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A Methodology for Ranking Road Safety Hazardous Locations Using Analytical Hierarchy Process

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Abstract

This study presents a methodology for ranking road safety hazardous locations using analytical hierarchy process (AHP). Road accident causes huge losses to the economy in terms of the cost incurred in hospitalization and treatment and damages to vehicles and property etc. There is an urgent need to reduce the number and severity of road accidents by implementing remedial measures at hazardous locations in the road network. Further, it is generally not possible to implement all remedial measures identified due to limited budget available for road safety improvement. Hence, it is needed to rank the hazardous locations so that depending on the available budget, the hazardous locations can be treated. However, literature review indicated that most of the methodologies require accident data for this purpose. Comprehensive road accident data is rarely available. Hence, this study presents a four stage methodology for ranking road safety hazardous locations which do not require accident data. The methodology presents a hierarchical structural for identification of safety factors. Road safety hazardous conditions are decomposed into safety hazardous condition at straight sections, safety hazardous condition at curve sections and safety hazardous condition at intersections. Analytical hierarchy process (AHP) is used to determine the weight of the different identified safety factors. The Safety Hazardous Index is developed using weight of safety factors and condition rating of safety factors. The Safety Hazardous Index is developed separately to evaluate safety at straight section, safety at curve section and safety at intersection. It is expected that this study will be useful in treating more hazardous locations depending on the available budget for road safety improvement.
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Keywords: Road safety; safety hazardous index; analytical hierarchy process; ranking of road safety hazardous locations;

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1. Introduction

This study presents a rational methodology for ranking road safety hazardous locations using analytical hierarchy process. Serious injuries & fatality due to road accidents are increasing every year worldwide. Road accident cause huge losses to the economy in terms of charges incurred in hospitalization and treatment and damages to vehicles and property etc. Therefore, there is an urgent need to reduce the number and severity of road accidents by implementing remedial measures at hazardous locations in the road network. Further, it is generally not possible to implement all remedial measures identified due to limited budget available for road safety improvement. Hence, it is needed to rank the hazardous locations so that depending on the available budget, the hazardous locations can be treated. Study of critical Literature indicate that most of the methodologies require accident data for this purpose. Often comprehensive accident data are not available. Even if accident data is available, it is difficult to analyze this data due to its poor quality. Further, some locations have high frequency of accident but fatality is less. Many locations with narrow bridges, slippery pavements, and rigid roadside obstruction have a high accident potential but may not yet have a history of high-accident occurrence. Therefore, it is important to develop a methodology for ranking road safety hazardous locations without using any accident data.

Hence, this study presents a four stage methodology for ranking road safety hazardous locations which do not require accident data. The methodology presents a hierarchical structural for identification of safety factors. Road safety hazardous conditions are decomposed into safety hazardous condition at straight sections, safety hazardous condition at curve sections and safety hazardous condition at intersections. Analytical hierarchy process (AHP) is used to determine the weight of the different identified safety factors. The Safety Hazardous Index is developed using weight of safety factors and condition rating of safety factors. The Safety Hazardous Index is developed separately to evaluate safety at straight section, safety at curve section and safety at intersection. Higher the value of Safety Hazardous Index at a particular location indicates more hazardous location in road network.

This paper consists of four sections. This first section highlights the need of the study. Second section presents a critical review of the literature for ranking of road safety hazardous locations. Third section presents the four stage methodology for ranking road safety hazardous locations and the last section presents the conclusions made from this study.

2. Literature Review

This section presents the critical review of literature available on methodologies for ranking road safety hazardous locations.

A number of statistical models have been used to estimate accident rates and/or accident frequencies at a specific location over a given interval of time used multiple linear regression models. In these models the dependent variable (either number of accidents or accident rate) is a function of a series of independent variables such as speed or traffic volume. Accident occurrence in these models is assumed to be normally distributed. These models generally lack the distributional property that is necessary to describe adequately the random and discrete vehicle accident events on the road and they are inappropriate for making probabilistic statements about accident occurrence. Several researchers (Mustakim, Yosof, Rahman, Sabad & salleh, 2008), (Meeghat, Mahmood, & Sobhani, 2011), (Gimotty & Chirachavala, 1982), (Evans, 1985), (Hutchinson, 1986), (Nassar, 1994), (HSIP, 1981), (Singh & Suman, 2012), (Latimer, 1992) (Wood and Simms, 2002) and (Amir Sobhani, 2011), have investigated models for accident injury severity. A few researchers investigated severe injury involvement models, for example (Jovanis & Chang, 1989) and (Blower, 1993). The following description of these models was taken from Nassar (1996). Statistical models of injury severity were undertaken by (Evans, 1985) and (Hobbs, 1981). Other researchers such as (Gimotty & Chirachavala, 1982) and (Nassar, 1994), have used accident data to study the effect of changes in risk factors on occupant injury severity. (Nassar, 1996) states that since injury is sustained by occupants of vehicles, an accident severity model should focus on occupants and their characteristics at the time of accident. Accident type (i.e. single-vehicle, two-vehicle and multi-vehicle) and accident dynamics play a major role in predicting injury severity. An accident severity model should be able to integrate with an involvement model to account for the expected number of injuries and fatalities in an accident. Some other researchers approached the problem from a micro-level analysis viewpoint. They have examined conflicts instead of crashes since conflicts occur more often than crashes (Federal Highway Administration 2003) and (Archer 2005). Traffic micro-simulation models have been utilized to replicate a conflict using surrogate safety measures (Rao & Rengaraju 1997), (Davis 2007), (Cunto 2008) and (Federal Highway Administration 2008).

Most of the studies are based on two methods of assessment (i.e. statistical modelling and micro-simulation) and used either accident or conflict data as the main element of the research. Although these methods improve the understanding of the safety performance of roads, they all require accident data. The preparation of such databases is, however, expensive and time-consuming; especially, when the data is prepared for a road network. As a result, there is often a general lack of this type of data; this is particularly the case in developing countries. An alternative approaches is to use road safety audit. Although this method can be conducted to diagnose the existing safety deficiencies, it does not provide a quantified measure of safety performance.

3. Methodology for ranking road safety hazardous locations using analytical hierarchical process

A framework for the proposed methodology for ranking road safety hazardous locations using analytical hierarchical process is presented in Figure 1.

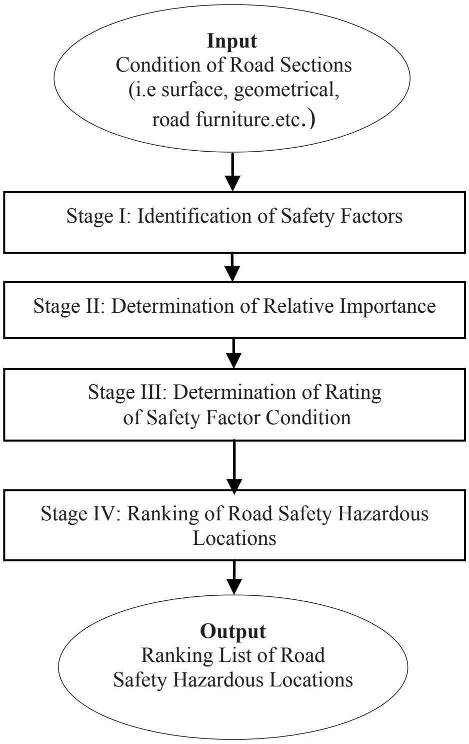

Figure 1: A Framework for Proposed Methodology for Ranking Road Safety Hazardous Locations

Based on the framework presented in Figure 1, four stages are identified for methodology of ranking of road safety hazardous locations. Stage I is identification of safety factors, it discusses about factors affecting road safety. At stage II relative importance of safety factors are determined using analytical hierarchy processes. Stage III discusses determination of rating of safety factor condition and stage IV presents development of safety hazardous index for ranking of road safety hazardous locations. Details of each of these stages are presented in the following sub sections:

3.1 Stage I: Identification of safety factors

In stage I, a hierarchical structure is developed to identify safety factors. The proposed hierarchical structure is presented in Figure 2. Road safety hazardous conditions are decomposed into safety hazardous condition at straight sections, safety hazardous condition at curve sections and safety hazardous condition at intersections

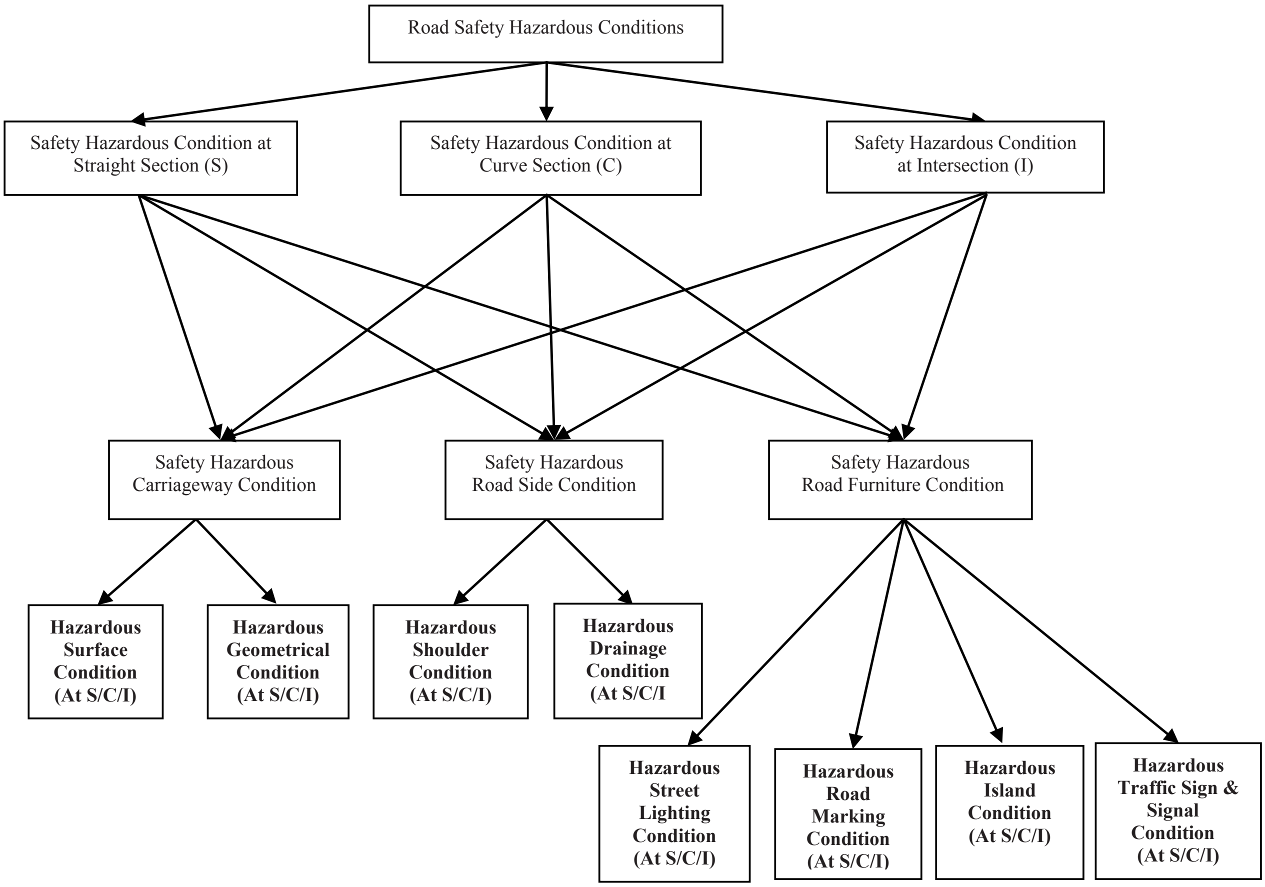

Figure 2: The Hierarchical structure of the Road safety Hazardous Conditions

Figure 2 identifies the safety factors affecting road safety. Eight safety factors are identified for each section (straight sections, curve sections, and intersections) with help of hierarchical structure of road safety. These Factors are as hazardous geometrical condition, hazardous surface condition, hazardous shoulder condition, hazardous drainage condition, hazardous street light condition, hazardous road marking condition, hazardous island condition and hazardous traffic sign and signal condition.

3.2 Stage II: Determination of relative importance (weights) of safety factors

The road sections and safety factors discussed in the previous section, may not equally affect the safety of a road. A system of weights therefore needs to be introduced to reflect the contribution to safety of each section and factor. The relative weights of the above sections and subsequent factors are determined using analytical hierarchy process (AHP). AHP can find the contribution of each safety factors in each section. Moreover, if there is a hierarchy of items, as is the case in this study, where there are Sections and then safety factors. Mathematically, AHP uses pair-wise comparisons to systematically scale the items. It calculates the eigenvalues of the Relative Weight Matrix (RWM), and determines the relative weights by determining the eigenvector (Agarwal, 2006). The analytical hierarchy process is as follows:

- Define the problem and determine the kind of knowledge sought.
- Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent Sections depend) to the lowest level (which usually is a set of the alternatives).
- Construct a set of pair wise comparison matrices. Each section in an upper level is used to compare the sections in the level immediately below with respect to it.
- Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every Section. Then for each Section in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained. To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one Section is over another Section with respect to the criterion or property with respect to which they are compared. (Saaty, 2008)

Table 1 presents relative importance of safety factors for straight section, curve section and intersections. Analysis details for determination of these weights are presented elsewhere (Patil, 2013)

Table 1: Relative importance (weight) of safety factors at straight section, curve section and intersections

S.No.	Name of Safety Factors	Straight Section (SFS)	Curve Section (SFC)	Intersection (SFI)
1.	Hazardous Geometrical Condition	0.0270	0.0675	0.1700
2.	Hazardous Surface Condition	0.0330	0.0825	0.1900
3.	Hazardous Shoulder Condition	0.0114	0.0228	0.0700
4.	Hazardous Drainage Condition	0.0086	0.0172	0.0400
5.	Hazardous Street Light Condition	0.0075	0.0175	0.0363
6.	Hazardous Road Marking Condition	0.0051	0.0119	0.0242
7.	Hazardous Island Condition	0.0016	0.0140	0.0290
8.	Hazardous Traffic Sign And Signal Condition	0. 0158	0.0266	0. 0705
	Total of Weights	0.11	0.26	0.63

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3.3 Stage III: Determination of rating of safety factor Condition

This Stage III discusses a methodology to determine rating of safety factor condition. Rating of safety factors is determined to each safety factor according to present condition of safety factors. Condition rating is assigned between zeros to one, zero is assigned for no deviation with standard condition and its value increases up to one for very poor condition of safety factors. Table 2 presents condition rating of road safety hazardous factors.

Table 2: Condition rating of a road safety factors

S.No.	State of Condition	Value
1.	Excellent Condition	0
2.	Good Condition	0.1 - 0.24
3.	Average Condition	0.25 - 0.49
4.	Poor Condition	0.5 - 0.75
5.	Very Poor Condition	0.75 – 1

3.4 Stage IV: Ranking of road safety hazardous locations

This stage IV presents a methodology to rank road safety hazardous locations. The Safety Hazardous Index is developed using weight of safety factors and condition rating of safety factors. The Safety Hazardous Index is developed separately to evaluate safety at straight section, safety at curve section and safety at intersection and presented in equation 1 to equation 3 respectively. Ranking of road safety hazardous locations is evaluated by determination of safety hazardous index at straight sections, curve sections and intersections.

- Ranking of Road Safety Hazardous Location at Straight Sections

$$SHIs = \sum_{\yen SF} W_{SFS}\, x\, R_{SFS} \qquad \text{Equation........ (1)}$$

Where,

SHIs = Safety Hazardous Index at straight section
W_{SFS} = Weight of safety factors at straight section (to be obtain from column 3 of table 1)
R_{SFS} = Condition rating of safety factors at straight section (to be obtain from table 2)

- Ranking of Road Safety Hazardous Location at Curve Sections

$$SHIc = \sum_{\yen SF} W_{SFC}\, x\, R_{SFC} \qquad \text{Equation........ (2)}$$

Where,

SHIc = Safety Hazardous Index at curve section
W_{SFC} = Weight of safety factors at curve section (to be obtain from column 4 of table 1)
R_{SFC} = Condition rating of safety factors at curve section (to be obtain from table 2)

- Ranking of Road Safety Hazardous Location at Intersections

$$SHI_I = \sum_{\yen SF} W_{SFI}\, x\, R_{SFI} \qquad \text{Equation........ (3)}$$

Where,

SHI_I = Safety Hazardous Index at intersection
W_{SFI} = Weight of safety factors at intersection (to be obtain from column 5 of table 1)
R_{SFI} = Condition rating of safety factors at intersection (to be obtain from table 2)

Further, Safety hazardous index for entire road section (SHI_{RS}) can be obtain by summation of safety hazardous index at straight section, curve section and intersections as presented in equation (4).

$$SHI_{RS} = SHI_S + SHI_C + SHI_I \quad \text{Equation........ (4)}$$

Where,

SHI_{RS} = Safety Hazardous Index at entire road section
SHI_S = Safety Hazardous Index at straight section
SHI_C = Safety Hazardous Index at curve section
SHI_I = Safety Hazardous Index at intersection

Further, it is to be noted that higher safety hazardous index at a particular location indicates more safety hazardous conditions at that particular location.

To illustrate how efficiently the proposed methodology is working in ranking safety hazardous locations, Safety hazardous index for different road section using data for section of NH-8 between Jaipur and Kiashangarh were determined. The safety hazardous index determined using proposed methodology for different sections were compared with the number of accident reported at those sections. The analysis results indicated that the methodology proposed in this study is able to rank safety hazardous locations satisfactorily. Detailed analysis and results are presented elsewhere (Patil 2013).

4. Conclusion

The main objective of this study was to development of a methodology for ranking of road safety hazardous locations. The following conclusions have been drawn based from the study:

- There is an urgent need to reduce the number and severity of road accidents by implementing remedial measures at hazardous locations in the road network. Further, it is generally not possible to implement all remedial measures identified due to limited budget available for road safety improvement. Hence, it is needed to rank the hazardous locations so that depending on the available budget, the hazardous locations can be treated.
- Study of critical Literature indicated that most of the methodologies require accident data for ranking of road safety hazardous locations. Often comprehensive accident data are not available. Even if accident data is available, it is difficult to analyze this data due to its poor quality. Therefore, it is important to develop a methodology for ranking road safety hazardous locations without using any accident data.
- A four stages methodology for ranking of road safety hazardous locations is proposed in this study. Various stages identified are Stage I: Identification of safety factors; Stage II: Determination of relative importance of safety factors; Stage III: Determination of rating of safety factors condition and Stage IV: Ranking of road safety hazardous locations.
- The methodology presents a hierarchical structural for identification of safety factors. Road safety hazardous conditions are decomposed into safety hazardous condition at straight sections, safety hazardous condition at curve sections and safety hazardous condition at intersections.

- The relative importance (weight) of safety factors of a road section is determined using the AHP using a system of weights which are suggested by an expert team. Weights are developed for safety factors at straight section, safety factors at curve section and safety factors at intersection,
- Another important outcome of this study is a Safety Hazardous Index. This Safety Hazardous Index can be used for ranking safety hazardous locations in a road network. The Safety Hazardous Index is developed using weight of safety factors and condition rating of safety factors. The Safety Hazardous Index is developed separately to evaluate safety at straight section, safety at curve section and safety at intersection. Higher the safety hazardous index at a particular location indicates more safety hazardous conditions at that particular location.

Thus, it is expected that this study will be useful in treating more hazardous locations depending on the available budget for road safety improvement. It is also expected that the approach presented in this study can be utilised to quantify the road safety audit results to rank high risk, medium and low risk locations

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