XVII International Symposium
"ROAD ACCIDENTS PREVENTION 2026"
Novi Sad, Serbia, 14th and 15th October 2026.

https://doi.org/10.68515/RAP.2026.17.31

APPLICATION OF THE METHODOLOGY FOR IDENTIFYING BLACK SPOTS (HAZARDOUS LOCATIONS) WITHIN THE TERRITORY OF THE CITY OF NIŠ

Jovan Mišić[a*], Aleksandar Trifunović[b] Dušan Radosavlljević[c]
[a]Akademija tehničko-vaspitačkih strukovnih studija, Aleksandra Medvedeva 20, Niš, Srbija, jovan.misic@akademijanis.edu.rs, https://orcid.org/0009-0004-5373-3109
[b]CeS.TRA d.o.o., Mekenzijeva 57/VI sprat, Beograd, Srbija, trifunovic.a@gmail.com
[c]Akademija tehničko-vaspitačkih strukovnih studija, Aleksandra Medvedeva 20, Niš, Srbija, dusan.radosavljevic@akademijanis.edu.rs

Abstract: The identification and analysis of locations with an elevated risk of traffic accidents represent one of the most important activities in the process of road infrastructure safety management. This paper presents the application of a methodology for the identification and ranking of black spots (hazardous locations) on the network of municipal roads and streets in the City of Niš, in accordance with the provisions of the Rulebook on the Methodology for Determining High-Risk Road Sections and the Identification and Ranking of Hazardous Locations (Official Gazette of the Republic of Serbia, No. 68/2019). The methodological procedure included the collection and processing of traffic accident data, statistical analysis of road safety indicators, identification of locations with an above-average level of risk, their ranking according to predefined criteria, and the implementation of road safety inspections at the identified hazardous locations. Based on the analyses conducted, the predominant road safety issues were identified, and targeted infrastructural, organizational, and regulatory measures were proposed to improve traffic safety. The research findings provide a professional and analytical basis for decision-making in the field of road infrastructure management, the prioritization of investments, and the implementation of measures aimed at the systematic reduction of both the number and severity of traffic accidents within the territory of the City of Niš. The application of the proposed methodology confirms the importance of a proactive approach to the identification and treatment of high-risk locations, thereby contributing to the improvement of the overall level of road safety in an urban environment.

Keywords: Black Spots, Hazardous Road Locations, Road Infrastructure Safety Management.

1. INTRODUCTION

The modern approach to road safety unequivocally indicates that road safety can be effectively managed and that traffic accidents are generally not random events, but rather the consequence of insufficient organized and systematic action addressing the fundamental factors that influence road safety.

The primary objective of road safety management is to reduce both the risk of traffic accidents occurring and the severity of their consequences. However, other adverse impacts associated with road transport should not be overlooked.

* Tel:+38169770993; e-mail address: jovan.misic@akademijanis.edu.rs (J. Mišić).

During the twenty-year period from 2003 to 2023, a total of 25,947 traffic accidents occurred on the road network of the City of Niš. Of these, 289 were fatal accidents, while 8,483 resulted in injuries. In the five-year period from 2019 to 2023, a total of 4,475 traffic accidents were recorded, including 1,973 accidents involving casualties.

Within the aforementioned period, traffic accidents on the territory of the City of Niš resulted in 70 fatalities and 2,634 persons sustaining serious or minor injuries. Among these casualties, 3 children were killed and 206 children were injured. Furthermore, 9 young persons lost their lives, while 801 young persons were injured. In the same period, 31 persons aged 65 years and older were killed, and 325 persons from this age group sustained injuries. These figures represent an unacceptable human and economic loss.

Traffic accidents occurring daily within the territory of the City of Niš contribute to an increased risk of road casualties and simultaneously constitute a significant economic, social, public health, and developmental challenge.

This paper applies a black spot identification and management methodology. First, a comprehensive analysis of traffic accidents was conducted for the period from 2021 to 2023. Based on the obtained results, potential hazardous locations within the territory of the City of Niš were identified. Subsequently, hazardous locations were defined and ranked according to the established methodology.

2. BLACK SPOT MANAGEMENT AND IDENTIFICATION

Black Spot Management is one of the oldest tools used in road infrastructure safety management. It belongs to the so-called reactive approach to road safety improvement, based on the principle that a problem is identified and addressed only after an undesirable event has occurred, namely after traffic accidents have taken place.

The procedure for the identification and management of black spots is internationally recognized as Black Spot Management (BSM). This tool is primarily intended for road authorities and road infrastructure managers, with the objective of eliminating or reducing the contribution of road and roadside environment factors to the occurrence and severity of traffic accidents.

According to the Norwegian road safety expert Rune Elvik, Black Spot Management consists of the following activities (Elvik, 2008):

- Definition and identification of black spots on road networks;
- Analysis of traffic accidents and risk factors at hazardous locations, with the aim of identifying contributory factors, particularly those related to road infrastructure and the road environment, that influence the occurrence of traffic accidents, as well as proposing appropriate treatment measures for the remediation of identified black spots and
- Implementation and evaluation of the applied treatments at hazardous locations to assess their effectiveness in improving road safety.

In the Republic of Serbia, the Law on Roads (Official Gazette of the Republic of Serbia, Nos. 41/2018, 95/2018 - other law, and 92/2023 - other law), within Article 90, stipulates that road authorities are obligated to carry out projects for the identification and ranking of hazardous locations (black spots). Specifically, managers of state roads are required to conduct such analyses at least once every three years, while managers of municipal roads and urban streets must perform them at least once every five years.

For the highest-risk hazardous locations, the public road authority is required to undertake a detailed assessment of road safety issues and implement appropriate measures aimed at mitigating the identified risks.

In addition to the Law on Roads, the procedure for the identification and ranking of hazardous locations (black spots), as well as the composition of the expert team responsible for black spot identification, is further regulated by the Rulebook on the Method of Determining High-Risk Road Sections and the Identification and Ranking of Hazardous Locations, the Composition of the Expert Team for Risk Mapping and the Identification and Ranking of Hazardous Locations, and the Requirements for Members of Such Teams (Official Gazette of the Republic of Serbia, No. 68/2019).

For the purposes of identifying and ranking hazardous locations (black spots), data on traffic accidents and the consequences of traffic accidents occurring on the road and street network are utilized.

The required traffic accident database includes information on:

- The type of traffic accident;
- The coordinates, i.e., the exact location of the traffic accident;
- The contributing factors that led to the occurrence of the traffic accident;
- The accident collisin type;
- The specific road location where the accident occurred;
- The area in which the accident occurred, i.e., within a built – up area (urban area) or outside a built – up area (rural area).

The methodology for the identification of black spots (hazardous locations) is illustrated in Figure 1.

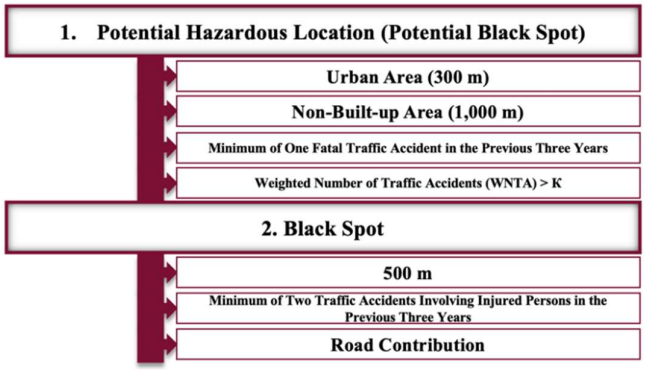


Figure 1. Methodology for the Identification of Black Spots (Hazardous Locations)

3. ANALYSIS OF TRAFFIC ACCIDENTS

According to the groups of contributing factors associated with the occurrence of traffic accidents, the following categories can be identified:

- Improper execution of driving maneuvers by drivers;
- Drivers undertaking inappropriate or ill-considered actions;
- Pedestrian-related errors and omissions;
- Driver errors resulting from impaired psychophysical condition, inattention, or distraction;
- Driver errors caused by inadequate visibility, restricted sight distance, or an insufficient perception of the road and traffic environment;
- Driver errors resulting from lack of experience, inappropriate behavior, or violations of traffic regulations, and
- Road and roadside environmental factors.

Based on the available database of the Road Traffic Safety Agency, an analysis was conducted on the territory of the City of Niš to determine the contribution of different groups of influencing factors to the occurrence of traffic accidents on major urban roads, minor urban roads, local roads, and unclassified roads during the period from 2021 to 2023. The results of the analysis are presented in Table 1.

Table 1. Groups of Contributing Factors to Traffic Accident Occurrence on Major Urban Roads, Minor Urban Roads, Local Roads, and Unclassified Roads within the Territory of the City of Niš during the Period 2021-2023

Groups of Contributing Factors	Traffic Accidents with Fatalities	Traffic Accidents Involving Seriously Injured	Traffic Accidents Resulting in Minor Injuries	Total Number of Traffic Accidents
Improper execution of driving maneuvers by drivers	8	73	423	504
Drivers undertaking inappropriate or ill-considered actions	41	228	1380	1649
Pedestrian-related errors and omissions	9	37	130	176
Driver errors resulting from impaired psychophysical condition, inattention, or distraction	5	35	180	220
Driver errors caused by inadequate visibility, restricted sight distance, or an insufficient perception of the road and traffic environment	0	3	16	19
Driver errors resulting from lack of experience, inappropriate behavior, or violations of traffic regulations	0	3	38	41
Road and roadside environmental factors	**2**	**7**	**48**	**57**

Based on the analysis of contributing factor groups, it is evident that the factor group related to drivers undertaking inappropriate or ill-considered actions was the most dominant. This group accounted for 63.08% of all fatal traffic accidents, 59.07% of traffic accidents resulting in serious injuries, and 62.30% of traffic accidents resulting in minor injuries.

The factor group associated with road and roadside environmental conditions accounted for 3.08% of fatal traffic accidents, 1.81% of traffic accidents involving serious injuries, and 2.17% of traffic accidents involving minor injuries.

In addition to the analysis of contributing factor groups, a detailed examination was conducted of the number of fatal traffic accidents and injury-related traffic accidents for which specific contributing factors were identified:

- Slippery pavement conditions caused by adverse weather conditions;
- Poorly maintained or inadequately maintained pavement surfaces;
- Lack of bicycle paths or bicycle lanes within built-up areas;
- Absence of sidewalks within built-up areas;
- Inadequate, missing, or insufficiently visible traffic signs, road markings, or roadside equipment, and
- The impact of traffic-calming measure.

The results of the analysis of contributing factors influencing the occurrence of traffic accidents on major urban roads, minor urban roads, local roads, and unclassified roads within the territory of the City of Niš during the period from 2021 to 2023 are presented in Table 2.

Table 2. Contributing Factors to Traffic Accident Occurrence on Major Urban Roads, Minor Urban Roads, Local Roads, and Unclassified Roads within the Territory of the City of Niš during the Period 2021-2023

Contributing Factors	Traffic Accidents with Fatalities	Traffic Accidents Involving Injured	Total Number of Traffic Accidents
Slippery pavement conditions caused by adverse weather conditions	0	16	16
Poorly maintained or inadequately maintained pavement surfaces	1	4	5
Lack of bicycle paths or bicycle lanes within built-up areas	0	1	1
Absence of sidewalks within built-up areas	0	1	1
Inadequate, missing, or insufficiently visible traffic signs, road markings, or roadside equipment	0	9	9
The impact of traffic-calming measure	0	1	1

When analyzing the contributing factors within the factor group related to road and roadside environmental conditions on major urban roads, minor urban roads, local roads, and unclassified roads within the territory of the City of Niš during the period from 2021 to 2023, it is evident that slippery pavement conditions caused by adverse weather circumstances were the most significant contributing factor, being identified in 16 traffic accidents involving injured persons.

Furthermore, inadequate, missing, or insufficiently visible traffic signs, road markings, or roadside equipment were identified as contributing factors in 9 traffic accidents involving injured persons.

Of particular concern is the finding that poorly maintained or inadequately maintained pavement surfaces were identified as a contributing factor in one fatal traffic accident and four traffic accidents involving injured persons. Such findings highlight the importance of continuous road maintenance and infrastructure management as essential components of road safety improvement measures.

4. DEFINITION OF THE LIST OF POTENTIAL HAZARDOUS LOCATIONS

For the purpose of identifying hazardous locations (black spots), potential hazardous locations (potential black spots) are first determined, representing the so-called first level of black spot identification in the Republic of Serbia.

Pursuant to Article 8 of the Rulebook on the Method of Determining High-Risk Road Sections and the Identification and Ranking of Hazardous Locations, the Composition of the Expert Team for Risk Mapping and the Identification and Ranking of Hazardous Locations, and the Requirements for Members of Such Teams (Official Gazette of the Republic of Serbia, No. 68/2019), a potential hazardous location (potential black spot) is defined as any road section with a maximum length of 300 m in urban areas or 1,000 m in rural areas where at least one fatal traffic accident occurred during the previous three calendar years and where the weighted number of traffic accidents (WNTA) over the same period exceeds the threshold value of k = 96.

According to the methodology for the final identification of hazardous locations (black spots) on state roads in the Republic of Serbia, the current threshold value of the weighted number of traffic accidents is set at k = 96. In practical terms, this corresponds to the occurrence of one fatal traffic accident, one traffic accident involving a seriously injured person, and one traffic accident involving a slightly injured person.

The weighted number of traffic accidents (WNTA) for a potential hazardous location (potential black spot) is calculated by multiplying the number of traffic accidents by weighting factors assigned according to the severity of accident consequences. The weighting coefficients are assigned values of 1, 10, and 85, respectively. The formula is as follows:

$$WNTA = N_{mi} \cdot 1 + N_{si} \cdot 10 + N_F \cdot 85 \quad (1)$$

A weighting factor of 1 is assigned to traffic accidents in which the most severe consequence is a minor injury, a weighting factor of 10 is assigned to traffic accidents in which the most severe consequence is a serious injury, while a weighting factor of 85 is assigned to fatal traffic accidents. Table 3 presents the list of potential hazardous locations (potential black spots) identified on major urban roads, minor urban roads, local roads, and unclassified roads within the territory of the City of Niš for the period from 2021 to 2023.

Table 3. List of Potential Hazardous Locations (Potential Black Spots) within the Territory of the City of Niš

Potential Hazardous Location (Potential Black Spot)	Urban / Rural Area	Traffic Accidents with Fatalities	WNTA
1. Ledena Stena (Intersection of Aleksa Nenadovića Street and Sumitrija Tucovića Street)	Urban	1	130
2. City Centre (Intersection of Generala Milojka Lešjanina Street and Davidova Street)	Urban	1	107
3. City Centre (From the Ambasador Hotel to the Basic Court, along Vožda Karađorđa Street)	Urban	1	115
4. Main Bus Station (From the intersection of Šumatovačka Street and 12 February Boulevard to the Main Bus Station)	Urban	1	121
5. Beginning of Nemanjića Boulevard (Intersection of 7. Juli Street and Cvijićeva Street)	Urban	1	105
6. Primary Health Care Centre (Along Vojvode Mišića Street, from the intersection with Jovana Skerlića Street to the Fire Station)	Urban	1	114
7. Crveni Pevac Intersection (Approach via Dr Zoran Đinđić Boulevard)	Urban	2	180
8. City Hospital (From the intersection of Dr Zoran Đinđić Boulevard and Zetska Street to the Pasteur Institute)	Urban	1	102
9. Stop Shop Retail Zone (From the access road to the NIS Petrol Station to the access road to the Wholesale Market, along Boulevard of Saint Emperor Constantine)	Urban	2	185
10. Saint Sava Park 1 (Roundabout at the intersection of Nemanjića Boulevard, Sremska Street, and Vizantijski Boulevard))	Urban	1	100
11. Saint Sava Park 2 (From the intersection of Vizantijski Boulevard and Branka Krsmanovića Street to the bridge over the Gabrovačka River)	Urban	1	100
12. Pantelej (Intersection of Somborski Boulevard and Despot Đurađ Street)	Urban	1	98
13. Durlan (Intersection of Knjaževačka Street and Ilije Birčanina Street)	Urban	1	140
14. Brzi Brod (Intersection of Boulevard of Saint Emperor Constantine and Dušana Spasića Street)	Urban	1	98

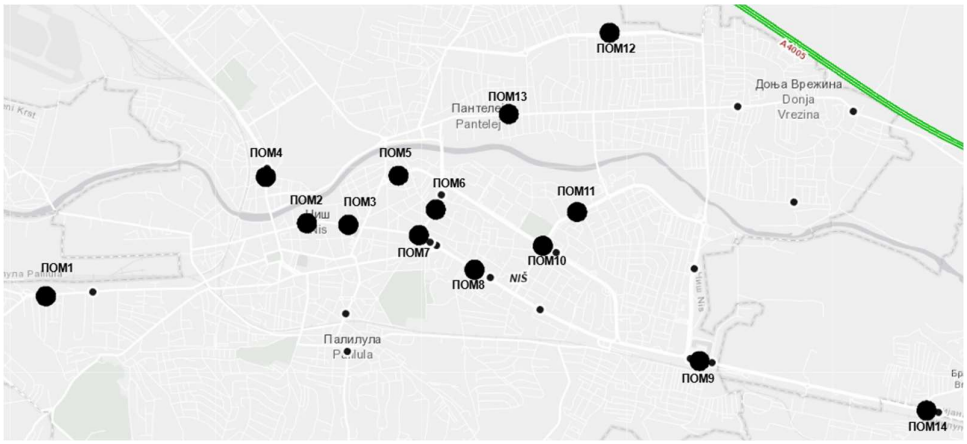


Figure 2. Spatial Distribution of the 14 Identified Hazardous Locations within the Territory of the City of Niš

5. DEFINITION OF FINAL BLACK SPOTS

Based on Article 9 of the Rulebook on the Method of Determining High-Risk Road Sections and the Identification and Ranking of Hazardous Locations, the Composition of the Expert Team for Risk Mapping and the Requirements for Team Members (Official Gazette of the Republic of Serbia, No. 68/2019), the identification of hazardous locations (black spots) is carried out on the basis of previously identified potential hazardous locations (potential black spots).

The maximum length of a road segment that may be classified as a hazardous location (black spot) is 500 m. A circular zone with a diameter of 500 m is established around each fatal traffic accident occurring on the observed road or street section. In cases where no fatal traffic accidents with identified road-related contributory factors are recorded on the analyzed road or street network, the circular zone may instead be established around a traffic accident involving serious injuries.

In order for a road or street segment to be identified as a hazardous location (black spot), at least two traffic accidents involving injured or deceased persons must be identified within the defined circular zone, where the road infrastructure or road environment was recognized as a contributing factor to the occurrence of the accident or to the severity of its consequences.

The contribution of the road and roadside environment to the occurrence or consequences of traffic accidents is identified on the basis of relevant accident characteristics contained in the Traffic Accident Database, including data related to:

1. The contributing factor group road and roadside environment factor, as well as contributing factors from other gropups that may be associated with the influence of the road and roadside environment;
2. The specific location of the traffic accident;
3. The category of “single-vehicle traffic accidents”;
4. Fatal traffic accidents that occurred at intersections, etc.

The identification of hazardous locations (black spots) is carried out on the basis of the calculated Weighted Number of Traffic Accidents (WNTA) within the defined circular zone on the observed road or street where at least two traffic accidents involving a recognized road-

related contributory factor have been identified. The WNTA is calculated by multiplying the number of fatal traffic accidents by a weighting factor of 85, the number of traffic accidents involving serious injuries by a weighting factor of 10, and the number of traffic accidents involving minor injuries by a weighting factor of 1.

The calculated WNTA values for the circular zone on the observed road or street are then compared with the established threshold value of the weighted number of traffic accidents (k). The threshold value is defined as k = 96.

If the calculated WNTA is equal to or greater than the threshold value ($k \geq 96$), the circular zone with a diameter of 500 m is identified as a hazardous location (black spot). Otherwise, the circular zone is not established, and the analyzed location is not classified as a hazardous location (black spot).

In order to identify hazardous locations, that is, the final black spots, all potential hazardous locations were ranked according to their WNTA values. The ranking of potential hazardous locations within the territory of the City of Niš is presented in Table 4.

Table 4. Ranking of Potential Hazardous Locations (Potential Black Spots) within the Territory of the City of Niš

Potentially dangerous location – black spot	Rank	Potential Hazardous Location (Potential Black Spot)	WNTA
Stop Shop Retail Zone (From the access road to the NIS Petrol Station to the access road to the Wholesale Market, along Boulevard of Saint Emperor Constantine)	1	WNTA 9	185
Crveni Pevac Intersection (Approach via Dr Zoran Đinđić Boulevard)	2	WNTA 7	180
Durlan (Intersection of Knjaževačka Street and Ilije Birčanina Street)	3	WNTA13	140
Ledena Stena (Intersection of Aleksa Nenadovića Street and Sumitrija Tucovića Street)	4	WNTA 1	130
Main Bus Station (From the intersection of Šumatovačka Street and 12 February Boulevard to the Main Bus Station)	5	WNTA 4	121
City Centre (From the Ambasador Hotel to the Basic Court, along Vožda Karađorđa Street)	6	WNTA 3	115
Primary Health Care Centre (Along Vojvode Mišića Street, from the intersection with Jovana Skerlića Street to the Fire Station)	7	WNTA 6	114
City Centre (Intersection of Generala Milojka Lešjanina Street and Davidova Street)	8	WNTA 2	107
Beginning of Nemanjića Boulevard (Intersection of 7. Juli Street and Cvijićeva Street)	9	WNTA 5	105
City Hospital (From the intersection of Dr Zoran Đinđić Boulevard and Zetska Street to the Pasteur Institute)	10	WNTA 8	102
Saint Sava Park 1 (Roundabout at the intersection of Nemanjića Boulevard, Sremska Street, and Vizantijski Boulevard))	11	WNTA 10	100

Potentially dangerous location – black spot	Rank	Potential Hazardous Location (Potential Black Spot)	WNTA
Saint Sava Park 2 (From the intersection of Vizantijski Boulevard and Branka Krsmanovića Street to the bridge over the Gabrovačka River)	12	WNTA 11	100
Pantelej (Intersection of Somborski Boulevard and Despot Đurađ Street)	13	WNTA 12	98
Brzi Brod (Intersection of Boulevard of Saint Emperor Constantine and Dušana Spasića Street)	14	WNTA 14	98

Following a comprehensive analysis of each potential hazardous location based on the Integrated Traffic Accident Database of the Road Traffic Safety Agency, supplemented by detailed field investigations, a final assessment of the identified potential hazardous locations was carried out. Based on the obtained results, the following locations were classified and ranked as hazardous locations (black spots):

1. Durlan (Intersection of Knjaževačka Street and Ilije Birčanina Street) – WNTA 13;
2. Ledena Stena (Intersection of Aleksa Nenadovića Street and Sumitrija Tucovića Street) – WNTA 1;
3. Primary Health Care Centre (Along Vojvode Mišića Street, from the intersection with Jovana Skerlića Street to the Fire Station) – WNTA 6 and
4. City Centre (Intersection of Generala Milojka Lešjanina Street and Davidova Street)– WNTA 2.

6. CONCLUSION

Road safety represents one of the fundamental prerequisites for sustainable urban development and the quality of life of the population. In this context, the application of the black spot identification methodology, namely the identification of hazardous locations within the territory of the City of Niš, has proven to be a significant tool for the systematic recognition of locations with an increased risk of traffic accident occurrence.

The conducted analysis confirmed that the application of standardized criteria and objective indicators enables the reliable identification of spatial concentrations of traffic accidents, as well as the ranking of locations according to their risk level and the need for intervention. The identified hazardous locations indicate the existence of certain deficiencies in road infrastructure that may increase both the likelihood of traffic accidents and the severity of their consequences.

The results of this study demonstrate that the timely identification and analysis of black spots provide a sound basis for the implementation of effective road safety improvement measures. Such measures may include the reconstruction of intersections, improvements to vertical and horizontal traffic signage and road markings, modifications to traffic management schemes, enhancement of facilities for pedestrians and cyclists, and the application of modern traffic management technologies.

A particularly important advantage of this methodology lies in its ability to support the rational allocation of limited financial resources to locations where the greatest reductions in traffic accidents and their consequences can be achieved. In this way, the process of planning

and implementing road safety measures is provided with a clear analytical and professional foundation.

It can be concluded that the continuous application of the black spot identification methodology within the territory of the City of Niš is an essential prerequisite for effective road safety management. Regular monitoring of road safety conditions, continuous updating of traffic accident databases, and periodic reviews of identified hazardous locations will enable timely interventions by the competent authorities and contribute to achieving the strategic objective of reducing the number of fatalities and injuries in road traffic, thereby creating a safer transportation system for all road users.

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