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Ranking Road Safety Hazardous Locations in Nepal (A Case Study of Kalanki Ch.10+600 km to Koteshwor Ch.20+994 km Road Section)

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Abstract
In Nepal, there are many emerging towns and cities due to rapid urbanizations which have arose issues of increased traffic density resulting in frequent road crashes like in Kalanki Koteshwor Ring Road Section. This study presents six stage methodological framework for ranking road safety hazardous locations based on Analytical Hierarchy Process (AHP) and field survey (condition rating) to identify the hazardous locations of Kalanki Koteshwor Ring Road Section by weighing the safety parameters of the road section and calculating the Safety Hazardous Index (SHI). The results show that road section 'Ch.12+600 km to Ch.14+600 km' is ranked as the most hazardous location with SHI 12.38 and 'Ch.10+600 km to Ch.12+600 km' is ranked as the least hazardous location with SHI 9.30 among the five road sections considered. This ranking can be a prompt technique for prioritizing the treatment of the hazardous locations keeping available road safety budget in mind.

Keywords
Road Safety, Safety Hazardous Index, Weightage of safety factors, Condition Rating, Analytical Hierarchy Process, Ranking of road safety hazardous location

1. Introduction

Road safety has become one of the major challenges of Nepal. Every year large number of innocent people loses their lives on Nepalese roads and many more seriously injured and disabled. According to official statistics provided by the Government of Nepal, 2,782 road deaths were recorded in Nepal in fiscal year 2075/76; in addition there were 14,744 injury victims. It is important to note that many road fatalities and injuries are not reported. This level of under-reporting is believed to be significant.

Government of Nepal (GoN) has been planning and allocating annual budget approximately 4 million US$ (Source: Ministry of Physical Infrastructure and Transport, MoPIT) for road safety programs to be executed through the concerned agencies like Department of Transport Management (DoTM) and Department of Roads (DoR) under MoPIT. However, the budgetary requirement for coping the recent scenario of road safety is more demanding. Due to such condition as well, the prioritization of crash prone locations and crash countermeasure becomes a must.

In the past, priorities of the road agencies were connectivity rather than safety. This coupled with the mountainous topography became one of the contributing factors for increased road crashes in the country. With the development of infrastructure and urbanization, the traffic density increased dramatically which resulted in reduction of efficiency of the road network. This compelled the concerned agencies to the upgradation of existing roads to multilane roads so as to increase the capacity of road network. However, there are several crashes reported in such newly constructed multilane road sections as well and one of such examples is Kalanki- Koteshwor Road Section.

2. Literature Review

There are generally four main factors that play a key role in road crash. These factors are road, human, vehicle and environment. Of these all, only road is capable of being easily improved by traffic and transportation engineers to decrease the rate of road crashes. Considering the fact, it is necessitate investigating and ranking the chief parameters of "Road" factor and their various features. There are various methodologies used in defining the risk of parameters or features causing road crash. The base of some studies is the road crash data and establishing statistical modelling of crashes. The base of other studies is explanatory approaches due to the lack of easy accessibility to road crash data or doubt on their accuracy [1].

There are three common methods to evaluate the road safety namely: "Traffic Conflict Technique", "Subjective Rating System", and "Multi Criteria Decision Making Approach". The concept of traffic conflicts was first proposed by Perkins and Harris as an alternative to crash data; particularly, when there is no accurate and reliable crash data. Their objectives were to define traffic incidents that occur frequently, can be clearly observed, and are related to road crashes. "Subjective Rating System" was initially used by Transport Road Research Laboratory in 1990 to identify and investigate main road parameters leading to crashes. This approach of subjective road safety evaluation involves a drive-through technique. "Multi Criteria Decision Making Approach" mainly apply to rank the parameters of road crashes [2].

The specific literatures advocate the efficacy of Multi Criteria Decision Approach such as AHP [3, 4]. AHP method has been extensively used in a large number of road safety researches and so many researchers have done in order to identify accident prone locations. For instance, Habibian et al. [1] , Agrawal et al. [5] suggested methodologies for ranking black spots in terms of Safety Index and Safety Hazardous Index respectively using AHP.

Mazdak et al. [2] evaluated traffic risk indexes in Iran's rural roads with regards to the two main criteria: Effect on Accidents number & Effects on Accident Severity using a Multi criteria Decision Making Approach of AHP to find the score of Risk Index of each chosen parameters and rank them with regard to the two main criteria.

Najib et al. [6] implied six steps of AHP to identify that 'driving faster than limited speed' has the highest weights among all the causes leading to the accidents in Malaysia.

Mahmoudreza et al. [7] attempted to identify & prioritize black spots in Baluchistan, Iran with no use of accident data but rather using AHP with the use of Expert Choice Software.

Mohammed et al. [8] utilized AHP to analyze the traffic accidents in Kuwait with the main objective to identify the most strategic policies to be used by the authorities in Kuwait in order to minimize the severe effect of traffic accidents both on human and property.

3. The Need and Objective of the study

3.1 The Need of the study

Kathmandu Ring Road (KRR) serves as the main arterial road in Kathmandu valley. KRR was built for accommodating higher traffic flow avoiding central city congestion. Therefore, it is anticipated to ease the traffic flow with the relatively higher speed for higher volume. But this wide urban arterial road after the completion has faced serious allegations of being unsafe. In last fiscal year 075/76, it was recorded that the newly constructed southern section of KRR "Kalanki- Koteshwor road section (10.394 km length)" has suffered 1060 number of road crashes including 17 deaths, 35 serious injury & 717 general injury. Similarly, in first six months of this fiscal year (076/77), 509 number of road crashes have been already reported with 9 deaths, 14 seriously injured and 427 minor injury (Source: Metropolitan Traffic Police Office, Kathmandu). The problem is alarming and hence proper & immediate actions ought to be taken to resolve it.

3.2 The Objective of the study

The main objective of this study is to investigate the main parameters of "Road" factor and their various features to rank safety hazardous locations in Kalanki-Koteshwor Road Section. For this, a terminology "Safety Hazardous Index" is defined as the risk of a parameter or a feature causing road crashes. The specific objectives of the study are:

- To identify geometric elements of roads and safety factors for each geometric element so as to prioritize safety factors using AHP.
- To conduct field survey for condition rating of safety factors.
- To determine the Safety Hazardous Index in order to rank the road safety hazardous locations.

4. Limitation

The limitations of the study are:

- Not more than 10 number of safety factors for each road element as it would be complex to deal with large numbers of factors during pairwise comparison.
- Expert's judgment has to be discarded in case of inconsistency greater than 0.10 resulting in reduction in sample size.

5. Methodology

5.1 Stydy Area

Kathmandu Ring Road (KRR) is an eight lane ring road circling around the cities of Kathmandu and Lalitpur. KRR has been classified as National Highway Category (Code H16). It has been rebuilt to meet the demands of traffic function and solve the problem of traffic congestion. However, in the present scenario, this road link is facing serious allegation of lacking road safety infrastructure to prevent the increasing number of road traffic casualties.

The Southern section of KRR from Kalanki (CH.10+600) to Koteshwor (CH.20+994) shown in Figure 1 was selected as study area.

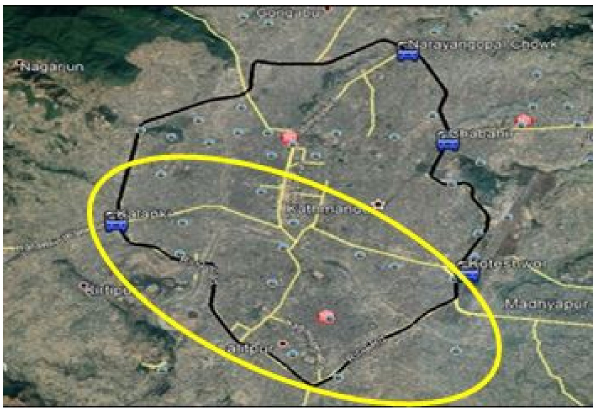

Figure 1: Location of study area

5.2 Overview of Methodology

The proposed framework for achieving the objectives of the research mentioned in Section 3.2 is divided into six stages as shown in Figure 2.

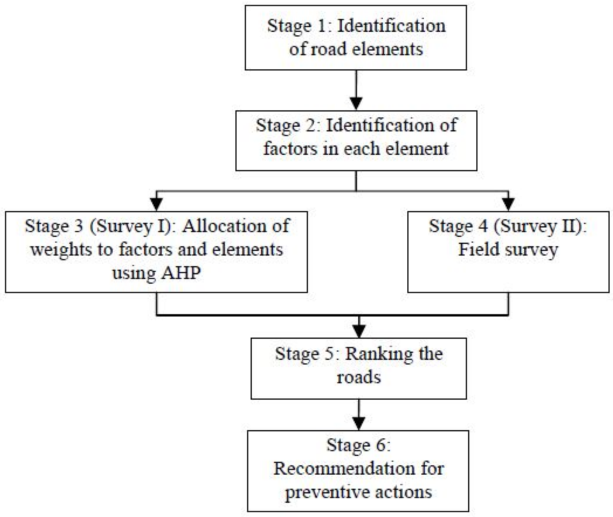

Figure 2: Methodology Flow Chart

5.2.1 Stage 1: Identification of road elements

On the basis of literature review related to AHP and road safety, study of "Design of Construction Drawing of The Improvement Project of Kathmandu Ring Road Project in Nepal" [9] , field visit and experiences, four road elements (straight, curve, bridge & merge and intersection) were identified in the selected road section.

5.2.2 Stage 2: Identification of factors in each element

Similarly, the safety factors affecting the safety of each element are also assigned as listed below.

1. For Straight Segments:
   (a) Speed limit signs and no overtaking signs
   (b) Lighting poles and reflective signs
   (c) Road marking
   (d) Shoulder width
   (e) Pavement maintenance condition
   (f) Drainage
   (g) Pedestrian Crossing facilities
2. For horizontal and vertical curves:
   (a) Speed advisory signs, sharp bend, steep up/ down grade warning signs
   (b) Lighting poles and reflective signs
   (c) Road marking before and in the curve
   (d) Shoulder width

(e) Combination of horizontal and vertical curves

(f) Pavement maintenance condition

(g) Drainage

(h) Sight distance provision

(i) Superelevation in horizontal curves

(j) Road Safety Intervention

3. For Bridge Segments:

(a) Speed limit signs, no overtaking signs and load limit signs

(b) Lighting poles and reflective signs

(c) Road marking

(d) Reduction in the pavement width and shoulder width

(e) Pavement maintenance condition

(f) Drainage

(g) Guardrails and bridge approach protection

4. For merge and intersection:

(a) Speed limit and warning signs

(b) Lighting poles and reflective signs

(c) Road marking before and in the curve

(d) Shoulder width

(e) Pavement maintenance condition

(f) Drainage

(g) Sight distance provision

(h) Distance to previous intersection

(i) Traffic Calming measures/ Appropriate geometry to reduce speed

(j) Pedestrain crossing facilities

5.2.3 Stage 3: Allocation of weights to factors and elements using AHP

The next step involved assigning the relative weights to the different options at each hierarchy level. To do so, Dr. Saaty's Intensity of Importance Scale as shown in Table 1 has been preferred. For this research, 20 experts performed the pairwise comparison.

Table 1: Saaty's rating scale

Relative Importance	Qualitative Scale	Comments
1	Equal	Two activities contribute equally
3	Moderate importance	Slightly favor one activity over another
5	Strong importance	Strongly favor one activity over another
7	Demonstrated importance	Very Strongly favor one activity over another, its dominance demonstrated in practice
9	Absolute importance	Very strongly to Extremely strongly preferred
2,4,6,8	Values between the levels above	Used only when a compromise in comparison is necessary
Reciprocal		If importance of item x to item y is aij then the importance of item x is aji=1/aij

After scaling the relative of data and constructing the pairwise comparison matrixes, the matrixes would be:

$$\begin{bmatrix} 1 & w1/w2 & \dots & w1/wn \\ w2/w1 & 1 & \dots & w2/wn \\ \vdots & \vdots & \ddots & \vdots \\ wn/w1 & wn/w2 & \dots & 1 \end{bmatrix} \tag{1}$$

Then the process was followed by calculation of matrix eigenvector, Aij and consistency index test (CI) of the criterion.

Eigen vector, Aij

$$= \frac{\sum_{i=1}^{n} (w1/w1 \times w1/w2 \times .... \times w1/wn)^{1/n}}{\sum (\sum_{i=1}^{n} (w1/w1 \times w1/w2 \times .... \times w1/wn)^{1/n})} \tag{2}$$

Eigen value,

$$\lambda = \frac{\sum_{j=1}^{n} (\sum_{i=1}^{n} Aij) wj}{Aij} \tag{3}$$

Consistency test,

$$CI = \frac{(\lambda max - n)}{(n-1)} \tag{4}$$

Consistency ratio,

$$CR = \frac{CI}{RI} \quad (5)$$

The consistency index was compared against a reference average random index (RI) which is given in Table 2. The ratio of consistency index, CI to the average random consistency index, RI is called Consistency ratio (CR). CR is acceptable if it is does not exceed 0.10 (Saaty and Wong 1983). If the CR of CI is greater than 0.10, the judgment matrix should be considered as inconsistent. Thus, the comparison should be repeated. Klaus D. Goepel version 11.10.2017 AHP Spreadsheet Template [10] is used for verifying pairwise comparisons.

Table 2: Random Index for different dimensions of RWM (Saaty and Wong 1983)

Dimension	RI
1	NA
2	NA
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45

5.2.4 Stage 4: Field Survey

Entire route of survey was divided into parts of 500 m section for condition rating. All road safety factors of the respective section were analyzed separately using rating scale as shown in Table 3.

This was carried out in following steps:

1. Reconnaissance Survey
2. Facilities Check
3. Comparison with guidelines
4. Condition Rating

Table 3: Condition rating of safety factors [5]

SN	State of condition	Value
1	Excellent	0
2	Good	0.1 - 0.24
3	Average	0.24 - 0.49
4	Poor	0.50 - 0.74
5	Very Poor	0.75 - 1.00

5.2.5 Stage 5: Ranking the roads

Combining the weight of safety factors and condition rating of each factor obtained from stage 3 and 4, Safety hazardous Index was developed using formulas as below.

Safety hazardous index at straight sections:

$$SHI_s = \sum W_{sfs} \times R_{sfs} \quad (6)$$

Safety hazardous index at curve sections:

$$SHI_c = \sum W_{sfc} \times R_{sfc} \quad (7)$$

Safety hazardous index at bridge sections:

$$SHI_b = \sum W_{sfb} \times R_{sfb} \quad (8)$$

Safety hazardous index at intersection sections:

$$SHI_i = \sum W_{sfi} \times R_{sfi} \quad (9)$$

Where, SHI_s, SHI_c, SHI_b, SHI_i = Safety Hazardous Index for straight, curve, bridge and intersections respectively.

W_{sfs}, W_{sfc}, W_{sfb}, W_{sfi} = Weight of safety factors at straight, straight, curve, bridge and intersections respectively.

R_{sfs}, R_{sfc}, R_{sfb}, R_{sfi} = Condition rating of safety factors at straight, straight, curve, bridge and intersections respectively.

Further, Safety hazardous index for every 2 km road segments of Kalanki- Koteshwor Road Section was obtained by summation of SHI of all elements.

$$SHI_{rs} = SHI_s + SHI_c + SHI_b + SHI_i \quad (10)$$

It is noted that higher the SHI at a particular road section, higher safety hazardous condition at that particular location. In this way, ranking the hazardous locations of 2 km stretch each in KKR allows the road safety authorities to implement road safety infrastructure for atleast 2 km stretch in eight lane ring road keeping limited available road safety budget in mind.

5.2.6 Stage 6: Recommendation of preventive measures

In this stage, the required countermeasures or preventive measures are to be suggested after identification of the hazardous locations along the study area based on the available budget and prioritization of countermeasures (which is not in the scope of this work).

6. Results and Discussion

The average weight developed from experts' pairwise comparisons using AHP for each element is summarized in graphical form as below.

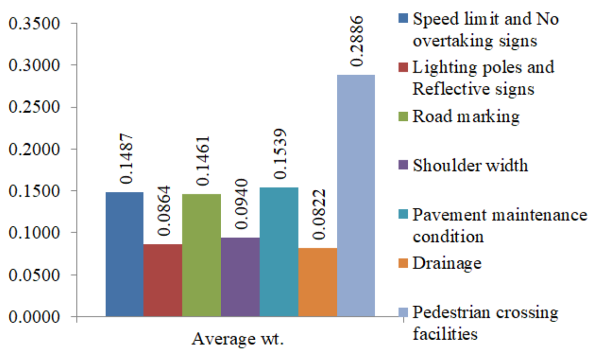

Figure 3: Average weights of factors in straight (S) element

Figure 3 shows the safety factor 'Pedestrain crossing facilities (28.86%)', 'Pavement maintenance condition (15.39%)', 'Speed limit & No overtaking signs (14.87%)' and 'Road marking (14.61%)' respectively has more importance in straight element of KKR.

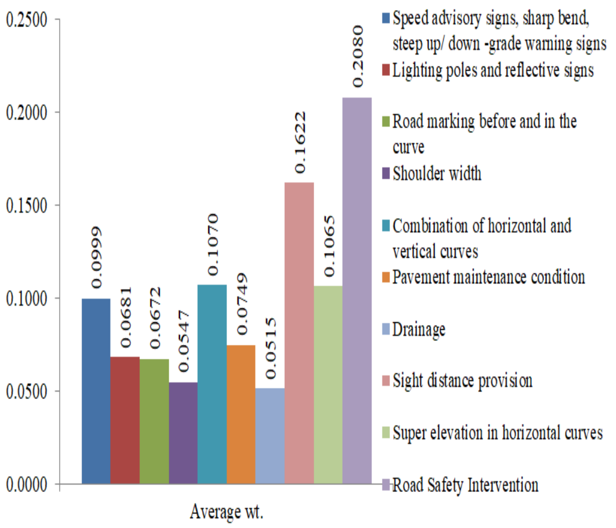

Figure 4: Average weights of factors in curve (C) element

Figure 4 shows 'Road safety intervention (20.80%)', 'Sight distance provision (16.22%)', 'Combination of horizontal & vertical curve (10.70%)' and 'Superelevation in horizontal curve (10.65%)' respectively has more priority in curve element.

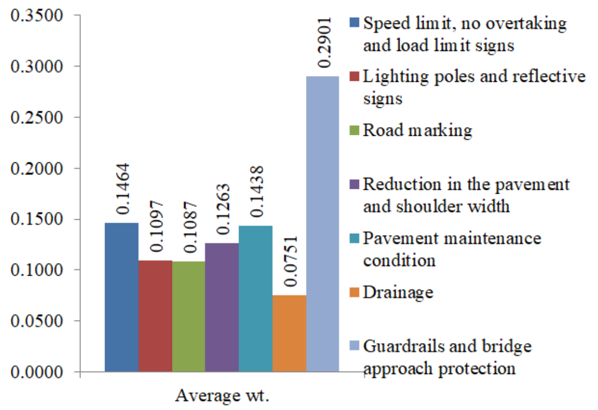

Figure 5: Average weights of factors in bridge (B) element

Figure 5 shows 'Guardrails & bridge approach protection (29.01%)', 'Speed limit & No overtaking signs (14.64%)', 'Pavement maintenance condition (14.38%)', and 'Reduction in pavement width & shoulder width (12.63%)' respectively has more importance in bridge element.

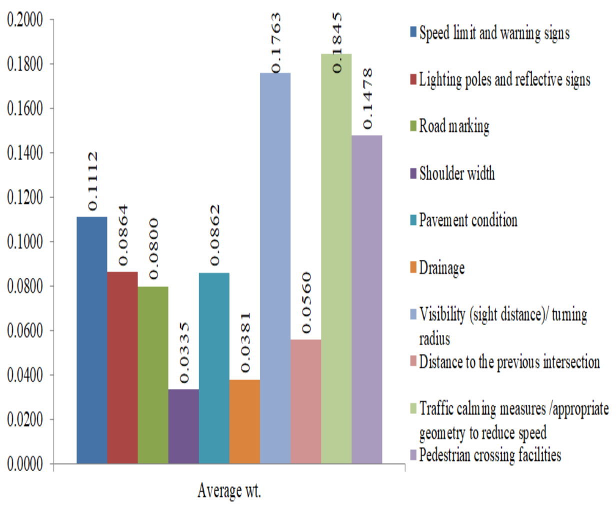

Figure 6: Average weights of factors in intersection (I) element

Figure 6 shows 'traffic calming measures/ appropriate geometry to reduce speed (18.45%)', 'Sight distance provision (17.63%)', 'Pedestrian crossing facilities (14.78%)' and 'Speed limit and warning signs (11.12%)' respectively has more weightage in intersection element of KKR.

Furthermore, Safety hazardous index for every 2 km road segments of entire southern section of Kalanki Koteshwor Ch.10+600 to Ch. 20+994 km was calculated combining the average weights given by experts and condition rating obtained by road inspection. Finally, ranking was done based on SHI value with the highest SHI as Rank (1) and so on as shown in Table 4.

Table 4: Safety Hazardous Index (SHI) for each 2km road section

SN	Chainage, km				
SHI	10+600 to 12+600	12+600 to 14+600	14+600 to 16+600	16+600 to 18+600	18+600 to 20+994
SHI (S)	5.45	5.36	6.37	5.26	6.01
SHI (C)	1.96	1.88	1.44	2.38	2.58
SHI (B)	0.40	0.76	0.00	0.00	0.46
SHI (I)	1.49	4.38	2.29	2.77	1.47
Total SHI	9.30	12.38	10.10	10.41	10.52
Rank	5	1	4	3	2

Here, Ch.12+600 to Ch.14+600 km was found to have highest SHI value of 12.38 as shown in Figure 7, which means this road section is the most vulnerable in consideration of 'Road' factor and it requires to be treated first with the safety counter-measures as per priority of such intervention & budget available.

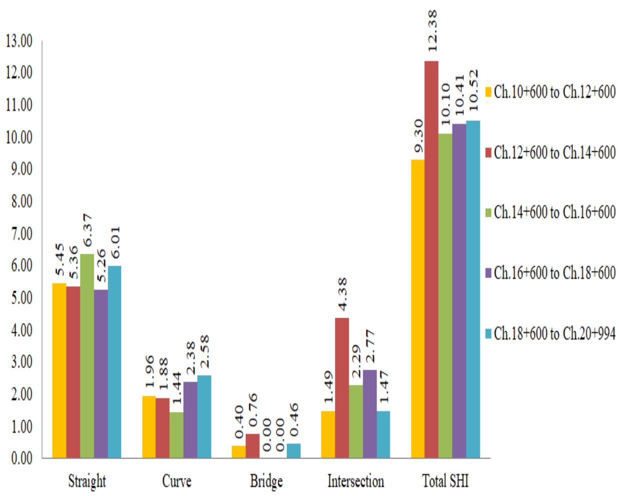

Figure 7: Safety Hazardous Index (SHI) for each road element and Total SHI for 2 km road sectionwise

7. Validation of Procedure

A sample of 460 number of road crash data recorded in Kalanki Koteshwor Road Section for the months of Bhadra to Magh, 2076 (Source: Metropolitan Traffic Police Office, Kathmandu) was used in order to validate the procedure. From crash data collected for six months period of the road sample, the total number of crashes was grouped for each 2 km road sections on the basis of the road crash locations. Then, the five road sections of KKR were ranked based on the number of crashes in each 2km length road section.

The main target of the procedure is to define priorities with respect to road safety, thus to test the procedure, a comparison was made of the rankings obtained by SHI score and crash history. Spearman's rank correlation was used to determine the level of agreement between the rankings obtained using the two techniques. The result from the Spearman's rank-correlation analysis provides validation for the SHI indicating that the ranking from the SHI and crash history agree with correlation coefficient of 0.80 with probable error 0.1086 as shown in Table 5.

Table 5: Correlation between SHI score and Crash history

SN	Chainage, km	Rank		Corr. Coeff.
		SHI (R1)	Crash (R2)	
1	10+600 to 12+600	9.30 (5)	54 (4)	0.80
2	12+600 to 14+600	12.38 (1)	116 (2)	
3	14+600 to 16+600	10.10 (4)	44 (5)	
4	16+600 to 18+600	10.41 (3)	91 (3)	
5	18+600 to 20+994	10.52 (2)	155 (1)	

8. Conclusion and Recommendations

The purpose of this study is to rank road safety hazardous locations in the southern section of Kathmandu Ring Road using six stage methodological framework based on pairwise comparison method of AHP and condition rating. This study has successfully identified that road section 'Ch.12+600 km to Ch.14+600 km' and road section 'Ch.18+600 km to Ch.20+994 km' as the first and second most road safety hazardous locations with score SHI=12.38 and SHI=10.52 respectively which suggests these sections are the most hazardous locations to be treated immediately as per their ranking. Furthermore, the rankings of road sections identified by the proposed method found to be in good agreement with the traffic 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 to the registering agents.

The staggering number of crash records in KKR shows the urgency for employing preventive measures. Since, all the road safety measures may not be possible to be implemented throughout the KKR section due to the insufficient availability of budget so the methodology developed in this study can be firstly useful for the implementing agencies to detect the hazardous locations more quickly; secondly, diagnose the difficulties of these locations more in detail, and finally be helpful to assign the limited budget to improve road problem and decrease the road crash numbers and severities.

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