ROAD INFRASTRUCTURE AND TRAFFIC PARAMETERS - MAIN FACTORS AFFECTING TRAFFIC SAFETY

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Abstract: *Within the transport process there is continuous interaction between the three main factors: behaviour of road users, infrastructure conditions and characteristics and vehicles. As a matter of fact, the aforementioned factors are key sources of causes for traffic accidents.*

The purpose of the present article is to propose such a road traffic organization that would reduce congestions, minimize the number of road accidents and the risk to health and life and would enhance safety. In this context certain characteristics of a specific road section in Bulgaria will be examined. Furthermore measures for improving traffic conditions and safety will be defined.

Keywords: TRAFFIC ACCIDENTS, ROAD TRANSPORT SAFETY, VEHICLE, TRAFFIC

1. Introduction

Road accidents lead to huge social and economic losses for society. They are becoming a serious problem for the Bulgarian health, since they have a direct impact on mortality and morbidity.

The traffic process is a continuous interaction between the three main factors: behavior of road users, safety of road infrastructure conditions and characteristics and vehicles. An important indicator also participates in the interaction - pre-medical and specialized medical care. Equal attention should be paid to the improvement of each of these factors by developing goals and programs related to a higher level of safety.

Because of the mentioned above, the following study is related to measures that would help to: reduce congestion in a chosen area, minimize the number of road accidents, reduce the risk, prevent traffic accidents and enhance safety. For the purposes of the study and monitoring of infrastructure impact on traffic safety, the following are selected: an intersection and a road area with a high concentration of accidents. The activities that form the safe behavior of road users, better construction and maintenance of road infrastructure, lower traffic conflicts and ensure participants' protection are of a particular concern.

2. Key factors affecting road traffic safety and the choice of road section

2.1 Overview of the main factors affecting traffic safety

Traffic safety depends on the failure-free operation of all the elements in the 'Driver - Vehicle - Road – Environment' System, hereinafter DVR system. The system's reliability depends on the perfection of its individual elements, which can be represented by the equation of the reliable operation of the system (1):

(1) $P_{DVR} = P_D \cdot P_V \cdot P_R$,

Where:

P_D - probability of a reliable operation of the driver;

P_V - probability of a reliable operation of the vehicle;

P_R - probability of a reliable operation of the road.

One of the main objectives is to study the influence of typical factors related to traffic safety. The most important and responsible element of the DVR system is the driver. His psycho-physiological capabilities are insufficiently studied and hard to maintain. Therefore the reliability of the driver can be assessed indicatively and this element appears to be the weakest in the system. According to formula (1), reducing the probability of a reliable operation of one of the three elements of the DVR system, safety deteriorates sharply and causes traffic safety problems, i.e. it leads to emergency situations that most often end with accidents.

The solution to the traffic safety problems, based on the systematic approach that takes into account the interactions and relationships of all elements in the DVR system, is shown in formula (2). The probability of an accident is presented as a function of factors, depending on the driver - D, vehicle condition - V, road conditions - R, traffic movement - TM and random factors - RF:

(2) $P_{RA} = f(D,V,R,TM,RF)$

The results of various studies on the factors above associated with accidents in several European countries are shown in papers [1, 6]. According to the data provided in these studies, it appears that the human factor is decisive in 68% of the accidents. When taking into account accidents in which the human factor is combined with other factors that are considered to have contributed for the accident, this rate reaches 91.5%. The human factor becomes even more important for reliable operation of the DVR system, if it is subjected to alcohol and drug influence. Research in Norway [3] shows the relative risk of a participation in an accident when drivers are with different levels of alcohol in their blood (grade of intoxication). The relative risk of participation into an accident increases in non-linear relationship with an increase in alcohol intoxication.

Different studies show that the biggest accident rate is in the highway and after that on secondary and tertiary roads. The traffic condition is presented by the characteristics intensity and speed. Accidents increase to about 80%, when the traffic intensity is increased from 10 to 100%. The proportion of people killed also increases by approximately 25 %, which means that an increase in intensity (especially when it gets close to the throughput of the road) raises driver's discipline, reduces the speed and hence leads to lighter consequences of accidents. Furthermore, streets with greater intensity are with better driving conditions. The rate of accidents in highways is the highest due to the high intensity and dissipation speed. Variance of speed has the most significant impact on traffic safety compared to the average velocity of the flow. Deviation from the average speed for the section leads to more interaction between vehicles and a greater likelihood of accidents. Drivers who move at a speed considerably lower or higher than the average speed of the traffic flow participate more often in accidents than those who stick to the average speed. Data for a tolerance of 50% of the average velocity of the flow (50 km/h) is given in [2, 7]. Surprisingly, the results show that the deviations from the average speed is the main reason for the accidents, not the level of speed. The highest velocity (speed limit) to pass through the turn without sideslip, provided that the driver did not slow down and/or accelerate the vehicle can be calculated by the expression:

(3) $V = \sqrt{gR(\varphi + tg\alpha)/(1 - \varphi tg\alpha)}, km/h$

Where:

R - turning radius;

α – transverse slope of the road;

g – acceleration of gravity;

φ - coefficient of adhesion in the transverse direction.

Taking into account all the factors that influence the number of road accidents, it can be said that they are the same for Bulgarian conditions, but it is necessary to pay attention to the statistics in terms of the specific conditions of the chosen road section.

With regard to Bulgarian conditions as a result of road accidents 601 people were killed and 8193 were injured on Bulgarian roads in 2012. There is a decrease of 56 killed and 108 injured compared to 2011. The reduction of the victims for the two years (2012 and 2011) compared to 2010, which is the base - 156 (20.6%), shows a significantly faster rate of decrement of the number of victims compared to the national strategy objectives for improving road safety in Bulgaria [5]. The implementation of targets for the reduction of road casualties in Bulgaria by 50% until 2020 [4] continues, paying close attention to the priorities set in the national and regional strategies and action programs related to active and passive safety.

2.2 Characteristics of the chosen road section

The causes of road accidents can be divided into two groups: subjective - related to human behavior, as a participant in the movement; objective - related to the imperfection of the traffic conditions and vehicles. The aim of this article is to analyze accidents in a chosen road section and to identify the most common reasons for their occurrence. The following main tasks are settled: identifying the object and scope of the study on various indicators of registered accidents; collection and processing of data from the records of accidents; identifying the methodology for processing data; statistical treatment of the data; analysis of the results obtained; conclusions and recommendations for improving traffic conditions and traffic safety.

The 'Pernik - Vladaia' road section is selected for the study, because it is part of the national road network in Bulgaria. The importance of the road section is defined by its affiliation to class road I-1, which is part of the national road network and important thoroughfare in the country. It is also a key link between the two neighboring countries: Romania and Greece. National Road I-1 is the westernmost of first class roads and connects the city of Vidin with the border checkpoint Kulata - Promachon, passing through Sofia. Its total length is 453.8 km. The road is part of the European route E79 - Oradea - Craiova – Vidin - Sofia - Thessaloniki. The concerned section starts from the 'Dragichevo' junction and ends up in the 'Vladaia' checkpoint. The section has a total length of 8.3 km. Daily thousands of cars, buses and trucks pass through it. The road surface is worn and not in a good condition. There are many bumps and holes that hinder the movement of vehicles and are a prerequisite for serious accidents. The number of accidents is extremely high and most likely the road is one of the busiest and most dangerous in the country. Traffic jams that occur because of the two-lane road pass 'Vladaia' are a routine.

According to the Bulgarian Road Infrastructure Agency the condition of the road surface of the section at the end of 2012 is acceptable. Cosmetic repairs associated with partial adjustments do not lead to a qualitative improvement of the road surface condition, as in the most cases increase roughness. There is a presence of longitudinal and mesh cracks, local subsidence and damages. The objective economic conditions in the country, the economic crisis, the closure of almost all industries in Pernik, led to rising unemployment in the city. The capital - Sofia, is a good alternative for searching and finding a job for many people living close to it. A significant part of the workforce in Sofia uses railways but there is also significant travel by private cars or public transport, using this road section. Travelers to Sofia are around 30 000 to 40 000 people. The movement is as follows: workers - 67 %, employees - 21 %, unemployed - 2 %, entrepreneurs – 6 % and others - 4%.

In this sense, the 'Pernik - Vladaia' road section is not only a part of the transport artery of the country and a mean for improvement of the functioning of the transport links, but also the impetus for socio-economic development of the region. The commissioning of the 'Lyulin' highway significantly relieved the traffic intensity (Tab. 1), but the section still remains extremely busy. One reason is the steady increase in the number of vehicles.

Years	2008	2009	2010	2011	2012
Traffic intensity vehicles/day	28000	29000	29000	18000	18000

Tab. 1 Traffic intensity per year in the chosen section

According to the 'traffic police', traffic over the years has doubled. The 'Lyulin' highway takes at least half of the potential traffic at the 'Pernik - Vladaia' section and almost 100 % of that of heavy vehicles. Traffic load reaches 90 % of the throughput of the road section and a pronounced unevenness in the morning and evening hours of the day. The flow is directed to the capital - in the morning and to Pernik – in the evening. Results obtained from the traffic counts show that the highest load is in the intervals 6:30 a.m. to 8:30 am and 4:30 to 6:30 pm, which is why they are defined as peak. An average daily traffic volume of 18 000 vehicles shows that 3 000 cars have passed through the terminal from which the observation was made during the peak hours. In some parts of the road section, where the traffic is one-way, separation of traffic flows is made in two-way traffic through road cones, which facilitates the movement.

An essential traffic characteristic is speed. Speed is limited primarily in conflict points between vehicles or between vehicles and pedestrians, as well as in areas with minimum turning radius according to weather conditions (respectively the coefficient of adhesion).

Parameters of the road that affect the speed driving mode are horizontal curves with their characteristic radii and the condition of the road surface (dry, wet and icy where the adhesion coefficients are 0.7, 0.2 and 0.4).

Drainage facilities in the greater part of the region are missing. Due to roadside vegetation, which varies seasonally, the visibility is limited. There is discrepancy between the actual road markings and visibility when cornering at the observed section. Some parts of the section are narrower than others. Speed limitation is made through road signs and artificial obstacles.

In the present road section there are three pedestrian crossings. Two of them are well signalized and marked with road signs. It should be noted that the third, except lane markings, does not have any other indicators. There are two well signalized intersections in the chosen section. Speed is limited to 40 km/h at the intersections. Speed limitation is 50 km/h in areas with high risk. Almost all of the remaining parts of the section have a limit of 60 km/h. These restrictions are aimed at reducing the number and severity of accidents, but they also reduce effectiveness of the transportation process, due to the lower average speed for the whole section, which is about 50 km/h. This leads to the formation of traffic jams in rush hours throughout the day. Continuous prohibitions for overtaking with the help of road signs lead to a strong variation in speed compared to the average speed of the site or the limited one. There are significant variations in velocity - from under 30% to over 110% at the section. The critical radiuses of the road curve are 2 and they cover about 800 meters of the road section or about 9.6 % of it. Longitudinal slopes uphill and downhill are negligible (less than 3%) and they do not affect significantly the speed mode. The

vertical signalization is acceptable - there are about 70 signs. Limits are signposted by road signs B26 and B24.

3. Analysis of traffic safety

Relative objective indicators to assess the status of road safety are weight factor of the consequences (severity coefficient) and mortality rate of the accident (fatality coefficient).

The weight factor is determined by the expression:

$$(3)\ K_S = \frac{n_f + n_i}{n};$$

The mortality rate is determined by the expression:

$$(4)\ K_f = \frac{n_f}{n_f + n_i},$$

Where:

n_f - number of casualties (fatal) in a road accident;

n_i - number of casualties (injured) in road accidents;

n - number of the registered serious road accidents.

3.1 Road conditions in the 'Pernik - Vladaia' section

A summarized data for accidents in the 'Pernik - Vladaia' section is given in tab. 2 for the 2008 - 2012 period. Coefficients K_s and K_f have the highest values in 2011:

Year	Traffic Accidents	Killed	Injured	K_s	K_f
2008	64	0	5	1,25	0
2009	48	0	3	1	0
2010	40	1	2	1,5	0,3
2011	36	2	3	1,67	0,4
2012	20	0	2	0,67	0
Total	**208**	**3**	**15**	**1,22**	**0,14**

Tab. 2 Accidents in the section "Pernik - Vladaia" (Aggregated data)

The distributions and estimations of road accidents are presented in tables 3, 4, 5 and 6, depending on the weather conditions, the condition of the road surface, the brightness of the place of accident and visibility of the road and its infrastructure.

Year	Clear	Cloudy	Rain	Drench	Snowfall
2008	31	15	6	8	4
2009	23	16	6	–	3
2010	25	10	5	–	–
2011	19	9	–	4	4
2012	15	–	5	–	–

Tab. 3 Distribution of accidents according to the weather condition

Year	Dry	Wet	Snowfall (taken measures)	Mud
2008	35	27	1	1
2009	33	14	1	–
2010	30	10	–	–
2011	28	8	–	–
2012	15	5	–	–

Tab. 4 Distribution of accidents depending on the road surface condition

Year	Daylight	Twilight	Artificial lighting	Dark
2008	42	6	13	3
2009	39	5	3	1
2010	27	6	6	1
2011	21	4	6	5
2012	10	5	2	3

Tab. 5 Distribution of accidents according to the brightness of the place of accident

Year	Excellent	Good	Poor	Unsatisf actory
2008	5	37	18	4
2009	1	31	15	1
2010	–	27	12	1
2011	15	13	4	4
2012	7	9	2	2

Tab. 6. Distribution of accidents according to the visibility of the road and its infrastructure

Most accidents occur in normal weather conditions: in clear weather - 113 or 54% (Tab. 3), dry roads - 141 or 68% (Tab. 4) and good visibility - 117 or 56% (Tab. 5). For the period between 2008 and 2012, there is no data for the passing vehicles and their distribution along the entire length of the road.

It can be assumed with sufficient accuracy that along the road traffic volume was not large and in the variable range. Under these conditions, the density of accidents for the mentioned period for the individual sections can be calculated using the equation:

$$(4)\ K_{da_i} = \frac{N_i}{L_i}, \text{ number of road accidents per km.}$$

From Tab. 2 the density of accidents for the period was 25 accidents/km.

3.2 Analysis of traffic conditions and safety of road section with a high concentration of accidents - I-1B

Terms and criteria for identifying and securing areas with a concentration of road traffic accidents (RTA) and categorizing the safety of roads (road infrastructure), open to the public, are regulated by Ordinance № 5 of the Ministry of Interior of the Republic of Bulgaria from 2003.

In the present 'Pernik - Vladaia' road section there is an area with high concentration of accidents (black spot), which is the intersection of Rudartsi. The identification number of the section is I-1B, with length of 300 m. The relative indicator of accident rate U_r (column 5 of tab. 7), according to the ordinance is given by:

$$(5)\ U_r = \frac{Z \cdot 10^6}{T \cdot Q \cdot L}, \text{ number of road accidents/ 1 mln. vehicle km,}$$

Where:

Z - number of accidents, occurring in researched road section for one period;

Q – average daily traffic volume for the same period of time (vehicles per day);

L – length of the road section (km);

T – number of days in which Z number of accidents have occurred, i.e. T = 365.

The severity of accidents occurring in the Rudartsi intersection (column 6, tab. 7) is defined as the ratio between the number of those who have been killed and/or injured and the total number of accidents.

Year	*Traffic accidents*	*Killed*	*Injured*	*Ur*	*Severity of accidents*
2008	34	0	3	11,089	0,059
2009	27	0	2	4,251	0,074
2010	29	1	0	6,621	0,034
2011	22	0	1	4,18	0,04
2012	11	0	1	3,15	0,09
Total	**123**	**1**	**7**	**5,86**	**0,06**

Tab.7 Aggregated data on accidents in site I-1B

The distributions and estimations of accidents in site I-B are presented in tab. 8, 9, 10 and 11, depending on the weather and road

surface conditions, the brightness of the place of accidents and visibility of the road and its accessories.

Year	Clear	Cloudy	Rain	Drench	Snowfall
2008	34	7	4	2	2
2009	13	11	1	–	2
2010	19	7	3	–	–
2011	13	7	–	1	1
2012	9	–	2	–	–

Tab. 8 Distribution of accidents according to the weather condition

Year	Dry	Wet	Snowfall (taken measures)	Mud
2008	23	9	1	1
2009	18	8	1	–
2010	24	5	–	–
2011	16	6	–	–
2012	9	2	–	–

Tab. 9 Distribution of accidents depending on the road surface condition

Year	Daylight	Twilight	Artificial lighting	Dark
2008	23	3	7	1
2009	25	1	1	–
2010	23	1	5	–
2011	16	1	4	1
2012	6	3	2	–

Tab. 10 Distribution of accidents according to the brightness of the place of accident

Year	Excellent	Good	Poor	Unsatisfactory
2008	–	26	8	–
2009	–	21	6	–
2010	–	23	6	–
2011	11	9	–	2
2012	5	5	–	1

Tab. 11 Distribution of accidents according to the visibility of the road and its infrastructure

Most accidents occur in clear weather - 88 or 72% (Tab. 8), on dry roads - 90 or 73% (Tab. 9) and good visibility - 84 or 68% (Tab. 11).

The most of the accidents occur during the periods of most active movement during the day, i.e. with the highest traffic volume. There is a rise in accidents due to poor perception of the movement and the road from drivers in the darkest part of the day. Drivers underestimate the situation and risk more than in conditions of poor visibility. The same applies to traffic movement on dry roads. Drivers are more careful and cautious on wet and snow-covered roads. Approximately 90 % of the accidents occur on straight horizontal sections. The obvious reason here is the absence of fast lane.

The most common accidents in the area are a consequence of driver's fault and are 'crashes with a moving vehicle ahead' and 'collisions between vehicles'. There is no practice in indicating poor road and weather conditions in 'Traffic Police' reports as a reason for an accident, although one of the accident causes is loss of control due to attempt of the driver to avoid bumps and holes in the lane. Most often the main reason related to road accidents is speeding, which does not allow the driver to avoid the collision. Other reasons include failure to comply with the necessary distance, which is a prerequisite for avoiding accidents or withdrawal of advantage. A small percentage of accidents are caused by inexperienced drivers or due to technical fault in the vehicle. Information processing allows a pooled analysis of the road section characteristics, contributing to the accident realization, to be made.

4. Activities for improvement of road conditions and safety

Based on the analysis, carried out in surveys and taking into account the objective and subjective factors the following measures can be identified to improve road conditions and safety in Bulgaria:

- by the supervisory authorities of 'Traffic Police': making arrangements for the exercise of active control, use of new tools for operational monitoring of traffic and the behavior of road users; increased control over compliance with the speed; zero tolerance for drivers engaged in serious violations of the Law of Road Traffic;

- by road users: learning the techniques and skills to control vehicles in complex traffic conditions, introduction to the benefits of timely information on the state of the road and the traffic conditions; targeted set of measures for younger and older drivers (over 65), introduction to the benefits of active and passive safety;

- from the bodies of administrative management (municipal and regional governments): to draw attention to the maintenance of markings and lanes; strict control over companies concerned with the excavation of roadways for maintenance and quality control of pavement reconstruction, continuous information on the Internet about the current status of road conditions and traffic in the area, construction of information equipment for speed registration and visualization of violations for places with high concentration of accidents. It is necessary that the road sections meet modern requirements for quality infrastructure.

5. Conclusion

The serious deficiencies in the training and qualification of drivers lead to increased number of accidents due to speeding and inability to respond quickly and adequately in distressed situations. The low road culture of the majority of road users violating traffic rules, poor state control and unsatisfactory road infrastructure conditions lead to the occurrence of accidents, which are enormous material and personal loss for society. It is necessary to identify priority areas in which traffic safety organizations to work. An interaction between state institutions is necessary to improve road safety at national, regional and municipal level.

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