DATABASE OF BLACK SPOTS ON MAIN ROADS IN SERBIA

Krsto Lipovac[1], Dragan Jovanovic[2], Miladin Nesic[3], Dejan Jovanov[4]
[1]Serbia, Academy of Kriminalistic and police studies, k.lipovac@gmail.com
[2] Serbia, Faculty of technical sciences, draganj@uns.ns.ac.yu
[3]Serbia, Academy of Kriminalistic and police studies, m.nesic@gmail.com
[4]SEETO, dejan.jovanov@seetoint.org

Abstract

The database of black spots was prepared for Public enterprise Roads of Serbia. The data of road and traffic volume from public enterprise Roads of Serbia and the data of accidents from police reports was taken into account. Two different black spot identification methods where used: subjective method and objective method. The first own is based on attitudes of experts and the second one is based on road accident data. For identified black spots prepared very important date for black spot management: data about traffic, accident, countermeasures, effects etc. The database of black spots will be helpful for design countermeasures particularly and for learning about effects of measures.

Key words: TRAFFIC ACCIDENTS, BLACK SPOTS, DATABASE

1. INTRODUCTION

Hazardous sites ("black spots") on the roads represent significant field of work in traffic safety improvement. The interventions at sites of accumulation of traffic accidents are considered as one of the most efficient approaches to prevention of traffic accidents on the roads[1, 2]. In addition to analysis and treatment, the identification of black spots, which represents the procedure of detecting of such places on the network of roads, singles out among the most significant black spot management (BSM) phases.[3].

Having considered the relevant bibliography, we noticed a number of attempts to find and define the most efficient methods that would enable measuring of safety of certain road sections and determine the most threatened and hazardous sites/spots. Despite huge efforts, the identification principles and techniques for hazardous sites/spots have not been standardised until today so that the used approaches differ from country to country[4]. Methodologies range from a simple marking of sites/spots with a large number of traffic accidents to techniques that are more sophisticated where the expected number of traffic accidents is evaluated and the potentials for safety enhancing are determined. General identification principles can be divided per principle based on the analysis of traffic accidents and "no traffic accidents" principle[3]. In one of his papers, Elvik analysed five techniques for identification of hazardous sites/spots: (1) recording the number of accidents during a specific period, (2) observing the accident rate (accidents per million vehicle kilometers) during a specific period, (3) combining a critical count of accidents and an accident rate above normal during a specific period, (4) using the empirical Bayes estimate of the expected number of accidents at each location, and (5) determining the size of the contribution of presumably local risk factors to the empirical Bayes estimate of the expected number of accidents at each location[5]. Pei Y. and Ding J. emphasise in their work 6 methods for identification of hazardous sites/spots that are used the most: (1) accident frequency method, (2) accident rate method, (3) matrix method, (4) method of total equivalent of number of accidents, (5) quality control method, and (6) critical rate method[6]. Certain researches of identification of hazardous sites/spots are based on subjective evaluations of participants in traffic[7]. In addition to principles and techniques, the defined criteria that need to be observed in identification of hazardous sites/spots can also be found in certain papers[8]. All this points that there is truly a wide range of options when it comes to methodology of identification of hazardous sites/spots on the roads.

For a number of years no system researches of hazardous sites/spots on the roads have been conducted in Serbia and more serious researches in this field of traffic safety have been initiated only recently [9, 10, 11]. This has created conditions for setting of the database on hazardous sites/spots on the roads in Serbia.

The subject of this paper is the method of identification of black spots on the roads. The paper analyses two identification methods for <<black spots>> in particular: objective (based on the analysis of traffic accidents, roads, and traffic) and subjective method (based on the analysis of attitudes and opinions of experts: representatives of road managers, police officers, and public road inspectors). The objective of the paper is to compare the above-mentioned identification methods and to determine the advantages and shortcomings of their application.

2. METHOD OF WORK

The research resulted with creation of two databases on hazardous sites on the roads (the main road network) in Serbia based on the following:

- Data on traffic accidents, road and traffic characteristics,
- Polls and interviews of the competent experts who deal at site with construction, maintenance, and supervision over the roads. This database is completed with the data collected at site.

Based on the detailed comparative analysis the authors have offered the interpretation of similarities and differences between those two databases.

2.1. Objective method of identification of hazardous sites/spots

Objective method of identification of hazardous sites/spots is based on the analysis of traffic accidents and their consequences, and road and traffic characteristic. The research territory included the network of main roads (34 roads in the total length of 4,912 km) of Serbia in the period from 2002 to 2006. The following indicators were used in the process of identification of hazardous sites/spots:

- Collective risk of occurrence of accidents and their consequences (CR), which represents the number of accidents and their consequences per road kilometre. This indicator does not take into account a different traffic scope on certain road sections. During the study we identified the following 4 evaluation criteria:
  1. Corrected Collective Risk of Accidents - KRsn* (corrected by the gravity of accidents)

$$\text{KRsn*} = \frac{\sum_{i=1}^{G} PBSN*_i}{G \bullet L} \bullet \left(\frac{accidents*}{km*year} \right) \qquad (1)$$

$$\text{PBSN*} = (n_1*1+n_2*20+n_3*150)*(1+(POG/(LTP+TTP+POG)) \qquad (2)$$

where:

n_1 - number of traffic accidents with damaged,
n_2 - number of traffic accidents with injuries,
n_3 - number of traffic accidents with fatalities,
POG - number of fatalities,
TTP - number of seriously injuries,
LTP - number of light injuries,
G - number of years,
L - lengths of the section considered (km)
1, 20, 150-weight

2. Collective Risk of Casualties - KR_S (corrected by the gravity of consequences)

$$KR_S = \frac{\sum_{i=1}^{G} PBN_i}{G \bullet L} \bullet \left(\frac{casualties}{km*year}\right) \tag{3}$$

$$PBN = 1*LTP + 5*TTP + 50*POG \tag{4}$$

3. Collective Risk of the Fatal and Seriously Injured - KR_{P+TP}

$$KR_{P+TP} = \frac{\sum_{i=1}^{G} (POG+TTP)_i}{G \bullet L} \left(\frac{fatalities + seriouslyinjuries}{km*year}\right) \tag{5}$$

4. Collective Risk of the Fatal Injured - KR_P

$$KR_P = \frac{\sum_{i=1}^{G} \Pi O \Gamma}{G \bullet L} \left(\frac{fatalities}{km*year}\right) \tag{6}$$

- Individual risk of occurrence of accidents and their consequences (IR), which represents the number of accidents and their consequences per number of vehicle-kilometres at a given site. During the study we identified the following 4 evaluation criteria:

1. Corrected Individual Risk of Accidents - IRsn* (corrected by the gravity of accidents)

$$IRsn^* = \frac{\sum_{i=1}^{G} PBSN^*_i}{L \bullet 365 \bullet \sum_{i=1}^{\Gamma} AADT_i} \bullet 10^6 \left(\frac{accidents^*}{mill. \bullet vehicle \bullet km}\right) \tag{7}$$

where:

AADT - Average Annual Daily Traffic (vehicles per day),

2. Individual Risk of Casualties - IR_S (corrected by the gravity of consequences)

$$IR_S = \frac{\sum_{i=1}^{G} PBN_i}{L \bullet 365 \bullet \sum_{i=1}^{\Gamma} AADT_i} \bullet 10^6 \left(\frac{casualties}{mill. \bullet vehicle \bullet km}\right) \tag{8}$$

3. Individual Risk of the Fatal and Seriously Injured - IR_{P+TP}

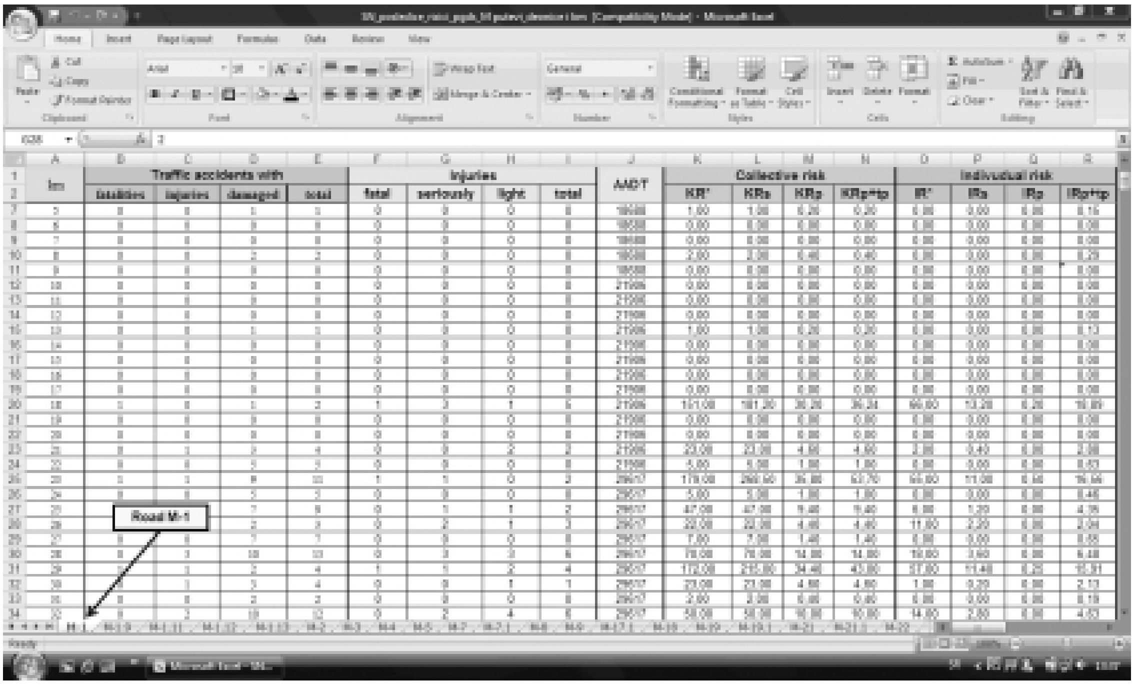
$$IR_{P+TP} = \frac{\sum_{i=1}^{G} (POG+TTP)_i}{L \bullet 365 \bullet \sum_{i=1}^{G} AADT_i} \bullet 10^6 \left(\frac{fatalities + seriously\ injuries}{mill. \bullet vehicle \bullet km}\right) \tag{9}$$

4. Individual Risk of the Fatal Injured - IR_P

$$IR_P = \frac{\sum_{i=1}^{G} POG_i}{L \bullet 365 \bullet \sum_{i=1}^{G} AADT_i} \bullet 10^6 \left(\frac{fatalities}{mill. \bullet vehicle \bullet km}\right) \tag{10}$$

The calculation followed the defining of evaluation parameters. All roads were divided into one-kilometre sections. Based on the data on traffic accidents and their consequences, each traffic accident and its consequences were “lowered down” onto the corresponding road and one-kilometre section (kilometre of the road). In such a way, the spatial distribution was defined and Tables were prepared (in MS Excel programme) for the basic data on accidents and casualties per one-kilometre road sections. The following basic data were determined for each kilometre: AADT, number of accidents with killed persons, number of accidents with injured persons, number of accidents with material damage, number of the killed persons, number of seriously injured and number of less seriously injured persons. Collective and individual risks of occurrence of traffic accidents and risks of casualties were calculated for all one-kilometre road sections (Figure 1).

Figure 1. The screen with the Table of one-kilometre sections with the basic data and calculated risks



2.2. Subjective method of identification of hazardous sites/spots

Subjective method of identification of hazardous sites/spots is based on the analyses of experts: representatives of road managers (Public Company “Putevi Srbije”), police officers and public road inspectors. The study was conducted in 2007 in several stages, as follows:

- The first step included the interviews with experts per regions aimed at identification of “black spot” candidates (potential black spots)
- The second, much more complex step in the process of identification of hazardous sites/spots, included verification of the noticed hazardous sites/spots by experts of the Traffic Safety Department, road managers and other stakeholders
- The third step included the setting up of a database on hazardous sites/spots on the public roads network. We used the basic GIS technology that relied on GPS co-ordinates of hazardous sites/spots and accompanying table and multi-media contents (photographs and video recordings). The outline of the database on hazardous sites/spots is available in two ways. The first is based on the basic GIS approach, via MapSourc programme, where the selection of the level of detailedness of the road network presentation is made according to one of the sixteen defined criteria as well as the final selection of the desired site/spot (Figure 2). The second is based on details of a hazardous site/spot created in MS Excel programme (Figure 3) containing the details of the hazardous site/spot. This is where the insight is possible into the existing photo and video documentation for the observed site/spot.

Figure 2. The MapSourc programme screen with one of the windows for the selected black spot

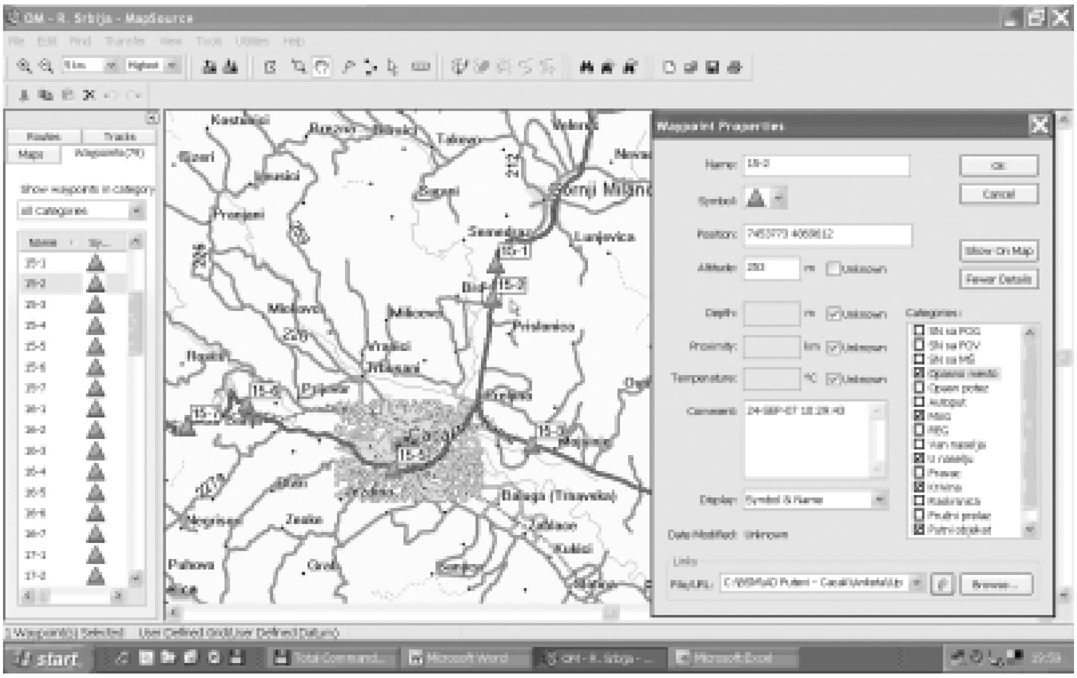
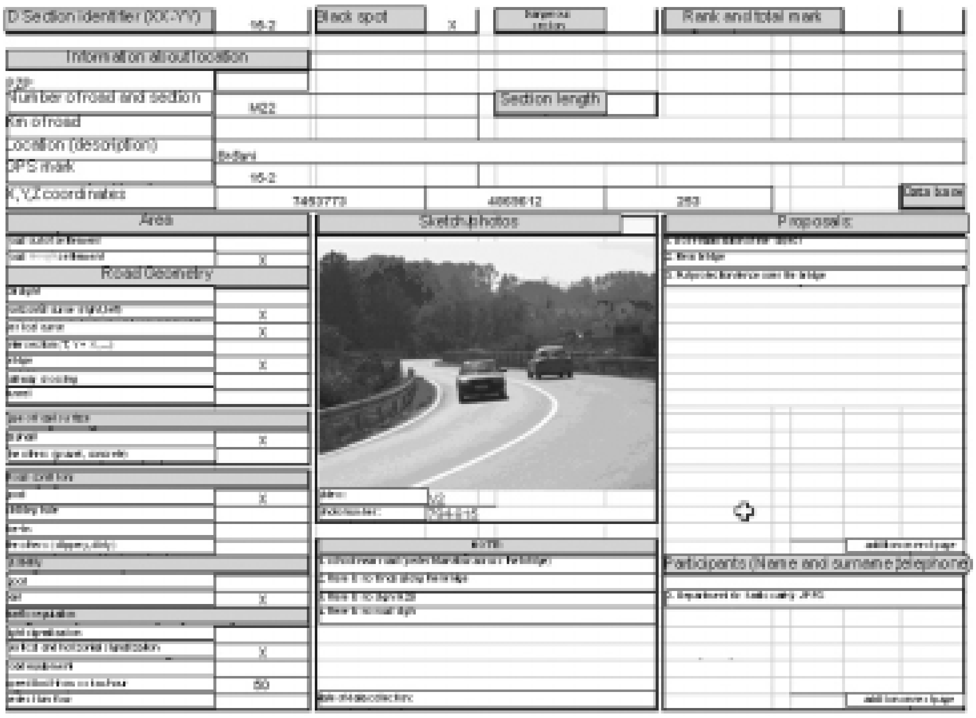


Figure 3. The MapSourc programme screen with the details connected with the selected black spot and the link for photo and video documentation



All the identified hazardous sites/spots (174 of them in total) have been classified into three categories, as follows:

- Rank I - hazardous site/spot with a very high risk of traffic accidents and high level of gravity of their consequences,
- Rank II - hazardous site/spot with a very high risk of traffic accidents and low level of gravity of consequences of the same, or vice versa, and
- Rank III - hazardous site/spot with a low risk of accidents and low gravity of consequences of the same.

3. THE MAIN RESEARCH RESULTS

The realised researches are very complex and voluminous. However, observing the limitations imposed in preparation of the present paper, the research results have been systematised and presented in short.

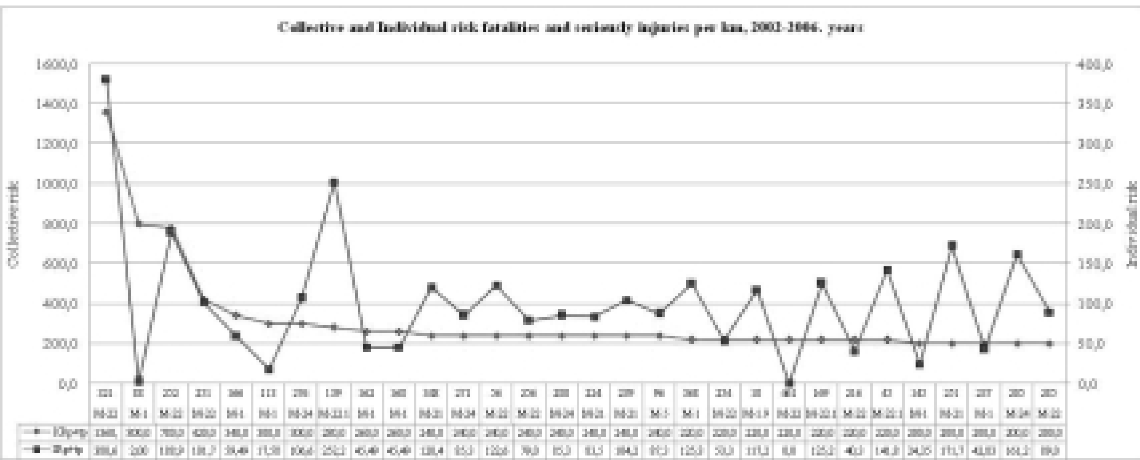
3.1. Hazardous sites/spots identified with objective method

This method was used to compile the rank list for all 4,912 one-kilometre sections according to the above-mentioned evaluation parameters. The kilometre sections were ranked separately for all four collective risk parameters (CR_C, CR_{K+SI}, CR_K, and CR_A^{C*}) with the belonging type of individual risk (IR_C, IR_{K+SI}, IR_K, and IR_{AC}*). For each of the above-mentioned parameters 30 riskiest kilometre sections were singled out (examples for CR_{K+SI}, and IR_{K+SI} were presented in Figure 4). A higher dispersion per risk type was expected due to a large number of the compared kilometre sections. However, despite this fact we can single out the kilometre sections that deviate significantly from all others, even from other ranked kilometres according to the size of collective risk, such as:

- The 321st km on the road M-22, which takes the first place according to the risk size under all risk parameters. It is also important to point out that the risk sizes for the subject kilometre section are quite higher in comparison to other kilometre sections that follow after it (about 58% higher number of the killed and seriously injured persons per 100 km of the road and about 90% higher number of the killed persons per 100 km of the road compared to the second ranked kilometre section),
- The 252nd km on the road M-22, which takes the second place according to the CR_C risk size and third place according to other ranked parameters,
- The 88th km on the road M-1, which takes the second place according to the CR_{K+SI}, and CR_{AC}* risk sizes, fourth place according to CR_C risk size, and 12th place according to CR_K risk size.

In addition to those kilometre sections, we could also single out the 348th km on the road M-21, and 166th km on the road M-1. The registered values of certain parameters are very high on those road sections and they belong among the most threatened kilometre sections. According to road classification, the structure of kilometre sections is quite homogenous. The ranked kilometre sections are located at 11 roads (M-1, M-22, M-21, M-24, M-7, M-22.1, M-24.1, M-1.9, M-5, M-4 and M-19). According to the number of most threatened kilometre sections, we can single out the roads M-1, 40 (33.3 %), M-22, 33 (27.5 %), M-21 17 (14.2 %) and M-24, with 12 (10.0 %) kilometre sections. It can be noticed that 85% of the ranked most hazardous kilometre sections are located on those four roads.

Figure 4. Collective (declining function) and individual risk of the killed and seriously injured persons per kilometres on the main roads (30 most threatened kilometre sections), Serbia, from 2002 to 2006



The riskiest hazardous sites/spots are presented on the risk maps, which represent the output result of the present study[12] (risk map for KR_{P+TP} was presented in Figure 8).

3.2. Hazardous sites/spots identified with subjective method

Having applied this method we identified 174 hazardous sites/spots, 57 (32.8%) of which belong to Rank I, 75 (43.1%) to Rank II and 42 (24.1%) to Rank III (Table 1).

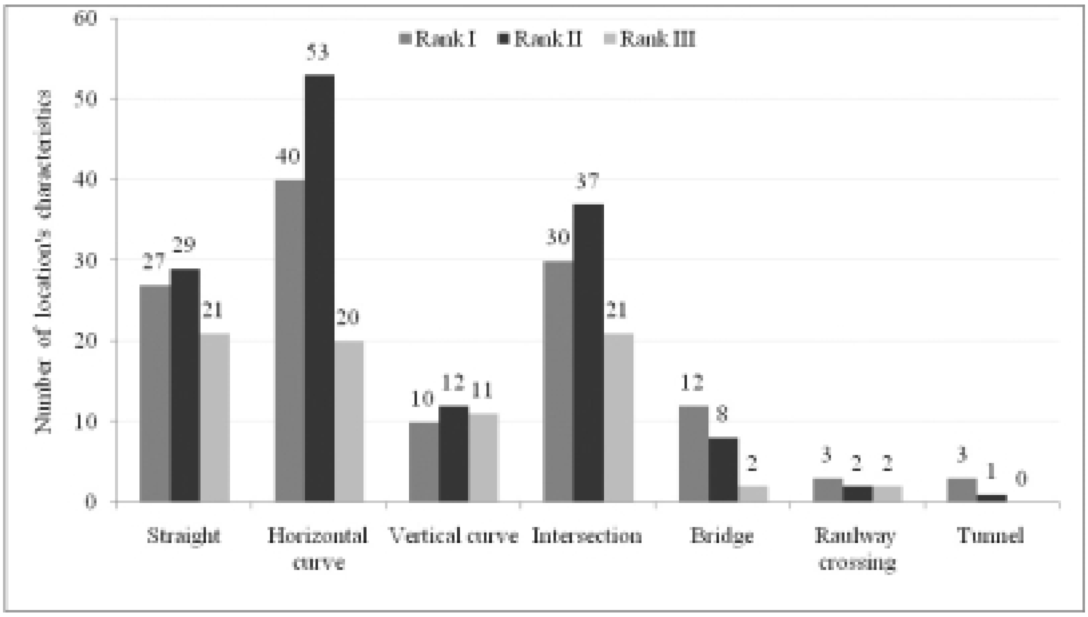
Table 1. Hazardous sites/spots on the main roads of Serbia identified with the subjective method

	Identified hazardous sites/spots	
	Number	%
Rank I	57	32,8
Rank II	75	43,1
Rank III	42	24,1
Total	174	100,0

During the field visit of the identified hazardous sites/spots, the most significant characteristics of hazardous sites/spots were noted, and structured, individually or in combination, according to the following elements: (1) straight, (2) horizontal curve, (3) vertical curve, (4) intersection, (5) bridge, (6) railway crossing, and (7) tunnel. Characteristics of the location of a hazardous site/spot are significant from the aspect of understanding the requests imposed in front of the participants in traffic, as well as of determining the risk size in traffic depending on the location type.

At 174 hazardous sites/spots, we registered 344 individual location characteristics in total. The largest share in their structure belongs to horizontal curves (113, or 32.8%), intersections (8, or 25.6%) and straight sections (77, or 22.4%), while the lowest share belongs to tunnels (4, or 1.2%) (Figure 5). Observing the above-mentioned elements on the road network, spatial distribution, and their length, the share of crossroads as hazardous sites/spots is evidently more significant compared to other elements. This can be explained by the fact that crossroads represent the sites where traffic flows intertwine and where the risk of occurrence of accidents is higher compared to other analysed characteristics.

Figure 5. Number of all registered characteristics of hazardous sites/spots sites according to the rank on the main roads

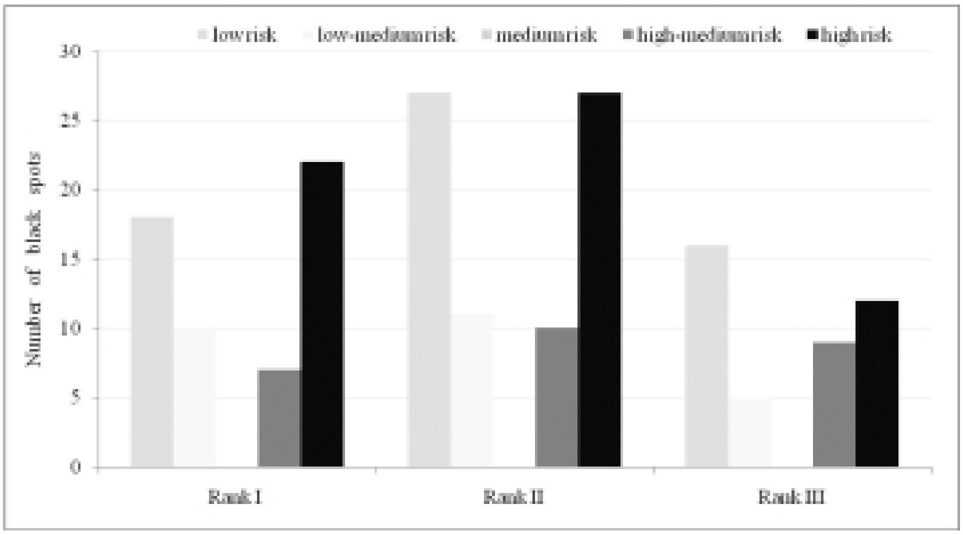


After the black spots have been identified and ranked, the road manager ordered the elaboration of 50 black spot analyses and treatments and started with their implementation at site.

3.3. Comparative analysis of the obtained results

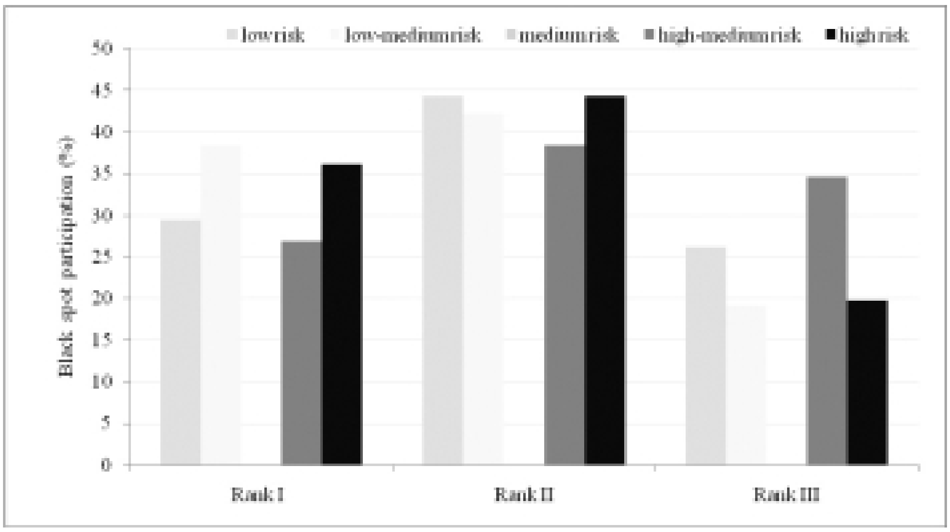
The distribution of hazardous sites/spots, which have been identified with the subjective method, has shown a significant differentiation in relation to hazardous sites/spots that have been identified with the objective method. All hazardous sites/spots (174), according to the subjective method, are distributed equally per kilometre sections (61 each) with a very low (green) and very high risk (black) (Figure 6). Higher matching between objective and subjective identification method has been accomplished for higher ranked hazardous sites/spots. This is also confirmed by the fact that 38.6% of hazardous sites/spots of Rank I are found at one-kilometre sections with a very high (black) risk, and 31.6% hazardous sites/spots are found at sections with a very low (green) risk, while 38.1% of hazardous sites/spots of Rank III are found at sections with a very low (green) risk, and 28.6% at kilometre sections with a very high (black) risk.

Figure 6. Distribution of the number of hazardous sites/spots according to the hazardous site/spot ranks and ranks of one-kilometre section that the relevant hazardous site/spot belongs to (according to KR_{P+TP})



At kilometre sections with a very high risk there are 36.1% of hazardous sites/spots of Rank I, 44.3% of hazardous sites/spots of Rank II and 19.7% of Rank III, while at kilometre sections with a very low risk there are 29.5% of hazardous sites/spots of Rank I, 44.3% of hazardous sites/spots of Rank II and 26.2% of Rank III (Figure 7).

Figure 7. Distribution of shares of certain hazardous sites/spots ranks according to one-kilometre sections that the relevant hazardous site/spot belongs to (percentage) (according to KR_{P+TP})



The following has been done for all hazardous sites/spots that have been identified with objective method:

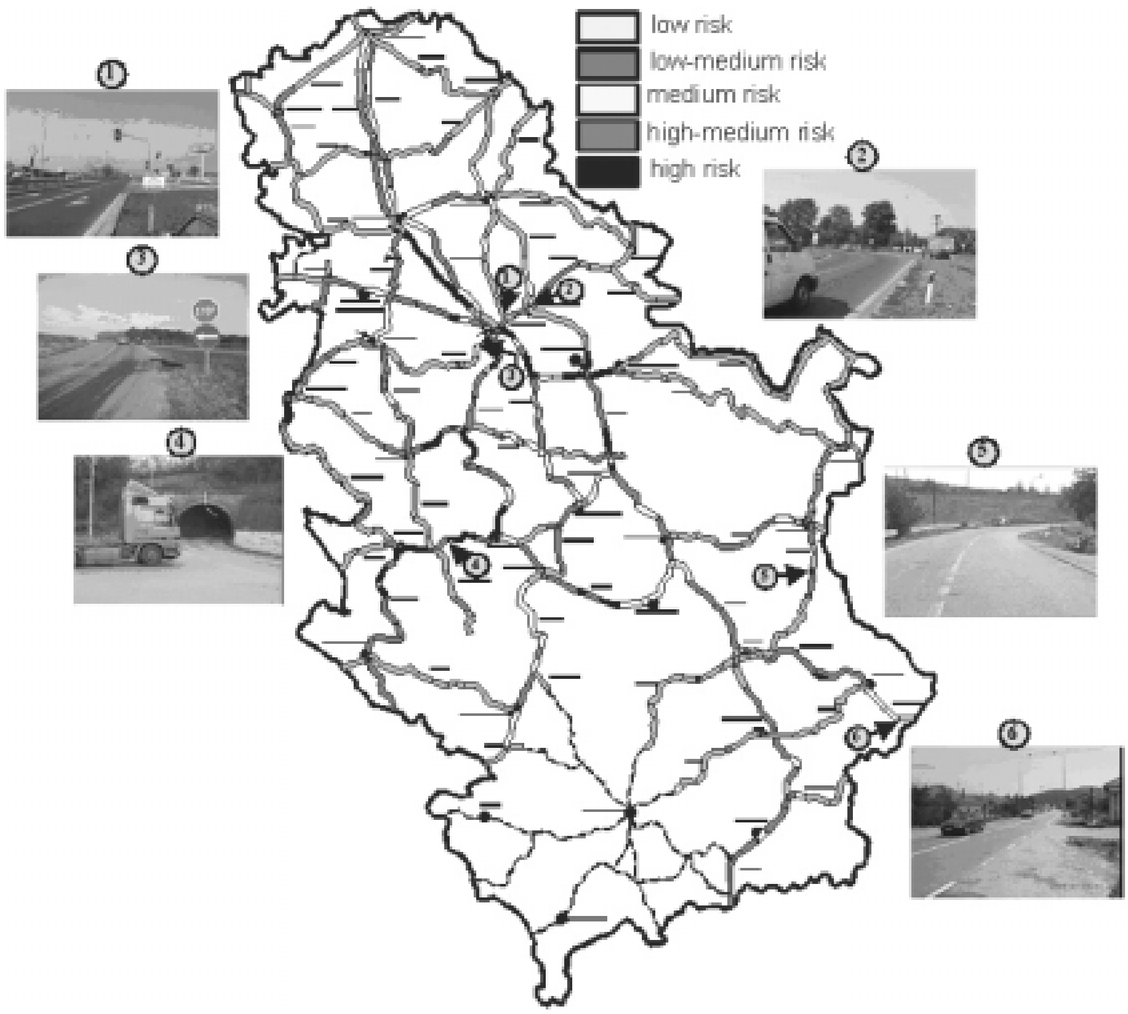
- Spatial distribution of the risk map
- Analysis of data on traffic accidents, their consequences and risks,
- Analysis of traffic safety problems.

The examples for six hazardous sites/spots of Rank I have been presented in Table 2 and Figure 8.

Table 2. Number of traffic accidents at hazardous sites/spots at green and black one-kilometre sections

	Black spot	Traffic accidents with (2002-2006.) fatalities	injuries	damages	total
at green one-kilometre sections	1	0	0	4	4
	2	0	1	5	6
	3	0	0	2	2
at black one-kilometre sections	4	0	8	21	29
	5	2	3	5	10
	6	1	7	24	32

Figure 8. Distribution of hazardous sites/spots that have been identified with objective method on the map risk (according to KR_{P+TP})



3.4. Discussion

The applied methods of identification, each within its field of application, are useful in identification of black spots on the roads and each of them has certain advantages and weaknesses. The interviewed experts identified certain hazardous sites/spots where no traffic accidents were registered for a longer period of time. It is the matter of sites/spots on the roads (bridges, tunnels, railroad crossings, horizontal and vertical curves, crossroads) that are well marked and where the risk in traffic is clearly visible for the drivers and other participants in traffic. Thus, most of those sites/spots are well marked (traffic signalisation and road furniture) and they are <<obviously>> dangerous so that drivers reduce speed significantly, intensify attention, and compensate in such a way for the risk against participation in traffic accidents. However, the level of services is significantly reduced at those sites/spots and it is necessary to conduct their thorough analysis. On the other hand, objective methods have singled out certain sites/spots that have not been recognised as hazardous by the interviewed experts. At most of those sites/spots the road conditions are <<good>> and there are no elements that would point to the drivers to the possibility of traffic accidents. Therefore, a significant number of accidents happen in certain situations in traffic due to fast driving and reduced attention. At such sites/spots, the drivers increase the risk of traffic accidents with their own conduct. The above-mentioned facts show that risk compensation is exceptionally significant factor that has to be taken into account in the process of black spots management.

Based on the previous analysis, the authors have identified the following most significant advantages of the described subjective method of identification of black spots:

- The results are obtained very fast,
- Simple application,
- It is acceptable in conditions of poor available data, namely low quality data on traffic accidents,
- It i It stimulates co-ordination and co-operation in the work of different stakeholders in traffic safety.

The main weaknesses of this method are reflected in the following:

- The quality depends on expertise and commitment of the interviewed experts,
- The interviewed experts recognise equally the sites of elevated risk (where there are a lot of traffic accidents) and sites of a reduced service level (where no accumulation of traffic accidents has been registered due to the risk compensation),
- They do not identify some very dangerous sites on the roads; in particular, they do not identify hazardous sections where the above average number of accidents happens under good road conditions.

The shortcomings/weaknesses that have been found could be overcome through: (1) better training and preparation of participants in interviews, (2) informing the interviewed with the actual number of traffic accidents, (3) better selection of persons to be interviewed, (4) multi-phased interviewing.

Despite loud denial within the recent years, the objective identification method has been widely applied in many countries. The main characteristics of this method include the fact that traffic accidents are still considered the best indicator of black spots on the roads, although the results of the analyses depend on the quantity and quality of the database, which is based on police reports. If the reports on traffic accidents or their consequences are incomplete, the reliability of the obtained results can be highly disputable, which can affect the accuracy of identification of black spots on the roads.

4. CONCLUSION

The fact that identification methodology of black spots has still not been harmonised at the global level points to the significance of further development and improvement of identification methods of black spots in order to determine the sites causing the occurrence of the higher risk on the roads in the most realistic way possible. The conducted researches in the process of identification of black spots on the roads in Serbia enable an organised and system acting of the road managers aimed at reduction of negative impact of the road on occurrence and consequences of traffic accidents. In addition to setting of the database on hazardous sites/spots on the roads, which represents the basis for BSM, another special contribution has been accomplished. It has been accomplished in the field of improvement and integration of joint acting of the competent institutions, primarily of road managers, traffic police, public road inspectors, supervision departments and road companies related to identification of hazardous sites/spots, on the one hand, and scientific workers from the University, on the other hand. This has contributed significantly to setting up of an efficient BSM system on the roads of Serbia.

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Poster Presentations