, in which 41.010 people were injuries and 5.800 died (20% of the total number of accidents, 22% of the total injured and as many as 36% of the whole of fatalities on all roads in Poland) [2].

2. The characteristics of the problem

Based on the study of literature, the paper presents selected road and traffic factors which were used in the construction of models in other countries. Due to the different nature of the factors affecting the number of accidents and fatalities, they have been divided into two groups: traffic and road.

The impact of road traffic (there is a large variability of this factor for different sections or over a year) consists of among others: annual-average daily traffic volume (SDNR), the share of heavy duty vehicles and the volume of pedestrian traffic.

Most of the available papers present results of studies on the influence of selected factors on the number of road accidents. However, very little data is available on specific models of predicting the number of casualties or fatalities depending on road and traffic factors.

In the majority of models a generalised linear regression model described by formula (1) has been applied:

$$LW = \exp\left\{\sum_{i=0}^{n} \beta_i \cdot X_i\right\} \tag{1}$$

where:
X_i- independent variables,
β_i - parameters of the equation.

The most frequently used independent variable taken into account in the construction of models is: the annual-average daily traffic volume (AADT) [4], [5], [8], [9], [10], [11], [12], [13], [14], [15]. It should be noted that with the increase in traffic the number of accidents and their casualties increases. Another factor affecting the number of accidents is the share of heavy duty vehicles traffic [12]. With an increase in the heavy duty traffic on multi-lane roads, the number of accidents decreases. In the case of vulnerable road users one of the factors affecting the number of accidents and deaths is the density of pedestrian crossings [13]. K. El-Basyouny and T. Sayed argue that with the increase in coincidence between pedestrian and vehicle traffic the number of accidents and casualties increases.

An important group of independent variables are road factors: road class, type, cross-section, bendiness, waviness, and surface, number of intersections, marking, or accessibility. These factors are stable over a long period of time.

Road class (motorway, express road, main roads, etc) aggregates many road and traffic factors. For example a motorway does not pass through built-up areas, there is very little accessibility, speed of travel is very high; this road varies greatly from a single carriageway road passing through many cities. In the road class its cross-section and width are often hidden. But in the case of modelling of roads in one class or type, road cross-section and road surface appear in the literature as one of the factors affecting the number of accidents (10) (13), (15).

One of the most important factors affecting the number of accidents and casualties is the density or the number of junctions [4], [5], [14]. There is a correlation between the number of junctions and speed outside built-up areas. In the area of junctions speed is often limited by regulation or as in the case of roundabouts the speed is reduced spontaneously by the geometric parameters of the junction, etc. [6], [14]. The problem of accessibility to the road and its impact on the number of accidents has been very widely and accurately described by Kiec in his paper [9]. In the studies generalised linear regression models were used. Kiec proves that with the increasing density of junctions, the number of accidents increases, in addition the increase in density of exits affects negatively the number of

accidents, but its impact is several times smaller than that of a single junction.
Bendiness, as the factor most often identified as the sum of the angles of route turn, while the waviness, as the absolute value of differences in height or % of road gradient on its length. In addition, some models include the curve radii influence on the number of accidents. The results showed an increase in accidents with a decrease of the horizontal curve radius on the road [10], [15].
The resultant combinations of these two groups of factors may also occur in the models of accident prediction. One of these items will be speed or number of vehicles exceeding the speed limit. It will be influenced by the traffic volume as well as for example road geometry, density of junctions or administrative constraints [6].

3. Research field

The research to develop models of road accident fatalities was started with the use of data available to the authors on the national road network managed by General Director for National Roads and Motorways. Input data consisted of the database on the national road network with a breakdown of over 5.5 thousand reference points (up to 5.1 thousand sections were analysed). Each section has information about: road number, beginning and ending reference codes, mileage, length, road class, volume from the general measurements in 2000 and 2005 divided into vehicle type structure, cross-section, the number of lanes and length of built-up sections.
For each of these sections the information about traffic events, their victims, and other characteristics attributed to a single accident were gathered. Data came from the System of Collision and Accident Records SEWIK. All data were verified in the various voivodship departments of General Directorate for National Roads and Motorways. The analysis covered data on accidents between years 2006 - 2008 [2].
Due to the large variations in the length of sections (the shortest ones did not exceed 100 m, the longest are more than 8 km) their aggregation was applied. In modelling of such short sections the density of events or casualties may be dependent only on one factor, such as a junction or a single accident. On many of these sections there are no events or one event can cause a very high density of accidents or casualties in very short distances. In order to avoid such problems, it was decided that for further work the section should be combined in longer stretches. The assumption was that the section's length was more than 20 km. It was attempted to

choose sections so that a minimum number of accidents with deaths and serious injury was 10 over the past 3 years.

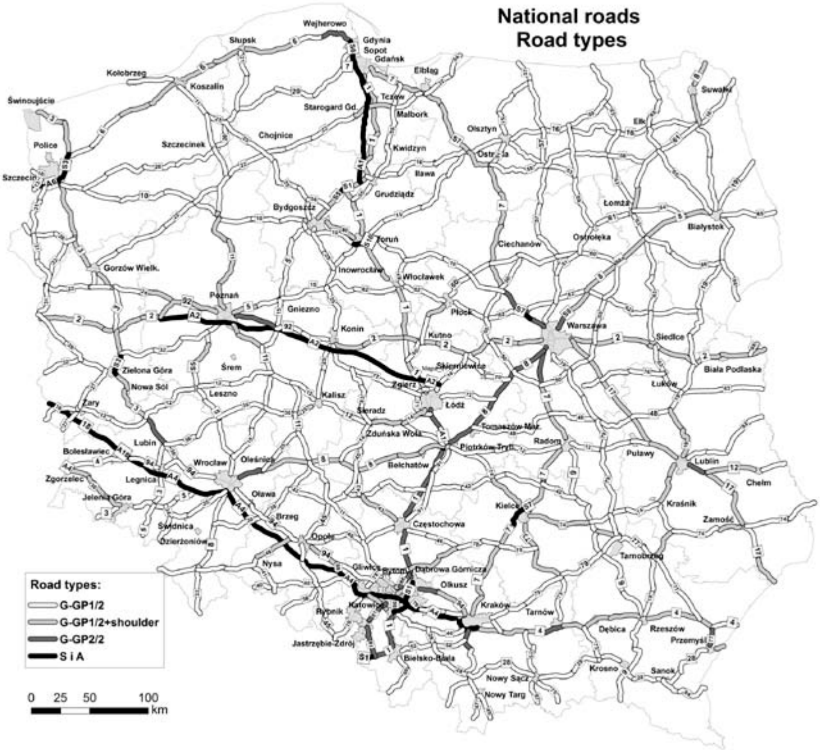

Fig. 1 National roads divided into road types

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The criteria for building a database with the combined reference sections were: cross-section, class, similar volume of traffic (it was attempted to select sections of the same cross-section, traffic volume and road class) junction with other national or voivodship road. On this basis the national road network was divided into 596 homogeneous sections, 533 of which constitute single carriageway roads, 26 - dual carriageway roads and 32 - express roads and motorways (Fig. 1). Total length of sections is more than 17 thousand km, average traffic volume 9.1 thousand, and vehicle – kilometres travelled in 3 years is almost 170 billion vehicle/km. Table 1 lists the length of sections, vehicle-kilometres travelled, the annual-average daily traffic volume broken down by type of road.

Table 2 and Figure 2 show the number and density of fatalities on selected sections of the particular road types in the years 2006 to 2008. . The largest density of fatalities occurs on dual-carriageway roads G-GP2/2 and on single carriageway roads with hard shoulder G-GP ½ + shoulder.

Table 1. The length of sections and traffic data on national roads in years 2006-2008

Road type	Section number n	Length SL	Vehicle kilometers travelled PP	Volume N
	[liczba]	[km]	mln poj km/ 3 lata	P/dobę
G-GP1/2	402	1.1647,2	78.352,7	6.144
G-GP1/2+shoulder	131	3.528,4	49.761,3	12.880
G-GP2/2	26	654,4	18.744,3	26.157
S2/2	14	291,4	5005,2	15.684
A2/2	18	747,1	15.821,8	19.341
Others	5	135,5	1.746,5	11.771
Total	**596**	**17004,04**	**169431,8**	**9100**

A – Motorways, S – Express roads, G – Main roads, GP – Main fast roads

Table 2. The density and number of fatalities on national roads in years 2006-2008

Road type	Number of fatalities LZ	Average number of fatalities on road section SLZ	Density of fatalities GLZ
G-GP1/2	3216	8,0	0,092
G-GP1/2+shoulder	1882	14,4	0,178
G-GP2/2	444	17,1	0,226
S2/2	102	7,3	0,117
A2/2	125	7,4	0,056
Others	46	9,2	0,113
Total	**5815**	**9,8**	**0,114**

Currently additional information on each section is gathered: road width (width of carriageway, shoulders) type of surface, shoulders, presence of pavements, separating belts, the presence of barriers separating traffic, density and junction types, the density of entries, speed limits, travel speed, data on bendiness and waviness of road section, occurrence of speed cameras or other enforcement devices.

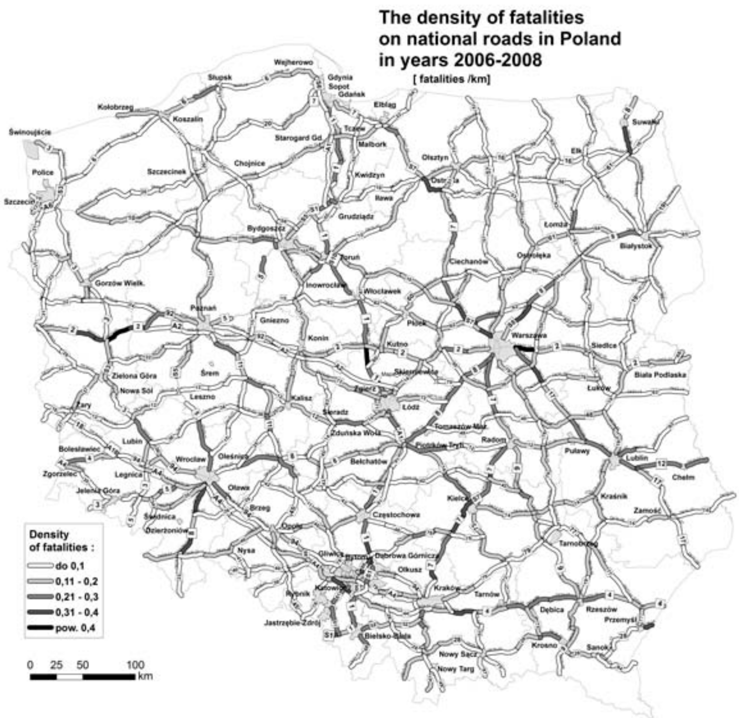

Fig. 2. The density of fatalities on national roads in Poland in years 2006-2008

4. Model selection

Several models of the dependence of the density of fatalities in road accidents from the factors identified in the analysed sections of national roads were constructed and analysed. The parameters of models were selected with the use of the STATISTICA programme. The most promising model showing the impact of the analysed factors on the level of loss in road traffic is the model described by the formulas: (2) for the density of fatalities, (3) for the number of fatalities. Table 3 presents the parameters of the analysed models.

$$GZ_k = \beta_{1k} * (N * 10^{-4})^{\beta_{2k}} * exp\{\beta_{3k} * PZ + \beta_{4k} * T_k + \beta_{5k} * UC_k\} \qquad (2)$$

$$LZ_k = \beta_{1k} * (N * 10^{-4})^{\beta_{2k}} L^{\beta_{3k}} * exp\{\beta_{4k} * PZ + \beta_{5k} * T_k + \beta_{6k} * UC_k\} \qquad (3)$$

where:
GZ_k – denisty of fatalities,
GZ_1 – denisty of fatalities on single carriageway roads,
GZ_2 – denisty of fatalities on dual carriageway roads, express roads and motorways

LZ_k – number of fatalities,
GZ_1– number of fatalities on single carriageway roads,
GZ_2– number of fatalities on dual carriageway roads, express roads and motorways,
N – annual- average daily traffic volume,
PZ – the percent of built-up area length [%],
T – road type, number of lanes,
UC – share of heavy duty vehicles [%].

Table 3 Summary of parameters of analysed models of density and the number of fatalities on national road network

Model	β_1 N	β_2 N	β_3 PZ	β_4 T	β_5 UC	P<0,05	R^2
GZ_1	0,110	0,570	-0,227	0,092	0,905	0,049	0,44
GZ_2	0,447	0,519	-1,062	-0,365		0,012	0,68

Model	β_1 N	β_2 N	β_3 L	β_4 PZ	β_5 T	β_6 UC	P<0,05	R^2
LZ_1	0,659	0,635	0,791	-0,241	0,103	0,844	0,048	0,47
LZ_2	10,190	0,603	0,363	-1,388	-0,364		0,043	0,71

Figures 3 - 8 show diagrams of dependence of modelled density GLZ and the number of fatalities LZ from analysed road and traffic factors on national roads in Poland. The traffic volume has the biggest effect on the density of fatalities measured by the number of victims per kilometer of road within a year. With the increase in traffic volume, the density of fatalities increases on all types of road. The biggest increase has been observed in the case of single carriageway roads. The worst road class is G-GP1 / 2 + shoulder. One of the reasons may be a large number of vehicles exceeding the speed limit, which combine with high accessibility and the lack of separation of traffic direction causes a high severity of accidents. The best conditions occur on express roads (mainly dual carriageway) and motorways. The danger level on these roads is almost four times lower than that on single-carriageway roads with hard shoulder with the same traffic volume (Fig. 3). An important element that affects the density of victims is the length of the built-up area sections. If this grows, despite an increase in the number of accidents, there is a reduction in density of fatalities. It results from the speed limit in built-up areas, causing a reduction of severity of accidents. The highest density of fatalities occurs outside built-up areas on single carriageway roads with hard shoulder and is almost 2.5 times higher than on dual-carriageways (G-GP2 / 2) in built-up areas (Figure 4).

The effect of the share of heavy duty vehicles on the density of fatalities occurs only on single-carriageway roads. The increase in this share causes the increase in the density of fatalities. These vehicles move slower than passenger cars, the conflict of the two different speeds and problems with overtaking heavy duty vehicles cause the increase in the number of fatalities. On the roads which have at least two lanes in each direction, overtaking heavy duty vehicles is much easier and above all not associated with such a high risk as on single-carriageway roads (Fig. 5).

The traffic volume, as in the case of density of fatalities, has also the greatest impact on the number of fatalities measured by the number of victims on a road section (average length of the section that was analysed is 25 km) within a year, with increase in traffic volume the number of fatalities increases. Here, as well, single-carriageway roads are characterised by a low level of traffic safety (Fig. 6).

Outside built-up areas the largest number of fatalities occurs on dual-carriageway roads G-GP2 / 2. This may be due to significantly higher speeds of travel. However, with the increase in the lengths of built-up area sections, the level of fatalities is falling faster than on other single-carriageway roads.

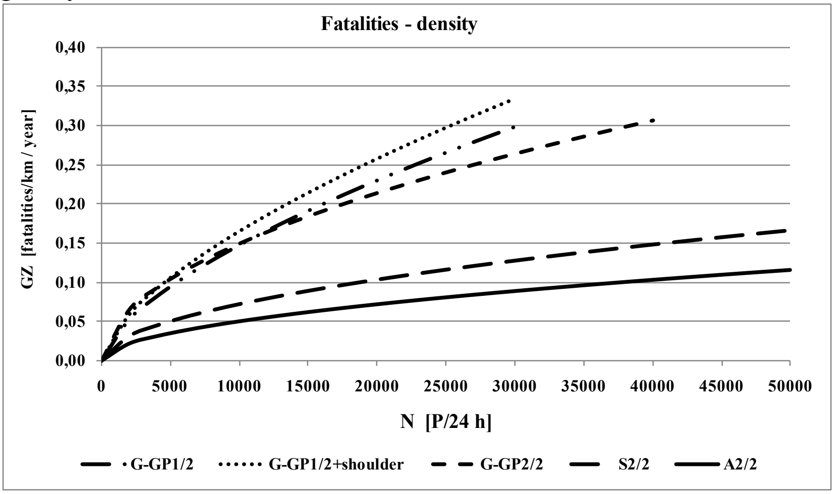

Fig. 3 The influence of traffic volume and road type on the density of accidents on national roads (the level of urban development 0%, average share of heavy duty vehicles)

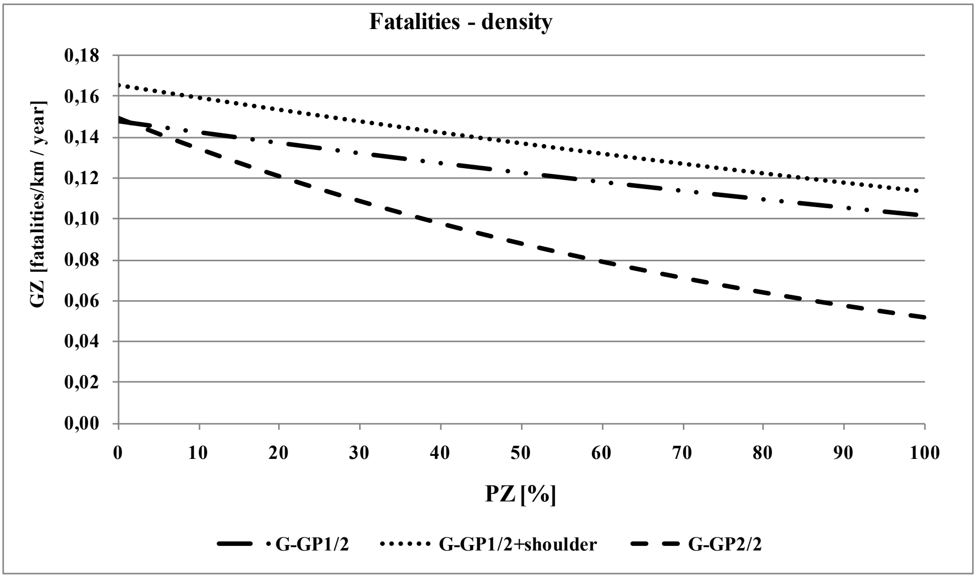

Fig. 4 The influence of built-up area sections on the density of accidents on national roads (volume 10 thousand vehicles, average share of heavy duty vehicles)

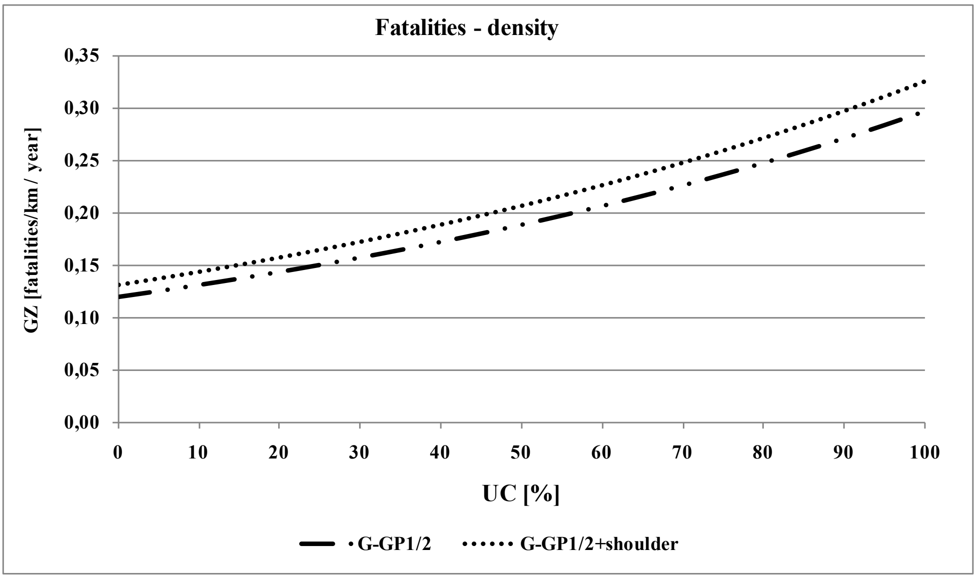

Fig. 5 The influence of share of heavy duty vehicles on the density of accidents on national roads (volume 10 thousand vehicles, average urban development)

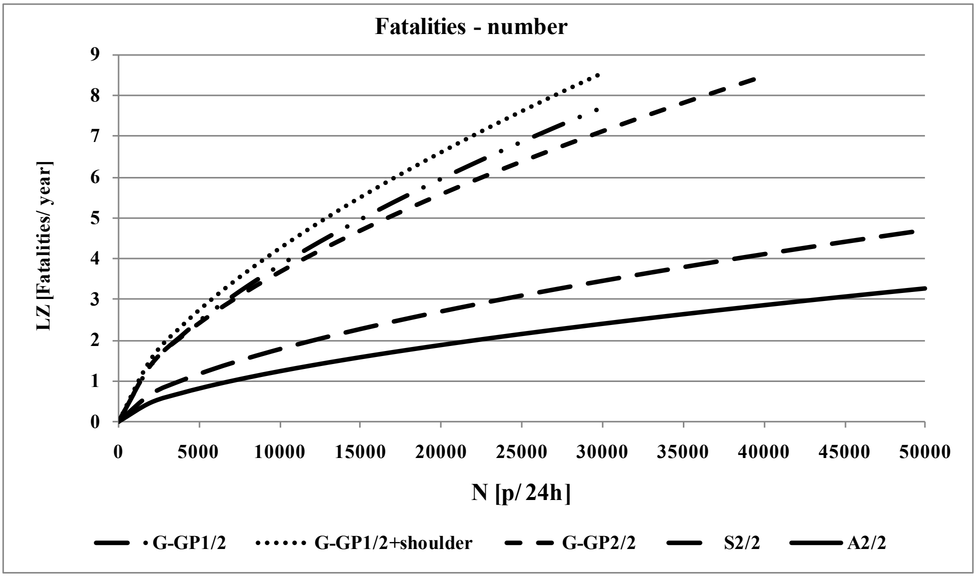

Fig. 6 The influence of traffic volume, road type on the number of fatalities on national road (average length of section 25 km, the level of urban development 0%, average share of heavy duty vehicles)

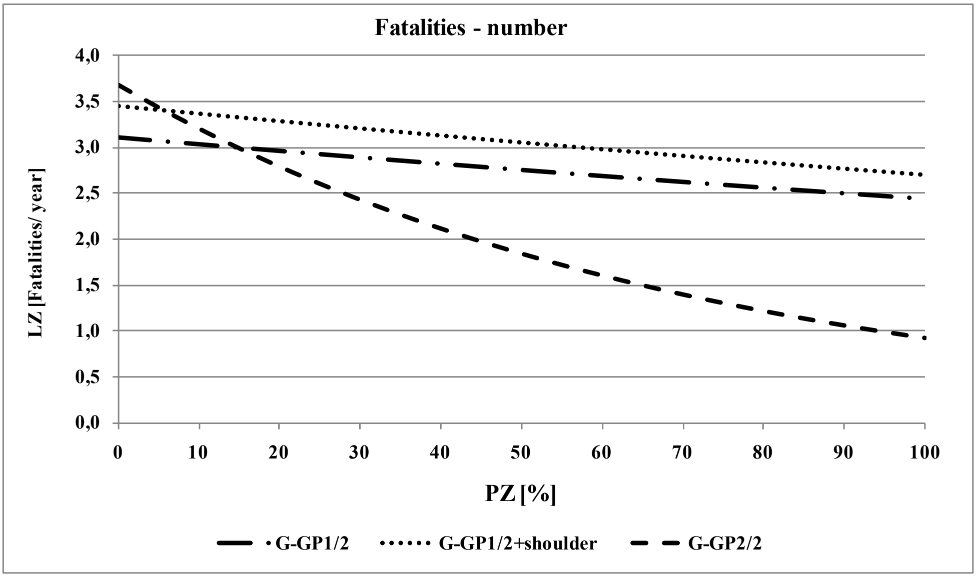

Fig. 7 The influence of built-up area sections on the number of fatalities on national roads (average length of section 25 km, volume 10 thousand vehicles, average share of heavy duty vehicles)

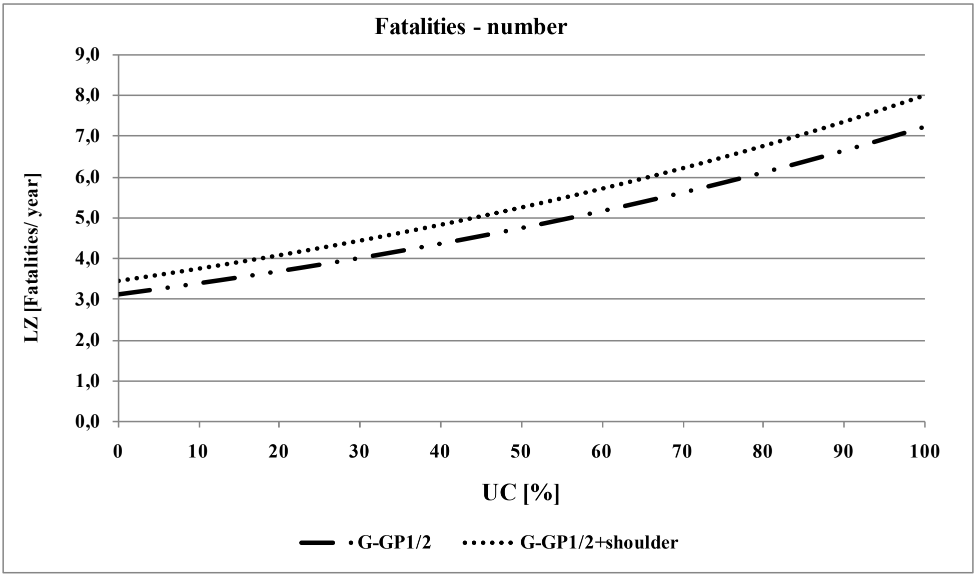

Fig. 8 The influence of share of heavy duty vehicles on the density of fatalities on national roads (average length of section 25 km, volume 10 thousand vehicles, average urban development)

5. Summary

The presented models show the influence of the most important factors on the number and density of fatalities on sections of the national roads.

This paper is the first step in creating models defining the impact of road and traffic factors on the level of road safety. Subsequently, other factors that influence the density of accidents as well as the casualties and fatalities will be selected. The choice will allow for creating models that will more accurately describe the existing dependences.

The development of models will allow for determining the impact of various road investments, to raise the level of road safety and define the effect of various solutions on the number of accidents and casualties. In addition, it will make it possible to create security models for network analyses of road safety throughout the country.

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