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Research Article

Identification and Prioritization of "Black Spots" without Using Accident Information

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It is attempted to identify and prioritize the accident prone points (black spots) in "Iraanshahr-Sarbaaz-Chabahar" road located in Baluchistan, Iran, without no use of accident data but rather using Analytic Hierarchy Process (AHP), which is the enhanced procedure of road safety audit technique. First, by surveying the whole route, all factors that could influence accidents in this road were specified; then the route was divided into eight sections; this division was performed based on the uniformity and homogeny of each section in terms of geometric design and regional conditions. In each section, potentially hazardous locations were identified and some questionnaires were prepared, which were filled by 5 road traffic experts familiar with the route; then the collected data were analyzed by Analytical Hierarchy Process (AHP) using Expert Choice Software and the black spots were identified and prioritized. Finally, these black spots were compared with the black spots that had been obtained by traffic police based on accident data.

1. Introduction

Based on the latest estimation by World Health Organization [1], about 1.25 million people were killed due to road accident injuries, with another 20–50 millions of individuals being physically disabled as a result of road incidents. Road accidents are known as the 9th major cause of mortality among 15–29-year-old individuals all over the world, with more than 60% of the road casualties happening to 15–44-year-old individuals. While the number of registered vehicles during 2000–2013 has increased by 90%, road fatalities have been less significant. Interventions to improve road conditions have largely contributed into road safety and reduced road fatalities throughout the world. During 2010–2013, a number of 79 countries have succeeded to reduce their count of road casualties, indicating the feasibility to improve road conditions to save many people's lives.

Based on WHO statistics, in 2012, road fatalities are the third cause of death in Iran following ischemic heart disease and stroke; and since road casualties and associated physical disabilities impose a large economic cost on governments, road modification and improvement can be considered as highly justified. The locations along a road where highest number of accidents occur are called black spots. Identification and modification of these spots can contribute into reducing number of the accidents.

Analytic Hierarchy Process method has been extensively used in a large number of road safety researches and so many researches have been done in order to identify accident prone locations. For instance, Agarwal et al. [2] suggested a method for ranking black spots using AHP. Their method presents a four-step ranking approach for black spots wherein no accident information is used. Borsos et al. [3] compared the ranking of black spots in Italy and Hungary and have

Figure 1: The Iraanshahr-Sarbaaz-Chabahar road.

introduced the methods and performances that are employed in Italy and Hungary for identifying and prioritizing the black spots. Machado et al. [4] studied black spots for vulnerable users of the road including cyclists and pedestrians in Brazil and Italy. The paper addresses spots and areas defined by the severity of road accidents measured by fatalities and injuries in a developing country (Brazil) as well as a developed one (Italy). In order to characterize black spots, Chen [5] used GIS via spatial analysis. In his study, it was discussed how to implement geographical coordination technology in order to record accidents with geographical information attached, and the relation between black spots and traffic features is used analyzing factors affecting the accidents. Isen et al. [6] used GIS to identify and analyze black spots. Shabiraliyani et al. [7] investigated a black spot in Ghazi-Khan Valley in Pakistan. They aimed to study effects of associated risks with road traffic on society and the factors contributing to the occurrence of the accidents at the Ghazi-Khan Valley. In their study, it was shown that human mistakes are the largest cause of the road accidents and in more than 80% of accidents in Pakistan, drivers' mistakes ended up with serious injuries. Nguyen et al. [8] identified black spots based on saving road costs. Rouhi and Behzadi [9] prioritized four conventional methods, based on frequency, rate, severity, and rate-severity, and proposed a hybrid method using AHP. La Torre et al. [10] used crash modification factors in order to form an accident prediction model that could be applied to different road networks in Europe. Reshma and Sharif [11] presented a method in which the accident analysis includes ranking of some major black spots using ARC GIS 10 software package. This research studied some major accident spots in South Bangalore, Karnataka in India. Sadeghi et al. [12] proposed a new method for affecting environmental traffic and geometric features to identify black spots and for road safety performance evaluation Bao et al. [13] discovered a hierarchical fuzzy topsis as a support system for promising intelligent decision which can be used to enable taking the hierarchical structure of indicators into account and it was more suitable in combining layered road safety performances indicators into one total index. The main purpose's research of Randhawa et al. [14] is to excavate appropriate accident data to evaluate the validity of the OOS criteria as related to commercial vehicles by using a two-phase project that analyzed the commercial vehicle safety alliance's out of service criteria for vehicles. Barić et al. [15] used AHP model in order to rate road section design to enhance the quality of decision-making enterprises in transport infrastructure. Sufian et al. [16] presented a study on fault and deficiencies of Bangladesh transportation system by analyzing some major elements including pedestrians, none motorized vehicles, and heavy vehicles.

Identification and modification of black spots are necessary in order to have a safe road. However, a large number of methods proposed for identification of the black spots require accident data and since the information is time-consuming and casualty-intensive to acquire, it can be very beneficial to present a method which can identify the black spots within a short time, so as to reduce the fatalities and achieve safe roads.

2. Research Methodology

The methodology used in the present paper is a modified version of road safety audit technique. Road safety audit technique is a field study of an existing road or one under construction or a traffic project or any other project which is in relation with road users. In this technique, highly qualified auditors together with a team investigate possibility of the occurrence of road accidents and its safety performance. In the present research, Expert Choice Software was used to consider causes leading to the occurrence of an accident. This software allows auditors to pairwisely compare causes of accidents, so as to reduce human errors and save time. Moreover, this software makes it possible to perform surveys on a large number of experts and compare simultaneously numerous factors contributing into accidents. Also, if a cause of accident either rises or fades in future, one can conveniently apply corresponding changes into the software and be provided with the new set of results rapidly. The present research identifies and prioritizes black spots along the "Iraanshahr-Sarbaaz-Chabahar" road (Figure 1); this two-lane highway is an essential mountain road for the region connecting strategic port of Chabahar (Baluchistan, Iran) which is the only seaport in Iran with direct access to the Indian ocean. This highway is undertaken by investigating the road and environmental, traffic, and geometrical conditions. For this purpose, first, entire length of the road was checked for road imperfections and the factors which were expected

Table 1: Section 1: Iraanshahr-Polchamani.

Potential black spots	Cause of having potential
Shahrderaz	Lack of interchanges at residential areas and traffic of smugglers' vehicles

Table 2: Section 2: Polchamani-Kalaat.

Potential black spots	Cause of having potential
Kalaat	Lack of interchanges at residential areas and traffic of smugglers' vehicles

to contribute into accidents along the road; listed as (A) to (I), the factors were as follows:

(A) Inappropriate horizontal curves
(B) Inappropriate vertical curves
(C) Lack of traffic signs
(D) Lack of adequate lighting at night
(E) Inappropriate sight distance
(F) Lack of road shoulder
(G) Lack of guard rail and passage of animals across the road
(H) Traffic of smugglers' vehicles
(I) Lack of interchanges at residential areas

Following with the research, the "Iraanshahr-Sarbaaz-Chabahar" road was divided into 8 uniform and homogenous sections in terms of physical and road performance properties. The sections were as follows:

Section 1: Iraanshahr-Polchamani
Section 2: Polchamani-Kalaat
Section 3: Kalaat-Sarbaaz
Section 4: Sarbaaz-Pashaamag Mortaan
Section 5: Pashaamag Mortaan-Jakigor
Section 6: Jakigor-Dashtyari
Section 7: Dashtyari-Konaarak
Section 8: Konaarak-Chabahar

At each section, potential black spots along the section were identified based on the geometry of the road within that section, environmental factors, and also the 9 factors mentioned above. Unfortunately, due to high unemployment rate, many people go for gas oil and goods (cloths, food stuff, etc.) smuggling to be able to afford life expenses. Meanwhile, high speed of smuggling vehicles, particularly those used to transport gas oil, has resulted in disastrous accidents upon which a large number of casualties has been incurred. Potential black spots along Sections 1–8 are reported in Tables 1–8, respectively.

Table 3: Section 3: Kalaat-Sarbaaz.

Potential black spots	Cause of having potential
Sarbaaz	Lack of interchanges at residential areas, lack of adequate lighting at night, and lack of road shoulder

Table 4: Section 4: Sarbaaz-Pashaamag Mortaan.

Potential black spots	Cause of having potential
Dapkor	Lack of interchanges at residential areas and inappropriate horizontal curves
Bepaataan	Inappropriate horizontal curves and traffic of smugglers' vehicles

Table 5: Section 5: Pashaamag Mortaan-Jakigor.

Potential black spots	Cause of having potential
Garikan	Lack of interchanges at residential areas and inappropriate horizontal curves
Jangal	Lack of interchanges at residential areas and inappropriate horizontal curves
Firouzabad	Lack of interchanges at residential areas, inappropriate horizontal curves, and inappropriate vertical curves
Derakhshan	Lack of interchanges at residential areas and inappropriate horizontal curves
Jakigor	Inappropriate horizontal curves

Table 6: Section 6: Jakigor-Dashtyari.

Potential black spots	Cause of having potential
Dashtyari	Lack of interchanges at residential areas and lack of traffic signs

Table 7: Section 7: Dashtyari-Konaarak.

Potential black spots	Cause of having potential
Oraki	Lack of interchanges at residential areas and lack of traffic signs
Nobandian	Lack of interchanges at residential areas and lack of traffic signs
Negur	Lack of interchanges at residential areas

As can be observed from Figure 2, the inappropriate horizontal curves together with the traffic of smugglers' vehicles have made Bepaataan a potential black spot.

According to Figure 3, inappropriate horizontal and vertical curves along with lack of interchanges at residential area are among the causes contributing to car accidents across the locality.

Figure 2: Section 4: Bepaataan.

Table 8: Section 8: Konaarak-Chabahar.

Potential black spots	Cause of having potential
Konaarak	Lack of interchanges at residential areas
Tis-Kopan	Lack of interchanges at residential areas

Figure 3: Section 5: Firouzabad.

Figure 4: Section 7: Nobandian.

Figure 5: Section 8: Konaarak.

Based on Figure 4, lack of traffic signs and the grade byway intersection at Nobandian are among the causes contributing to car accidents across the locality.

According to Figure 5, Konaarak byway crossing serves as a local black spot due to lack of traffic signs and intersection.

For each section, two questionnaires were prepared and 5 experts who were familiar with the region were asked to score the effect of each factor contributing into accidents on 1–10-level scale. Questionnaire 1 was used to score each of the contributing factors into accidents, while Questionnaire 2 scored potential black spots based on each of the contributing factors into accidents.

The questionnaire results were averaged, with the contributing factors into accidents as well as potential black spots being subjected to pairwise comparisons; that is, they were fed into a matrix of comparison in Expert Choice Software where they were analyzed based on numerical comparisons.

Table 9 that is presented by Saaty [17] was used to compare the criteria including inappropriate horizontal curves, inappropriate vertical curves, lack of traffic signs, lack of adequate lighting at night, inappropriate sight distance, lack of road shoulder, lack of guard rail and passage of animals across the road, traffic of smugglers' vehicles, and lack of interchanges at residential areas in a pairwise fashion and also to compare the alternatives including the Shahrderaz crossing, Kalaat byway crossing, Sarbaaz Bridge, Dapkor, Bepaataan, Garikan, Jangal, Firouzabad, Derakhshan, Jakigor, Dashtyari, Oraki, Nobandian, Negur, Konaarak byway crossing, and Tis-Kopan

Table 9: AHP preference scale.

Numeric value	Preference level
9	Extremely preferred
7	Very strongly preferred
5	Strongly preferred
3	Moderately preferred
1	Equally preferred
2, 4, 6, and 8	Intermediate values between the two adjacent judgments

byway crossing in a pairwise fashion; the table indicates the level of priority as measured numerically with a number ranging within 1 to 9. Undertaking the pairwise comparisons on the criteria and alternatives, we ended up with 8 and 9 matrixes, respectively. As examples, the resulting matrix from comparing, in a pairwise fashion, the criteria within the scope of Section 1 is demonstrated in Table 10, while Table 11 presents the corresponding pairwise comparison matrix to the inappropriate horizontal curve criterion.

3. Results and Analyses

The reported stats by highway police corresponds to 2015, and by 2016 when the present research has been performed, numerous instances of black spots were corrected or undergoing corrective actions. For example, although the inappropriate horizontal curves at three black spots (Garikan, Firouzabad, and Nobandian) were corrected even before this research was initiated, results of survey (using the designed questionnaire) on traffic experts and outputs of Expert Choice Software recognized the same three locations as black spots but now because of the lack of interchanges.

In Section 1, the most effective factor contributing into accidents was found to be lack of interchanges in residential areas. According to Table 1, there was only one potential black spot along the section with its cause being the lack of intersections in residential areas; as such, the potential black spot can be considered as an actual black spot.

According to the stats released by traffic police, in 2015, inappropriate horizontal curves have been the most significant cause of accidents along Sections 2 and 3; the curves were modified in early 2016. Accordingly, based on field investigations performed in the present research, in 2016, due to the factors mentioned in Tables 2 and 3, Kalaat and Sarbaaz have had the potential to become black spots. However, since the horizontal curves were corrected in early 2016, the inappropriate curves had no more served as a main cause of accident in the mentioned tables. Analysis of the questionnaires using Expert Choice Software shows that inappropriate horizontal curve represents the main cause of accidents at these points, and knowing that the curves are now corrected, the corresponding points may no more be black spots.

Establishment of a highway police station within Dashtyari and correction of inappropriate horizontal curves at two

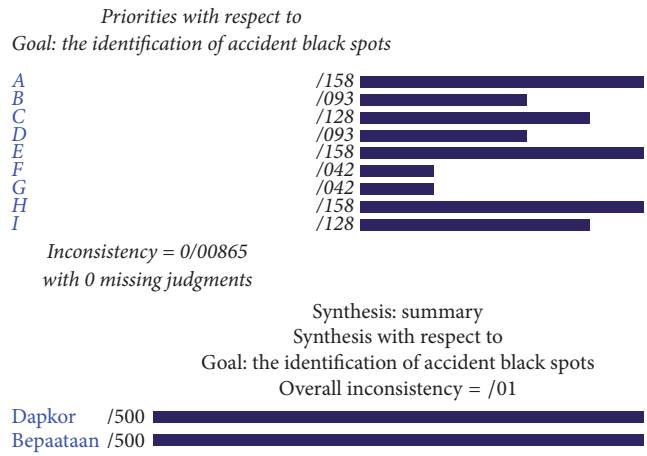

Figure 6: Section 4: Sarbaaz-Pashaamag Mortaan.

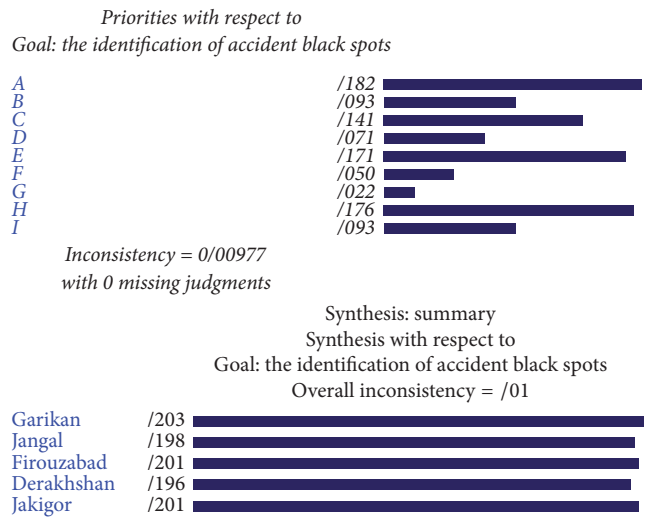

Figure 7: Section 5: Pashaamag Mortaan-Jakigor.

black spots, namely, Sarbaaz and Kalaat, were completed during the same period as that in which the present research was being performed. Accordingly, the most important causes of accidents in Dashtyari (traffic of smugglers' vehicles) and Kalaat and Sarbaaz (inappropriate horizontal curves), as evaluated based on the results of survey on traffic experts, were eliminated. That is to say, based on experts' opinions, these two points were not recognized as black spots. Other black spots are also undergoing corrective actions.

According to Figure 6, inappropriate horizontal curve and traffic of smugglers' vehicles were two important factors contributing, simultaneously, to the accidents occurring within Section 4. The potential black spots at Dapkor and Bepaataan were of the same priority as they suffered from both of the factors.

Inappropriate horizontal curve was the main contributing factor into accidents happening within Section 5. According to Table 5, all potential black spots within this section are actual black spots, and based on Figure 7, the spots

Table 10: Pairwise comparisons matrix on the criteria within Section 1.

		1	2	3	4	5	6	7	8	9
1	Inappropriate horizontal curves	1	1	$\frac{1}{4}$	$\frac{1}{7}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{4}$	$\mathbf{\frac{1}{8}}$
2	Inappropriate vertical curves		1	$\frac{1}{4}$	$\frac{1}{6}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{4}$	$\mathbf{\frac{1}{8}}$
3	Lack of traffic signs			1	$\frac{1}{2}$	2	1	2	1	$\mathbf{\frac{1}{2}}$
4	Lack of adequate lighting at night				1	3	2	3	2	**1**
5	Inappropriate sight distance					1	1	1	$\frac{1}{2}$	$\mathbf{\frac{1}{4}}$
6	Lack of road shoulder						1	1	1	$\mathbf{\frac{1}{3}}$
7	Lack of guard rail and passage of animals across the road							1	$\frac{1}{2}$	$\mathbf{\frac{1}{4}}$
8	Traffic of smugglers' vehicles								1	$\mathbf{\frac{1}{2}}$
9	Lack of interchanges at residential areas									**1**

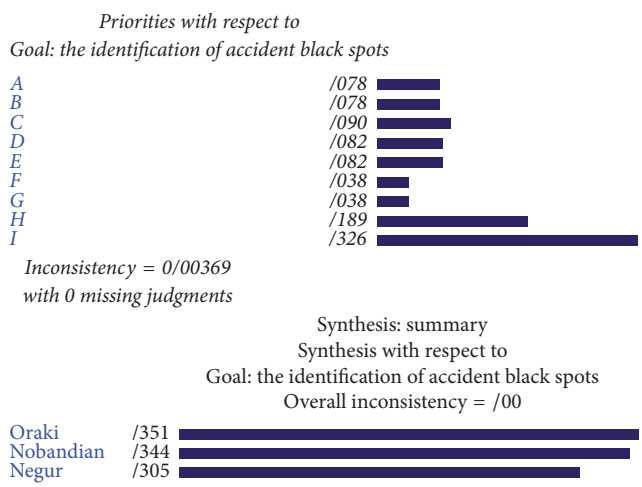

Figure 8: Section 7: Dashtyari-Konaarak.

were prioritized into the following order: Garikan, forest, Firouzabad, Derakhshan, and Jakigor.

In Section 6, the most significant factor contributing into accidents within this section was found to be smugglers' vehicles. However, based on Table 6, lack of interchanges was introduced as a potential factor contributing to the development of black spots within the section.

Lack of interchanges was found to be the most important cause of accidents within Section 7; and according to Table 7, all of the three locations mentioned were identified as actual black spots, with their prioritization (Figure 8) being as follows: Oraki, Nobandian, and Negur.

Lack of interchanges was an important cause of accidents within Section 8; as such, both potential black spots reported in Table 8 could be actual black spots as they had no interchanges. However, according to Figure 9, Konaarak was

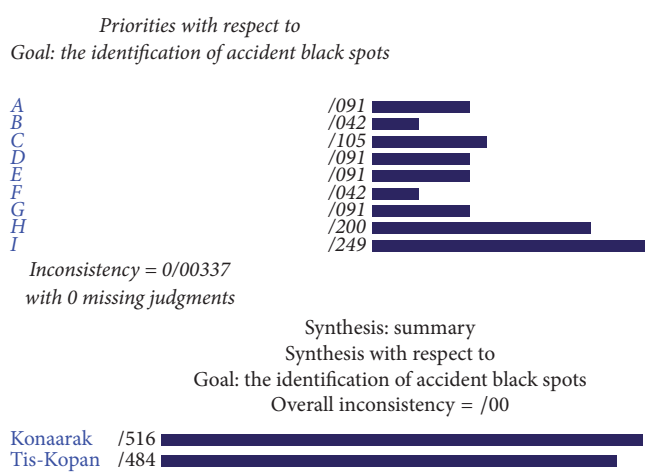

Figure 9: Section 8: Konaarak-Chabahar.

Table 11: Pairwise comparison matrix to the inappropriate horizontal curve criterion.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Shahrderaz	Kalaat	Sarbaaz	Dapkor	Bepaataan	Garikan	Jangal	Firouzabad	Derakhshan	Jakigor	Dashtyari	Oraki	Nobandian	Negur	Konaarak	Tis-Kopan
1	1	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{1}{6}$	1	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
2		1	1	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	1	4	4	2	2	2	2
3			1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	1	1	1	1	1
4				1	1	1	1	1	1	1	6	6	3	3	3	3
5					1	1	1	1	1	1	7	7	3	3	3	3
6						1	1	1	1	1	8	8	4	4	4	4
7							1	1	1	1	8	8	4	4	4	4
8								1	1	1	8	8	4	4	4	4
9									1	1	6	6	3	3	3	3
10										1	6	6	3	3	3	3
11											1	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
12												1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
13													1	1	1	1
14														1	1	1
15															1	1
16																1

recognized as the top priority black spot followed by Tis-Kopan as second.

4. Conclusion

The three major causes of accident, respectively, are as follows:

(1) Lack of interchanges along the "Iraanshahr-Polchamani," "Dashtyari-Konaarak," and "Konaarak-Chabahar" roads.

(2) Inappropriate and nonstandard horizontal curves along "Polchamani-Kalaat," "Kalaat-Sarbaaz," "Sarbaaz-Pashaamag Mortaan," "Pashaamag Mortaan-Jakigor," and "Jakigor-Dashtyari."

(3) Traffic of smugglers' vehicles whose drivers are known to drive at high speed and minimum care along "Sarbaaz-Pashaamag Mortaan" and "Jakigor-Dashtyari" sections, imposing the largest contributions into road accidents at black spots along "Iraanshahr-Sarbaaz-Chabahar" road. The traffic of smugglers' vehicles shall be recognized as a cause of accident which is present every day with various severities along the day, so that serious interventions shall be undertaken to address this cause considering its large deal of risk at residential areas surrounding the road and intersections. The black spots recognized using the proposed method in the present research (with no use of accident information) are tabulated in Table 12, with the extracted black spots from accident information (as reported by traffic police) presented in Table 13.

Accident index is a number obtained for a given black spot based on the registry of accidents' information during the period under study; it indicates the significance of the black spot. The value of accident index can be calculated via

$$P = \frac{1000 \times I}{365 \times A \times T}, \tag{1}$$

where T is the length of the period during which accident information and data are collected (in years) and I is the accident intensity factor at accident point per T period, which can be calculated via

$$I = X + 3Y + 9Z, \tag{2}$$

where X is the number of accidents ending up with damage, Y is the number of accidents ending up with injuries, Z is the number of accidents ending up with fatality, at the accident point per T period, and A is the road performance factor which is considered to be 2, 4, 6, and 8 for byways, main roads (province-wide), main roads (national-wide), and expressways, respectively.

4.1. Comparing Black Spots Extracted with/without Accident Information. Comparing the extracted black spots according to Tables 12 and 13, police reports indicated the "Kalaat Crossing" as a black spot, while the proposed method failed to identify that. Further, the three crossings of "Shahrderaz," "Konaarak," and "Tis-Kopan" were recognized, by the proposed method in this research, as black spots, while they were excluded in the police reports.

Table 12: Identification of black spots without using accident information.

	Black spots
1	Shahrderaz
2	Dapkor
3	Bepaataan
4	Garikan
5	Jangal
6	Firouzabad
7	Derakhshan
8	Jakigor
9	Oraki
10	Nobandian
11	Negur
12	Konaarak
13	Tis-Kopan

4.2. Comparing Prioritization of Black Spots with/without Accident Information. Comparing the prioritization results of AHP with no use of accident information to those obtained directly from accident information indicates that the Dapkor and Bepaataan black spots at Section 4 were of the same priority in both methods. However, when not using accident information, the spots within Section 5 were prioritized as follows: Garikan, forest, Firouzabad, Derakhshan, and Jakigor, while the corresponding order of priority using accident information was Garikan, Firouzabad, forest, Derakhshan, and Jakigor. Further, in Section 7, the black spots were prioritized, using the proposed method, as follows: Oraki, Nobandian, and Negur, while traffic police statistics indicated the following order of priority: Nobandian, Oraki, and Negur.

5. Summary

Being based on geometrical plan of the road as well as a survey participated by several experts, identification of black spots using the proposed method in this research resulted in 10 of the reported black spots by traffic police, with the prioritization results being in good agreement with police reports. Therefore, this method can be used wherever accident information and statistics are not properly recorded due to either lack of required facilities or inadequate training of the registering agents.

Table 13: Identification of black spots using accident information reported by traffic police in 2015.

	Black spots	Code of region	Accident index
1	Kalaat	28034	54.8
2	Dapkor	28039	41.4
3	Bepaataan	28039	41.4
4	Garikan	28038	49.8
5	Jangal	28037	41.1
6	Firouzabad	28036	49.32
7	Derakhshan	28040	41.1
8	Jakigor	28041	41
9	Oraki	28051	41.1
10	Nobandian	28050	42.47
11	Negur	28050	20.55

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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