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Identification and Ranking of Road Safety Hazardous Locations: Case Study of Kotre–Aabhukhaireni Section of Prithvi Highway

Srijan Subedi Chowi[1], Padma Bahadur Shahi[2 *], Sudeep Thapa[3]

[1]*Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal, srijansubedichowi@gmail.com*
[2] *Nepal Engineering Council, Minbhawan, Kathmandu, Nepal, pb_shahi@yahoo.com*
[3] *Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal, sudeepthapa0818@gmail.com*

Abstract

In Nepal, due to rapid urbanization, there are many emerging towns and settlements near highways, which have raised issues of increased traffic density resulting in frequent road crashes like in Kotre- Aabhukhaireni section of Prithvi Highway. Higher crash rates depict lower safety conditions. To improve safety conditions and reduce the loss of life and property, hazardous conditions along the highways need to be identified and ranked for treatment purpose. This study is based on a methodological framework for identifying hazardous locations based on a Field Survey (condition rating) and Analytical Hierarchy Process (AHP) for ranking road safety hazardous locations of Kotre- Aabhukhaireni road Section of Prithvi Highway by weighing the safety parameters of the road section and calculating the Safety Hazardous Index (SHI). Field condition rating with a focus on pavement surface conditions, structural conditions, shoulder and drainage conditions, pedestrian infrastructure and vehicle restraint system, street lighting, traffic signs, island and road marking conditions was conducted, and risk factors were identified by comparing these variables against norms.
The study identified 15 different locations as safety hazardous locations. The results showed Yampa, Baradi, and Chirrkeni as the most hazardous ones with an SHI index of 0.852, 0.773 and 0.712 respectively, among the study section considered. In contrast, Dhaaptar was considered as the least hazardous one with SHI value of 0.210.

Keywords: Road Safety, Analytical Hierarchy Process, Identification and Ranking, Road Safety Hazardous Locations, Weightage of Safety Factors, Condition Rating, without using crash records

1. Introduction

Road crashes are increasing in the world. Thousands of people are killed or severely injured on world roads every day. Road traffic injury is now the leading cause of death for children and young adults aged 5-29 years. It is the eighth leading cause of death for all age groups, surpassing HIV/AIDS, tuberculosis and diarrheal diseases (World Health Organization , 2018).The burden of road traffic injuries and deaths is disproportionately borne by vulnerable road users and those living in low and middle-income countries (World Health Organization , 2018).As per the report, the number of deaths on the worlds roads remain high with 1.35 million people dying each year. With an estimated 1.7 billion people, South Asia represents around 25 percent of the world's population and is the least urbanized region in the world. It has 10 percent of the world's vehicle fleet, and accounts for 25 percent of worlds crash fatalities (Keats, et al., 2020).The rates of road traffic death are highest in Africa (26.6/100,000 people) and South-East Asia (20.7/100,000 people) (World Health Organization , 2018).

Nepal is among the low-income countries in South Asia (Keats, et al., 2020) . Road crash fatalities have been on an increasing trend in recent years. Due to increased fleet and speed, traffic safety management has emerged as a challenging issue in Nepal. Considering the heavy loss of lives and wealth in road crashes the concerned road and traffic management agencies have started to incorporate road safety issues in their program. Before taking any

*Corresponding Author

measures for the betterment of the existing conditions, data collection and analysis of the hazardous places along the roads and the hazardous factors causing such crash is essential. However, studies on identification and treatment of hazardous road locations is given less priority in developing countries like Nepal

Though the data obtained from this can provide a lot of useful information for formulation of road safety strategies. Study of different literatures suggests that a large number of methods that are proposed for identification and treatment of the safety hazardous road locations require detailed crash information. These crash record-based methods which are considered as a solution to the road safety problems require information which are quite expensive, time consuming and casualty-intensive to acquire. Also, it is generally not possible to implement all the remedial measures identified due to limited available for road safety improvement. It can be very beneficial to present a method that is able to identify the hazardous road locations without the use of crash data within a short time (Mahmoudreza, et al., 2017)

1.1 Statement of the Problem

Road crashes are increasing along National highways and feeder roads. In between the fiscal years 2016-2019 , Prithvi Highway(Kotre- Aabhukhaireni section alone) has recorded a total of 207 road traffic crashes resulting 35 fatalities, 31 serious injuries and 22minor injuries and 119 property damage only (District Traffic Police report, Damauli).With due priority it is necessary to focus on road safety issues because these road traffic crash related fatalities and injuries continue to be an important morbidity and mortality problem in Nepalese Highways (Ojha, 2021).Crashes along the roads could also be influenced by roadside parameters like road geometry, road alignment, and other road traffic and road side environmental factors. So, Road Safety improvement from the perspective of road environment condition and transportation infrastructures along the roads is necessary. However, hazardous locations along highways and road networks are present in randomly dispersed form and it is needed to identify and rank hazardous locations present amidst road networks so that depending upon the available budget, these hazardous locations can be treated.

Unfortunately, in less developed countries like Nepal, the importance of accurate recording of crashes for future uses is not properly explained and present crash database has many shortcomings. In comparison to length of road, fewer police presence in highways with the lower importance grade has led to the failure to record many crashes. Further, due to the lack of recording geographic co-ordinates, there is no proper information for identifying crash hazardous locations with crash record-based method. Thus, reliance on the methods based on crash data for identification and ranking of hazardous road locations needs to be reconsidered. To improve the level of safety conditions on highways and overcome the problems faced on the crash-based methods it is necessary to identify and rank safety hazardous locations independent of the information from the crash records. Prevailing efforts in road safety seems to be more focused on the vehicle and driver issues, often neglecting the role of road infrastructures. So, identification and treatment of hazardous segments with focus on road infrastructure needs to be carried out.

1.2 Research Question

Based on the above problems, the following research questions have been formulated:

- What are the “road” related factors for the identification of hazardous locations along highways?
- How do we rank the hazardous road locations for treatment purposes?

1.3 Research Objectives

The main objective of this research is to identify hazardous locations and rank those locations for safety improvement. For this, the terminology “Safety Hazardous Index” is defined as the risk of a parameter or feature causing road crashes. The specific objectives of the study are:

- To determine road-related factors for identifying safety hazardous locations.
- To derive the relative weights of identified risk factors and identify the hazardous road locations along the study section of Prithvi Highway.

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1.6 Significance of the Study

This study aims to identify and rank the road safety hazardous locations without using crash records. Prithvi Highway is the main link road to connect Kathmandu Valley with western Nepal, including some big cities like Pokhara and Narayanghat. This two-lane highway, after completion is now facing serious allegations of being unsafe due to rapid urbanization and land use patterns. Increased crash statistics in recent years shows the necessity for the identification and treatment of hazardous section along this highway. This analysis provides an insight into the influence of road safety factors on road crashes in the study region. So, this information could be used by concerned authorities like the Department of Roads (DOR) and the Department of Transport Management (DoTM) to improve road features along the study region. The findings from this study can be used to identify highest and lowest risk segments along a highway or even for network safety analysis of a region. The data obtained will be help treat safety issues before any further crashes occur. The findings of this Study and the data obtained can be used as a base for further research on determination of proactive measures for the identification of hazardous locations where standard crash data are limited or unavailable.

1.7 Scope of Study

The purpose of this study is to identify road safety hazardous locations and rank these locations for proper treatment. This study considers deficiencies among road cross-section elements and other road environment-related physical parameters as the risk factors that contribute in making an individual site a road safety hazardous site. Based on the presence of these factors on any location, safety hazardous locations are identified. This study uses the AHP method to analyze the judgmental opinions obtained from the respondents to rank those identified hazardous locations.

The Study was conducted along Prithvi highway on a span of 70 kilometers starting from Kotre Bridge to Aabhukhaireni within Tanahun district on the year 2077 B.S. The study collected opinions from 20 respondents who were familiar with the study section and had worked in Department of Roads, division office Damauli. All the respondents were engineers familiar with the region and had experience on works related to road safety. Judgment-based opinions were collected using an online questionnaire form sent through email, and the response was analyzed using the AHP method to derive relative weights.

2. Literature Review

Potential safety hazardous locations along a road are generally those sites whose nature of the problem(s) are unknown, and the potential treatments are yet to be determined. The basic definitions, identification criteria, and treatment methods for proper treatment of Safety hazardous locations along the roads vary country wise across the globe (Rune , 2008)

2.1 Identification based on Crash Data

The record-based hazardous road location identification method is also known as the reactive approach. This method of identification of hazardous locations relies on the analyses of available accident data to identify potential safety hazardous locations. Potential safety hazardous sites or locations are generally those sites whose nature of the problem(s) are unknown, and the potential treatments are yet to be determined. Some of the commonly used methods for the identification of hazardous road sections based on accident data are listed below.

- Accident Frequency

- Accident Rate
- Critical Accident Rate
- Equivalent Property Damage Only Index
- Relative Severity Index
- Empirical Bayesian Method

2.2 Identification without using Crash Data

The following are some of the methods which don't require an accident data mainly and are based on expert guidance.

2.2.1 Analytical Hierarchy Process (AHP) Method

The Analytical Hierarchy Process is a model based on decision modeling which relies on developing a hierarchy to analyze a decision. The analytical Hierarchy Process (AHP) structures the problem as a hierarchy. By reducing the complex decisions to a series of pair-wise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. Furthermore, AHP is a helpful tool for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision-making process. For using the analytical hierarchy process, we should follow the following steps (M & E, 2017).

- Develop a model for the decision: Break down the decision into a hierarchy of goals, criteria, and alternatives.
- Derive priorities (weights) for the criteria: The importance of criteria is compared pair-wise to the desired goal to derive their weights. We then check the consistency of judgments, that is, a review of the judgments is done to ensure a reasonable level of consistency in terms of proportionality and transitivity.
- Derive local priorities (preferences) for the alternatives. Derive priorities or the alternatives with to each criterion separately (following a similar process as in the previous step. Check and adjust the consistency as required.
- Derive overall priorities (model synthesis): All alternative priorities obtained are combined as a weighted sum to take into account the weight of each criterion to establish the overall priorities of the alternatives. The alternative with the highest overall priority constitutes the best choice.
- Perform sensitivity analysis: A study of how changes in the weights of the criteria could affect the result is done to understand the rationale behind the obtained results.
- Making a final decision: Based on the synthesis results and sensitivity analysis, a decision can be made.

2.2.2 Floating Car Data (FCD) Method

This method is based on Global Positioning System (GPS) data from moving cars. This model is based on the same idea as the Swedish Conflict Study Technique, from which it is known that there is a connection between the numbers of serious conflicts, which can be seen as near accidents, and the number of accidents in a location. It is assumed that strong decelerations (m/s2) and in particular jerks (m/s3) in the same way as conflicts indicate near accidents, and that there is connection between the number of really strong deceleration and jerks and the number of accidents in the location. (Lahrmann & Niels, 2012).

2.3 Ranking Methods

AHP model has been used by widely implemented in a large number of road safety related researches and many researchers have used this method to identify and rank road safety hazardous locations. For instance, (Agrawal, et.al., 2013; Habibian , et.al., 2011) used AHP as a tool in their methodology to rank black spots in terms of Safety Hazardous Index and Safety Index respectively, whereas (Mahmoudreza, et al., 2017) attempted to identify and priorities black spots using AHP but without the use of accident information.

2.4 Saaty's Scale

For the determination of weight of items in AHP, Saaty, 1990 suggested the use of Relative weight matrix (RWM). This process is based on pair-wise comparisons. An expert is asked to compare each two items and associate a relative importance to a pair. The relative importance is assessed using the scale as shown in table below. If an item 'x' is more important than item 'y' then its importance is mapped on a scale of 1 to 9 whereas, the relative importance of item 'y' to item 'x' is the reciprocal of the importance of item 'x' to item 'y'((Habibian , et al., 2011); (L., 2008); (M & E, 2017)).

Table 1: Saaty's Rating Scale

Relative importance	Qualitative Scale	Description
1	Equal importance	Two criteria pay equally to the accident factor
3	Moderate importance	Experience and judgment slightly favor one criterion over another
5	Strong importance	Experience and judgment strongly favor one criterion over another
7	Demonstrated importance	A criterion is favored very strongly over another
9	Absolute importance	The evidence favoring one criterion over another is of the highest possible order of affirmation
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	

Study of critical literatures indicated that most of the studies that were done are based on statistical modeling. Although statistical model-based methods help better understand and improve the understanding of the safety performance of roads, they all require crash data. Comprehensive crash data are not available and even if crash data is available, it is difficult to analyze this data due to poor quality. The preparation of such databases is often expensive and time-consuming. As a result, there is often a general lack of this type of crash data; particularly in the case of developing countries like Nepal. Safety audit-based techniques has also been presented as an alternative to this problem but literature reviews showed that this technique was limited either for ranking purpose only or was limited to identification only. In this research, identification of safety hazardous locations will be carried out by field condition rating and for the ranking of those identified hazardous locations AHP model will be used. Crash records are not required for both the cases. AHP was used over FCD in this research work since research methods for FCD method itself needs to be finalized since the researchers who worked on FCD methods gave different theories for the identification of hazardous road locations. (Lahrmann & Niels, 2012).

3. Methodology

The research was conducted to identify and rank hazardous road locations within Kotre – Aabhukhaireni Section of Prithvi Highway. Based on the literature reviews, the methodology chosen for this research was exploratory survey research. Following chapter highlights the research flowchart, approach used to perform the research, data collection sample size etc.

3.1 Research Design

The study was an exploratory survey research. To achieve the objectives of this research, analysis of online questionnaire data and field survey data is required. So, online questionnaire survey, reconnaissance survey and field condition rating, comparison with guidelines were carried out to fulfill the data requirements of this research. The data obtained were analyzed and this provided the current scenario of the road safety hazards in the selected study section. The study was designed to study existing condition of the road network and then to identify and rank hazardous road locations. Methodological flowchart developed and followed for the research study is presented in table 3.1.

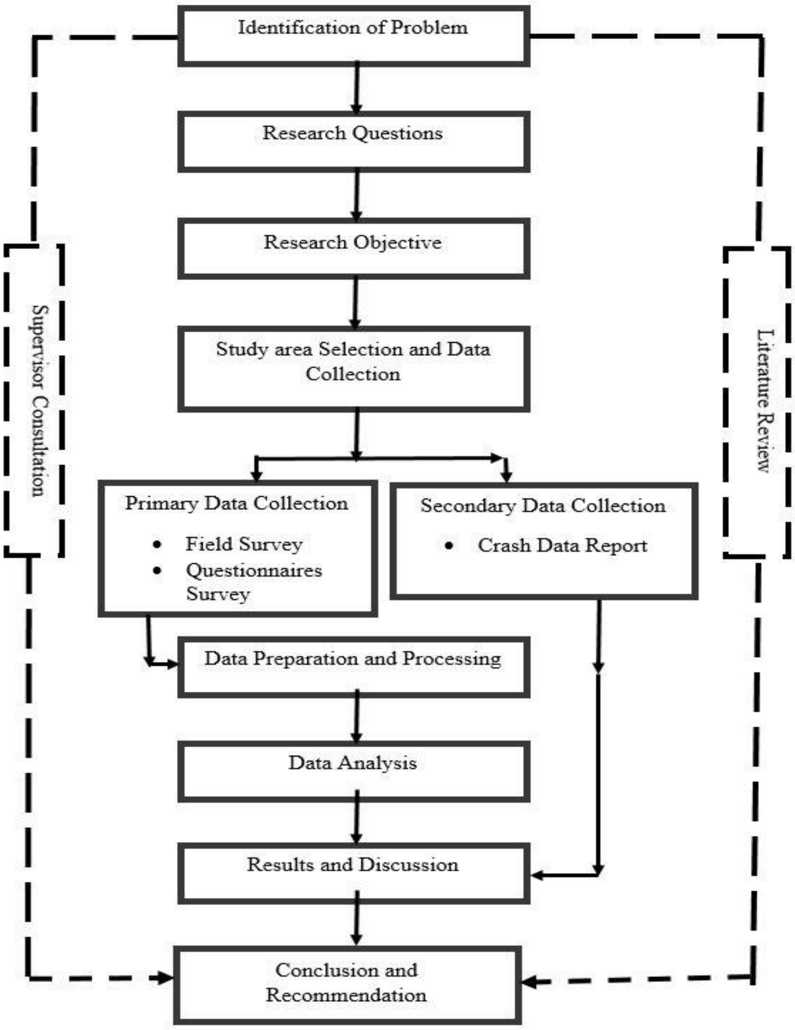

Figure 1: Methodological Flow Chart

3.2 Research Approach

In this study qualitative research approach has been followed. This approach was used since this research deals with questionnaires that relates to variations in experience and judgment.

3.3 Study Area

Road segments of Prithvi Highway, starting from Kotre Bridge to Aabhukhaireni (Marsyandi hydropower Station) section located in Tanahun District of Gandaki province was selected in this work as study area. The total length of the study section chosen for this research was 70 kilometers starting from Kotre Bridge to Aabhukhaireni within Tanahun District of Gandaki Province. This section length is chosen for the study purpose as crashes along this section of the highway was found to be in increasing order in recent years as per the records presented by district traffic police office.

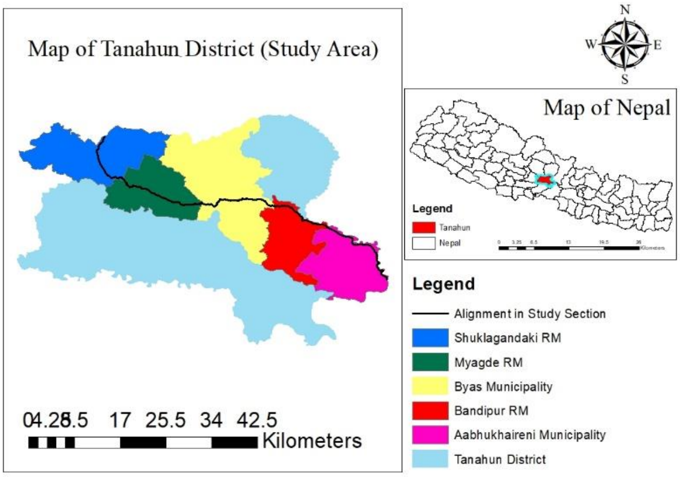

Figure 2: Site area

3.4 Study Population and Sample Size

This study evaluates opinions regarding factors of road crashes using pairwise comparison questionnaire form. So the respondent population for this study is required to have knowledge about the criteria and factors involved in the form along with their familiarity with the road environment conditions within the study area. So the questionnaire form was asked to a selected groups of highway department personnel involved in department of roads, road division Damauli, and engineers well familiar with the region.

The population under this study includes engineers from department of roads division office Damauli, and Kaski who are familiar within the study route and had adequate knowledge about elements and factors considered in the study that may influence the occurrence of crashes. The study population size was 22.

A census is attractive for small population since it eradicates sampling error and provides data on all the individuals in the population. Another approach is to use the sample size as those of studies similar to the one with the research planned. (Panta, 2016(Revised))

Literature review of similar studies conducted were also studied for determination of the typical sample size used. (Najib, et al., 2012) Used linguistic judgment data collected from three experts in his research study. (Habibian , et al., 2011) Conducted his research study from the results of the survey conducted on five experts in Iran. (Mahmoudreza, et al., 2017) Concluded his research using the judgments passed by five road traffic experts familiar with route.

Literature reviews have recommended census study on all the individuals however from study population 22, the sample size of 20 respondents was used for this research purpose. The 2 samples were discarded due to inconsistencies during AHP calculations

3.5 Data Collection

3.5.1 Primary Sources

The primary data for this work consisted of an actual field survey and an online questionnaire survey data. Actual field survey was carried out to study the current infrastructure conditions. For data collection through field survey, the study route was divided into five sub sections. This division was performed based on the uniformity and homogeny of each section in terms of regional conditions. Further these sub sections were divided into three classes. The classes were straight sections, curved sections and intersections. A checklist was prepared following the guidelines and sample checklists as per road safety audit manual. (Traffic Engineering and Safety Unit, 2053).Checking the site against "norms" was carried out by comparing the "road" factors condition against minimum prescribed values obtained from Nepal road standard 2070 published by Department of Roads. Following are the suggested headings for site inspection recommended by road safety Note 8 ((Traffic Engineering and Safety Unit, 2053).

- Drainage conditions
- Pavement surface condition

- Cross section elements and road side safety structures
- Pedestrian infrastructure
- Traffic signs, signals
- Markings
- Road Guidance signs, symbols
- Vehicle restraint systems
- Lightening
- Vegetation

The above-mentioned headings were also recommended by the authors of different literatures and research articles working on this issue. Findings from the research study by (Habibian , et al., 2011), (karlaftis & Golias, 2002), (Sajed , et al., 2019), (Agrawal , et al., 2013) were studied and according to the recommendations and relevance with the objective of this study the headings were finalized. The risk attributes chosen for the study are also identified in Road Note 8. Although, these risk attributes are not only the factors that contribute in road safety, other factors like super elevation transition, gradient change also affect road safety, but vague information is available on the proven relationship between these factors and crash statistics in our highway conditions. Another research study focused on establishing the relationship between crash frequency and these factors is required which in fact does not comply with the objective of this exploratory research. For this very reason, the study is focused on the analysis of these Road Note 8 identified factors.

Questionnaire survey was conducted to obtain opinion of transportation engineers and technical employees from department of roads, division office Damauli about various safety hazardous road conditions. These engineers and employees were asked to fill the online questionnaire form sent through their mail. They were asked to rank the safety hazardous conditions according to the Saaty's scale according to their own perception. The information thus obtained was used to derive the relative weightage of various safety hazardous road conditions using Analytical Hierarchy Process (AHP) methodology. The hierarchy table for online questionnaire used in shown in Appendix 4.

Description of the information's is listed down in the following Table 2: Description of Information Obtained. The description of the criteria presented here in table 3.1 are recommendations provided by Permanent International Association of Road Congress (Turner & Griffith, 2003).

Table 2: Description of Information Obtained

Criteria	Description
Hazardous pavement conditions	Condition of road surface in (ruts, cracks, potholes), soiling conditions problematic for two –wheeled vehicles. Appropriate Conditions of cross section for the function of all road users. Appropriate width conditions for driving lanes, shoulders Presence of breakdown bays in absence of hard shoulders Presence of Space and width for pedestrians waiting on traffic islands Presence of facilities to capture falling rocks
Hazardous structural Conditions	
Hazardous shoulder conditions	Type of shoulder, width, fences, access to the carriageway Are drain grades on the road surface arranged so that two wheeled vehicles can safely use the road? Overgrown verge, protruding manhole covers, insufficient single gradient drainage.
Hazardous Drainage Conditions	Design of drain outlets, transverse barriers in troughs Necessity of road area to be lighted. Traffic area lighted sufficiently or not?
Hazardous street lighting conditions	Presence of areas with special lightening conditions e.g., pedestrians' crossings, pedestrian paths Light poles shielded or not? Visibility of road markings and how easy to recognize them? Are transitions (merging lanes, entrance and exit lanes sufficient and clearly marked? Are remainders of old markings visible?
Hazardous road marking conditions	Do road markings match the road signs? Are the traffic signs clearly visible and legible (not blocked by vegetation, advertisement boards and banners) Condition of traffic signs and visibility at night Are the signposts adequately shielded?

Criteria	Description
Hazardous Traffic signs and signals	Are restrictions such as passing prohibitions or speed limits necessary or sensible in intersections? Do the center islands in roundabouts sufficiently divert the incoming traffic? Is lightening necessary, or is the existing lightening system sufficient? Can the road be crossed safely by bicyclists and pedestrians?
Hazardous island conditions	Are there obstacles on center islands in roundabouts that could be struck by a vehicle leaving the road? Is there traffic congestion in the roundabout or on the approaches? Are there objects on the center island that could cause severe consequences in the event of a collision?
Hazardous island conditions(continued)	
Hazardous road guidance system	Are guidance systems present or necessary on the section to influence the traffic flow with information? Condition of the guidance systems at the intersection. Is visibility at night sufficient?
Hazardous vegetation conditions	Does the vegetation block the visibility? Does the vegetation cause light/shadow alteration? Can vegetation cause sudden changes in the road conditions like slower evaporation on wet road surface? Can vegetation cause limitations on road for road users like pedestrians?
Hazardous pedestrian infrastructure	Presence or absence of unprotected crossings at the intersection? Are the pavement widths sufficient for persons with reduced mobility, or are there obstacles? Are there other obstacles in the clearance zone that could cause problems for pedestrians? Are there schools in the inspected area? Is additional or special measure needed here? Are school routes protected (crossing guards)? Are pedestrian crossings appropriately lighted?
Hazardous vehicle restraint system	Are there short, avoidable gaps in the vehicle restraint system? Are solid obstacles along the road adequately shielded by vehicle restraint systems? Is the length of the vehicle restraint system sufficient? Is it in good condition? Are impact absorbers necessary?

(Source: (Turner & Griffith, 2003))

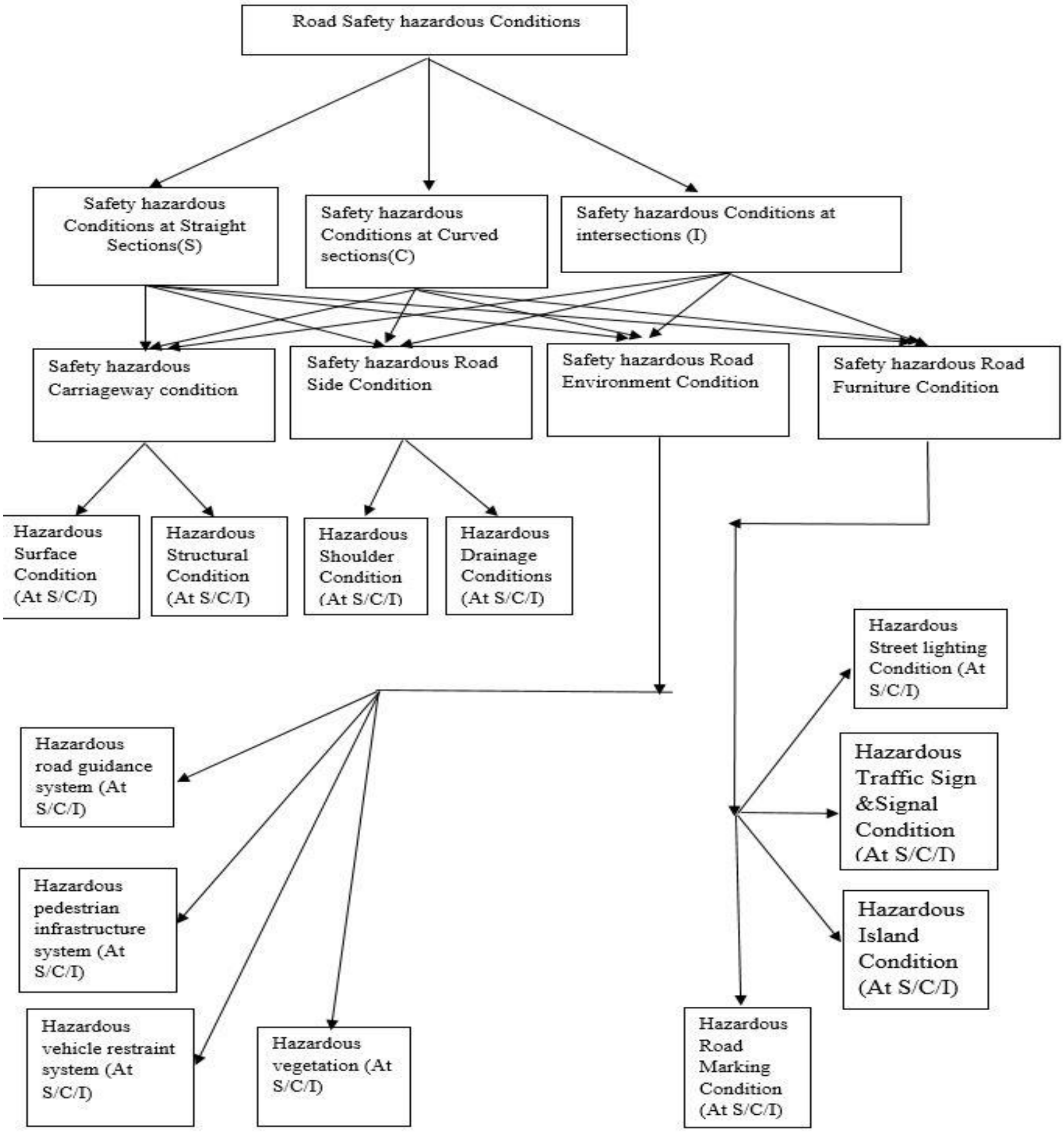

Figure 3: Hierarchical Structure of Criteria

Source: (Agrawal , et al., 2013)

The online questionnaire form was designed on the basis of the above-mentioned Hierarchical structure for analytical hierarchy process. The survey form included a total of 63 questions divided into 16 sections.

3.5.2 Secondary Sources

Crash Records obtained from District traffic police office Tanahun in the form of word documents and scanned crash data reports were used as secondary data source for this research work. The use of this secondary data was done only to compare the obtained results from this research with findings from crash-based methods within the study section. Secondary data obtained hereby from traffic police provided information about the approximate location of the crash, type and number of vehicles involved, time of the day, road section type, pavement surface condition of the road section, type of the collision, fatalities involved etc. Information regarding road side attributes, road infrastructure and road side facilities present at the time of crash reporting etc. were lacking on this data.

3.6 Data Analysis Tools and Techniques

Based on the data obtained from field investigation and online questionnaire, inferences were made in this section. The detailed analysis was done in this section. The basic flow chart of the data analysis is provided inFigure 4: Flowchart of Data Analysis.

. The algorithm that was used is as follows.

Stage 1: Identification of "road" Factors

On the basis of literature review related to AHP and road safety and field visit, road safety conditions along the study section were divided into Straight sections, Curved Sections and Intersections. Road infrastructures in each of these sections were subdivided into safety conditions in terms of Carriageway conditions, Road side condition, Road environment condition and road furniture conditions. A reconnaissance survey was carried out along the study section. Physical infrastructures present along the road sections were listed, and classified as per the sub headings mentioned above (carriageway elements, road side elements, road environment elements and road furniture elements). Field condition and measurements were taken. By comparing the observed road conditions against norms and minimum standards, road infrastructures that were not complying were listed as road factors affecting safety. The road infrastructure related headings under which the road segment was studied are listed below:

For Straight Sections

a) Drainage Condition
b) Road Surface Condition
c) Structural Condition
d) Shoulder Condition
e) Road guidance provision
f) Pedestrian Infrastructure facilities
g) Vehicle restraint provision
h) Vegetation
i) Road Markings
j) Street lighting provisions
k) Traffic Sign and signal conditions

For Curved Sections

a) Drainage Condition
b) Road Surface Condition
c) Structural Condition
d) Shoulder Condition
e) Road guidance provision
f) Pedestrian Infrastructure facilities
g) Vehicle restraint provision
h) Vegetation
i) Road Markings
j) Street lighting provisions
k) Traffic Sign and signal conditions

For Intersections

a) Drainage Condition
b) Road Surface Condition
c) Structural Condition
d) Shoulder Condition
e) Road guidance provision
f) Pedestrian Infrastructure facilities
g) Vehicle restraint provision
h) Vegetation
i) Road Markings
j) Street lighting provisions
k) Traffic Sign and signal conditions
l) Island Conditions

Road infrastructures that were observed not in functional state or not in compliance with minimum guidelines were listed as safety hazardous factors and the locations on which these shortcomings were observed are listed as hazardous locations. Most of the risk attributes considered for straight, curved and intersections are similar since these factors are common road infrastructures identified on Road Note 8 that contribute on safety parameters of the highway alignment. Although, there still are a lot more unique parameters (e.g., gradient change, introduction of super elevation on curves) contribute on safety factors, they are discarded since such parameters needs individual case assessment and establishment of relationship with crashes. This could lead to a whole different aspect of the research.

Stage 2: Allocation of Relative weights to factors and elements using AHP

The next step involved is to allocate the weightage of safety hazardous parameters identified on stage 1. For this analysis Analytical Hierarchy Process (AHP) is used. 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 (Saaty 1990). The process is as follows:

1. Set up a RWM for each level in the hierarchy
2. Calculate the eigenvector of the RWM(s).
3. Measure the consistency of the comparisons.

The weights of the items will be found out by using a RWM (Saaty, 1990). Experts will be asked to compare each two items using a questionnaire and associate a relative importance to the pair. Experts who are familiar with the region and the road and transportation officers directly concerned will be asked to state the pair-wise comparisons in order to construct the RWM. The relative importance is assessed using Saaty's scale (Saaty and Wong 1983). To determine relative importance of categories. After scaling the relativeness of the data and constructing the pairwise comparison matrix, the decision matrix would be as follows as shown in table 2

Table 3: Decision Matrix for each level

Matrix	A	B	C
A	1	A	B
B	1/a	1	C
C	1/b	1/c	1

Here a, b, c are the comparisons with respect to each other in Saaty's scale

Since these numeric values are derived from the subjective preferences of individuals. It is impossible to completely eradicate the inconsistencies in the final matrix of judgments. So, before deriving any conclusion by processing this decision matrix, consistency check will be carried out for the respondent's judgments. The consistency check involves calculation of Consistency Index (CI).

In order to determine the Consistency Index, Eigenvector vector (Aij) value of each decision matrix will be calculated.

Eigen Value will be calculated using the formula shown as below (M & E, 2017).

$$\lambda = \frac{\sum_{j=1}^{n}(\sum_{i=1}^{n} A_{ij})wj}{A_{ij}} \quad \text{Eq. (3)}$$

Once the Eigen vector value is determined, the matrix is subjected to consistency check with the following formula (M & E, 2017).

$$\text{Consistency Index (CI)} = \frac{(\lambda_{\text{max}}-1)}{(\text{n}-1)} \quad \text{Eq. (4)}$$

The consistency index is compared against a reference average random index (RI). The ratio of consistency index, CI to the random consistency index RI is called consistency ratio (CR).CR is acceptable if it does not exceed 0.10 (L., 2008). If the CR of CI is greater than 0.10, the judgment matrix should be considered as inconsistent. The calculation will be repeated for all developed decision matrix of each individual responses.

Consistency ratio,

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

Online based calculator software designed especially for the calculation of priorities and consistency check of the decision matrix used in AHP model. (Goepel, 2018).

The results for relative weights of each element under each class (straight section, curved section and intersections) are calculated. The individual relative weights values obtained from each individual decision matrix of individual responses were calculated and averaged. The averaged values thus obtained was used for further analysis.

Stage 3: Field Survey

The calculated weights thus obtained was then used to conduct an overall assessment of the study road section based on the relative importance of each element. The overall safety assessment was carried out through field survey. This was carried out in following steps:

1. Reconnaissance Survey

2. Facilities check

3. Comparison with guidelines

4. Condition Rating

Inspection and scoring of each criterion based on the deviance with standard conditions was carried out. For scores of the actual field conditions with standard safety conditions, scores were assigned from 0 to 1, where 0 is assigned for no deviation with standard condition and its value will increase up to one for very poor condition. Table 3.4 below represents the condition and scores to be assigned.

Table 4: Score Table of Safety Factors

S.No.	State of condition at the field	Value
1	Excellent condition (No deviance	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

Source: (Agrawal , et al., 2013)

Stage 4. Determination of Safety Hazardous Index

Now a safety Hazardous Index (SHI) of the road will be determined as the weighted sum of the factor scores as below.

Ranking of Road Safety hazardous locations at Straight Sections

$SHIS = \Sigma\ WSFS \times RSFS$ Eq. (6) (Agrawal , et al., 2013)

Where,

SHIS = Safety Hazardous Index at Straight Section

WSFS = Weight of Safety Factors at Straight Section

RSFS = Condition rating of Safety Factors at Straight Sections

Ranking of Road Safety Hazardous Location at Curved Section

$SHIC = \Sigma\ WSFC \times RSF$ Eq. (7) (Agrawal , et al., 2013)

Where,

SHIC = Safety Hazardous Index at Curved Section

WSFC = Weight of Safety Factors at Curved Section

RSFC = Condition rating of Safety Factors at Curved Sections

$SHII = \Sigma\ WSFI \times RSFI$ Eq (8) (Agrawal , et al., 2013)

Where,

SHII = Safety Hazardous Index at Intersection

WSFI = Weight of Safety Factors at Intersection

RSFI = Condition rating of Safety Factors at Intersections

Further it is understood that higher the safety hazardous index at a particular location more safety hazardous conditions are present at that particular location. Thus, more hazardous the location is.

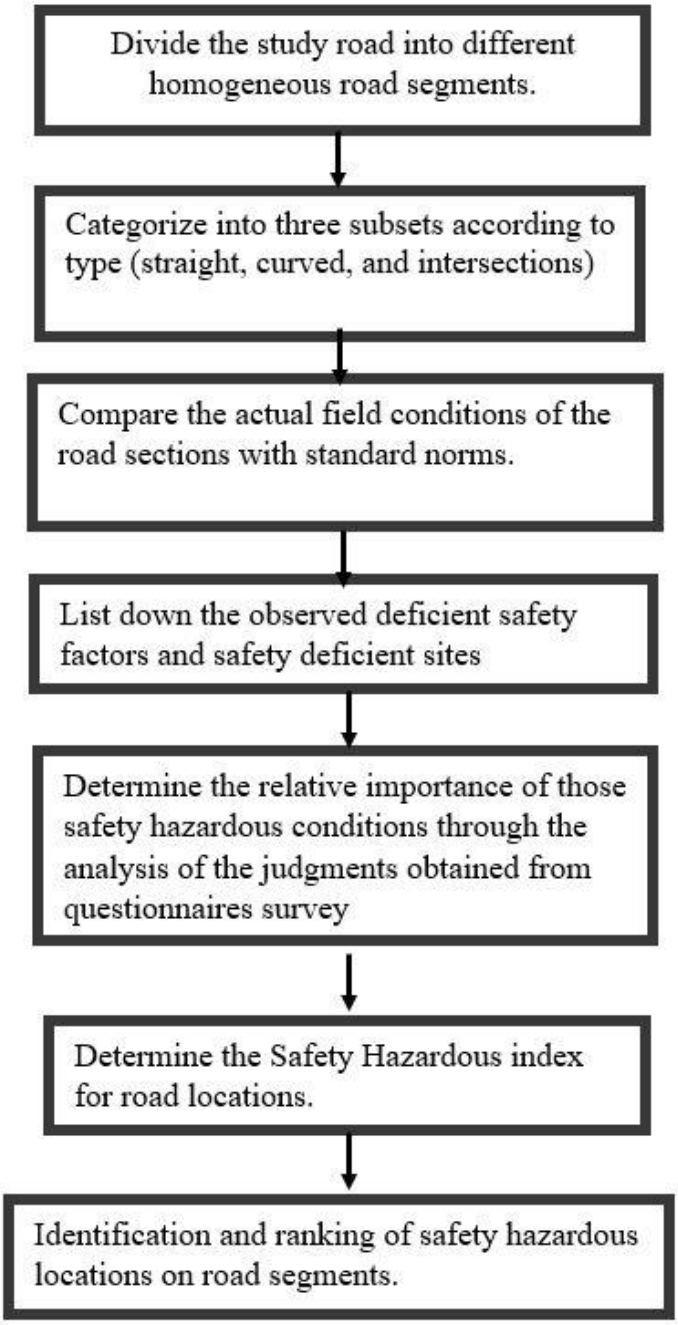

Figure 4: Flowchart of Data Analysis.

3.7 Validity and Reliability of Research Tools

Validity:

This study uses Analytical Hierarchy Process as a methodological tool to analyze the primary data obtained from the questionnaire responses. The questionnaire set is based on Saaty's scale. Research studies summarized on the literature review in chapter 2 mentioned above have also used and followed the same method presented by Saaty and have concluded their research. This method has been used as a tool for decision making during Multi-criteria Decision analysis in other fields of research also. (Agrawal , et al., 2013), (Habibian , et al., 2011) (Mahmoudreza, et al., 2017) have followed this methodology in their respective studies.

Reliability of Research Tools

The questionnaire set prepared and used for this research was tested for Reliability Test. The questionnaire set consisted of 63 questions based on Saaty's scale. To measure the internal consistency of the questionnaire, the questionnaire was subjected to Cronbach's alpha test. Cronbach's alpha, α, developed by Lee Cronbach in 1951, measure's reliability of multiple- questions to see if multiple- question surveys are reliable.

The formula for Cronbach's alpha is

$$\propto = \frac{N.\bar{c}}{\bar{v}+(N-1).\bar{c}}$$ Eq. (9) (Mohamad, et al., 2018)

Where

- N = the number of items.
- $\bar{c}$ = average covariance between item- pairs.
- $\bar{v}$ = average variance.

A rule of thumb for interpreting alpha for dichotomous questions or Likert scale questions is shown in table below.

Table 5: Cronbach's alpha value range and Internal Consistency

Cronbach's alpha	Internal Consistency
$\propto \geq 0.9$	Excellent
$0.9 > \propto \geq 0.8$	Good
$0.8 > \propto \geq 0.7$	Acceptable
$0.7 > \propto \geq 0.6$	Questionable
$0.6 > \propto \geq 0.5$	Poor
$0.5 > \propto$	Unacceptable

(Source: (Mohamad, et al., 2018))

Cronbach's alpha test was carried out in SPSS. For the purpose of analysis, responses from questionnaire sets were fed in SPSS. There are 63 items in a questionnaire of which the reliability of its measurements needs to be measured. From literature review about minimum requirement on sample size determination for Cronbach's Alpha test, it was found that 5 questionnaire is sufficient to determine the internal consistency of questions within a set if the number of questions within a set is more than 60((Mohamad, et al., 2018).

The test was carried out on 5 questionnaire sets and the alpha value was found to be 0.947. As per prescribed values and range illustrated by the rule of thumb presented in table 4, the consistency of questions within the questionnaire was found to be excellent.

3.8 Research Matrix

The process involved in data collection, analysis and its conclusion process are tabulated in Table 3.5. The research matrix utilized in this research work consists of mainly three steps as defined by the objectives column. The data required to fulfill these objectives are presented in second column. The third column presents data collection techniques and methods used to get data needed in second column. The fourth column presents the analytical tools that were used in this thesis work. These consists of two tools: the first is the "Analytical Hierarchy Calculator" platform and second is an open-source platform provided by the Google Spreadsheets. The first tool was used to generate relative weightage of the safety hazardous factors on the roads on the perception of the respondents. The second tool was used to collect the questionnaires survey used in this work.

Table 6: Research Matrix

Objectives	Required Data/ information	Collection Technique	Analytical Tools	Outcome
To determine risk factors for identifying safety hazardous locations	Primary Data: Field Survey (condition check against norms)	Field survey in person along with a set of checklists	Comparison with standard norms and minimum safe values as per guidance from	To obtain a List of safety deficiencies along the road segments and list of identified potential safety hazardous

Objectives	Required Data/ information	Collection Technique	Analytical Tools	Outcome
			Nepal road Standard 2070	locations that needs further study and treatment
To determine the relative weights of identified risk factors and identify the hazardous road locations along the study section	Primary Data: Online Questionnaire Survey data, field condition rating score	Online Method through emails and field survey	Analytical Hierarchy Process (AHP)	Relative weights of road safety factors and SHI scores

4. Results and Discussion

4.1 Identification of Risk Factors

This research work identifies and prioritizes road safety hazardous locations along "kotre-Aabhukhaireni" section of Prithvi highway. This two-lane two-way highway is an essential road for the region connecting strategic bridge of Muglin which links Pokhara with Kathmandu and Narayanghat. For identification of risk factors, first entire length of the study section was checked for road imperfections. A checklist was prepared and the road facilities were compared with norms, Nepal Road Standard 2070, and Infrastructure Risk Rating Manual. Infrastructures and other site factors not complying with minimum road standards were listed as Safety hazardous factors. Locations where such deficiencies were observed were noted as Safety Hazardous locations. The field condition survey was carried out with the focus on the following headings:

- Carriageway Condition and roadside safety structures
- Traffic signs and signals
- Street lighting condition
- Road shoulder width condition
- Presence and Adequacy of Guard rails
- Road marking Condition
- Drainage conditions
- Pedestrian Infrastructure
- Vehicle restraint system

The field inspection was carried out by dividing the road section into five sections on the basis of uniformity of regional characteristics and road environment conditions. The sections are as follows.

Table 7: List of road sections

Section	From-To	Distance
Section 1	Kotre Bridge to Kumle Khola Bridge Khairenitaar	11km
Section 2	Kumle Khola Bridge to Tharpu Bus Stop	12km
Section 3	Tharpu Bus Stop to Madi Bridge Damauli	10km
Section 4	Madi Bridge Damauli to Dumre	17 km
Section 5	Dumre- Marsyangdhi Powerhouse Station Aabukhaireni	20km

At each section, infrastructures condition were compared with guidelines as per Nepal Road Standard 2070 to identify safety hazardous locations. The minimum conditions and threshold values described by Nepal Road Standard 2070 and used in this study are listed in Appendix 2.

Instead of identifying a particular point site, a segment length of 300m length is taken into consideration during field survey. Most of the segments identified as safety hazardous locations lack proper guard rails, breakdown lanes, sufficient shoulder width and Proper Street lightening facilities for better night driving. Depending upon the field inspection, safety hazardous locations along sections 1-5 are reported in the tables below respectively.

Table 8: Section 1- Kotre- Kumle Khola Bridge

Safety Hazardous Locations	Section Type	Observed shortcomings	Remarks
Bhimad Chowk	Intersection	Lack guard rails at the edges Insufficient shoulder width Insufficient stopping sight distance Inappropriate pedestrian infrastructure	No any safety barriers present, observed shoulder width ranges from 0.3m to 0.6m, pedestrian infrastructures were absent even though the road passes through local market area with a school nearby.

Table 9: Section 2- Kumle Khola Bridge –Tharpu Bus Stop

Safety Hazardous Locations	Section Type	Observed shortcomings	Remarks
Seraphat	Straight Section	Lack of access control measures at residential areas Lack of adequate lighting at night Lacks proper pedestrian infrastructure	Access to private properties and other link roads were provided at less than 300m interval without any safety considerations.
Chhirkeni	Curved Section	Absence of guard rails and road edge barriers Insufficient shoulder width Open drain lining Insufficient lateral clearance	Road passes through a vertical drop of more than 3m but lacks proper safety barriers, observed shoulder width was 0.55m, also lateral clearance was less than 1.5m due to deposition of eroded soil
Nirmal Basti	Curved Section	Hazardous drainage conditions no drain cover present Inappropriate shoulder width Lack of Access control measures	Absence of drain cover on drainage channels, shoulder provided herewith suffer abrupt changes on width.

Table 10: Section 3- Tharpu Bus stop- Madi River Bridge, Damauli

Safety Hazardous Locations	Section Type	Observed shortcomings	Remarks
Dhayere	Straight Section	Lack of street lighting Lack of pedestrian infrastructure	Section Passes through a school area and playground but lacks sufficient lighting and footpath facilities
Jamune	Straight Section	Lack of traffic signs and signals Open drainage along the road Lack of pedestrian infrastructures and insufficient shoulder width. No street lighting	Shoulder –unpaved -0.45m. No street light, no barrier along the edges, drain channels open throughout the length.

Table 11: Section 4- Madi River Bridge, Damauli- Dumre

Safety Hazardous Locations	Section Type	Observed shortcomings	Remarks
Kamalbari	Straight Section	Hazardous drainage condition Inappropriate shoulder width Inappropriate street lighting conditions for night driving	Shoulder width less than 0.75m, no street lights, open drain channels in built up areas.
Deurali	Straight Section	Hazardous roadside arboriculture Lack of street lighting Lack of pedestrian infrastructure Narrow carriageway. Inappropriate shoulder width	Trees and weeds growth within the shoulder. Width per lane was observed 3.0m with a decrease of 0.5m each making it a narrow zone. No lighting, no traffic signs to notify drivers about the narrow zone. Shoulder width varies abruptly along the carriageway.
Taalghar	Straight Section	Lack of traffic signs and signals Insufficient shoulder width Insufficient street lighting conditions for night driving	No lighting, untreated shoulder with width less than 0.75m, broken traffic signs.

Table 12: Section 5- Dumre- Marsyandi hydropower station

Safety Hazardous Locations	Section Type	Observed shortcomings	Remarks
Bimalnagar	Straight Section	Inappropriate access control mechanism to access private property. Insufficient traffic signs and signals. (Absence of road markings. Insufficient safety measures against rock fall from the adjacent vertical cliff. Inappropriate street lighting conditions for night driving Insufficient pedestrian infrastructures.	Built up areas within the right of way, access to private properties at less than 300m interval, no any safety against the potential rock fall from the vertical cliff above, no street lighting facilities.
Yampa	Curved Section	Inappropriate access control mechanism to access private property. Lack of traffic signs and signals Insufficient shoulder width Lack of guard rail and road edge barriers Hazardous vegetation growth within the shoulder width forcing pedestrians to use carriageway width. Insufficient lateral clearance due to vegetation growth and human settlement	Hazardous vegetation growth within the shoulder width forcing pedestrians to use carriageway width. Insufficient lateral clearance due to vegetation growth and human settlement encroachment
Baradi	Intersection	Lack guard rails at the edges Inappropriate street lighting conditions for night driving Hazardous vegetation condition	Vertical cliff present, crown of trees obstructing vertical clearance and plantation adjacent to the shoulder.
Satrasayephat	Straight Section	Lack of proper access control measures and animal passage across the road Inappropriate shoulder width Hazardous drainage condition	Road passes along the built-up section, shoulder width varies abruptly along the road, open drainage channels
Dhaaptar	Curved Section	Insufficient pedestrian infrastructure Lack of traffic signs and signals Lack of access control mechanism near the school area	Road passing from school areas and settlement areas. Footpath absent, street lights insufficient.
Markhichowk	Intersection	Lack of proper access control measures and animal passage across the road Lack of traffic signs and signals Insufficient shoulder width Insufficient street lighting conditions for night driving	Road passing from school areas and settlement areas. Footpath absent, street lights insufficient or broken and are not available for night driving.

In the above-mentioned tables, starting from table 4.2 to 4.6, road sections along with factors which were expected to contribute into crashes along the roads were listed

Figure 5: Section 1: Bhimad Chowk

According to Nepal Road Standard 2070, for a class II standard road present on rolling terrain, the recommended design speed is 60Km/hr. The study section was also tallied with the minimum recommendations with these standards recommended for a class II highway on a rolling terrain and the deficient physical parameters were listed as hazardous safety factors.

As can be observed from figure 4.1, the lack of guard rails at the edges, insufficient shoulder width, and insufficient stopping sight distance for the vehicles moving on the highway made "Bhimad Chowk" a hazardous road location. For example: among the road cross section elements, the minimum shoulder width for a class II highway should not be less than 0.75m but the shoulder width was found to be less than 0.5m while inspection. So, this is considered as one safety hazardous condition on this spot. Similarly, it can be seen that guard rails and safety barriers are not present near the edge of the road even though there is a drop of more than 3m. Thus, this spot is considered as potential hazardous spot with lack of guard rails and safety barriers at the edges.

Figure 6: Section 2: Chhirkeni

According to figure 4.2, insufficient guard rails and safety barriers along the edges, absence of proper drain cover, insufficient shoulder width and insufficient lateral clearances are expected to cause crash in this spot. So, due to deficiencies of these road cross section elements "Chhirkeni" is considered as safety hazardous location.

Figure 7: Section 3: Jamune

Based on figure 4.3, absence of safety barriers and guard rails, insufficient shoulders, absence of drainage cover, insufficient street lightening conditions for night driving are among the causes that make "Jamune" a potential safety hazardous section.

Figure 8: Section 4: Deurali

According to figure 4.4, Deurali section serves as a potential safety hazardous location due to absence of straight lightings for night driving, insufficient pedestrian infrastructure, narrow carriageway section compared to upstream and downstream section followed by absence of guard rails and inappropriate roadside arboriculture

Thus, hazardous road locations along with road factors were identified and now for ranking these identified locations, the relative weights of these factors were derived as described below.

4.2 Determination of Relative Weights

The road sections and safety hazardous factors discussed above may not equally affect the safety of a road. So online questionnaire survey was conducted to obtain the opinion of local expert who were working on the region. Engineers working along the region and technical employees working under department of roads, division office Damauli were asked to fill up the form through online. The hazardous safety factors taken into consideration in the online questionnaire form are derived from the safety deficiencies present along the study section. So, online questionnaire was also limited to those personnel's only who are familiar with the study region and have sufficient technical knowledge to pass their judgments properly. The analysis of the questionnaire form for the determination of relative weights of safety hazardous factors is discussed below.

4.2.1 Questionnaires Survey Analysis

After identification of potential safety hazardous locations, an online questionnaire survey was conducted to find out the relative weights of safety hazardous factors discussed above. The questionnaire form used to collect the information is presented in Appendix 2. The responses from this questionnaire were used to prepare a comparison matrix and the resulting matrix was used to determine the relative importance of safety hazardous locations using Analytic Hierarchy Process. The Calculations required for this analysis were mathematically based on the solution of an Eigen value problem. To avoid probable human error during calculation of the relative weights and consistency checks, online AHP calculation tool named "AHP –online Calculator" was used. (Goepel, 2018).This is an online based Calculator which checks the consistency values of the input matrix and gives relative priorities of the individual inputs that were fed in the form of RWM matrix.

Example of AHP calculation and interpretation of results obtained from the analysis of one of the online questionnaire forms is discussed to explain the whole methodology.

Table 13: Decision Matrix

Criteria (level 01)	Straight section	Curved section	Intersection
Straight Section	1	1/5	1
Curved Section	5	1	3
Intersection	1	1/3	1

Table 4.7 shows the comparative decision of the respondent developed from his judgments from the questionnaire survey. It is a decision table in matrix form, about which parameter the respondent thinks is important over the other. The scale used in this decision matrix is the same as tabulated in **Error! Reference source not found.** a bove. Here the respondent have prioritized safety conditions at curved sections must be given strong priority over

safety conditions at straight sections and among intersections. This judgmental opinion implies if hazardous locations among straight sections, curved sections and intersections are to be treated, in his opinion the hazardous location identified along the curved portion of the road contributes more for the crashes and it should be treated first. Similarly, the decision matrix in the above table 4.7 shows moderate importance of intersections with respect to straight section.

Table 4.7 was checked for consistency among the comparisons before using the decision matrix for further analysis. Consistency determination was done using AHP based online software package named "Online –AHP Calculator". (Goepel, 2018). The consistency ratio for this decision matrix was obtained below 10%. (M & E, 2017).So, this decision was considered consistent enough for further calculation. Based on the pairwise comparisons obtained from the respondent, table 4.8 below shows the resulting weights for the criteria of level 01 discussed in table 3.1 above.

Table 14: Priority Table for the decisions on level 01

S.No	Categories	Priority (relative Weightage)	Rank
1	Straight Sections	15.6%	3
2	Curved Sections	65.9%	1
3	Intersections	18.5%	2

Consistency Ratio CR= 3%

Here the number of comparisons were three, the consistency ratio for the decision matrix developed was three percent and was within the tolerable limits. This process was repeated for the safety criteria of level 02 and level 03 discussed in table 3.1 above. Decision matrix and priority table with relative weights for criteria of level 02 with respect to hazardous conditions along straight sections are shown in table 4.9 and 4.10 respectively.

Table 15: Decision matrix along Straight sections

Criteria (level 02)	Hazardous Carriageway conditions	Hazardous roadside conditions	Hazardous road furniture conditions	Hazardous road environment condition
Hazardous Carriageway conditions	1	3	1	1
Hazardous roadside conditions	1/3	1	1/3	1/3
Hazardous road furniture conditions	1	3	1	1/3
Hazardous road environment condition	1	3	3	1

The consistency ratio CR for this decision matrix was 5.7%.

Table 16: Priorities along Straight sections

Categories	Priority (relative weightage)	Rank
Hazardous Carriageway conditions	28.7	2
Hazardous roadside conditions	9.6	4
Hazardous road furniture conditions	22.3	3
Hazardous road environment condition	39.4	1

Consistency Ratio CR= 5.7%

Similarly for the same criteria (level 02 of table 3.1) compared along curved sections, following are the decision matrix and priority table obtained from the respondent as shown in table 4.11 and 4.12 respectively.

Table 17: Decision matrix along Curved Sections

Criteria (level 02)	Hazardous Carriageway conditions	Hazardous roadside conditions	Hazardous road furniture conditions	Hazardous road environment condition
Hazardous Carriageway conditions	1	1	1	3
Hazardous roadside conditions	1	1	1	3
Hazardous road furniture conditions	1	1	1	1
Hazardous road environment condition	1/3	1/3	1	1

Table 18: Priorities along curved Sections

Categories	Priority (relative weightage)	Rank
Hazardous Carriageway conditions	30.9	1
Hazardous roadside conditions	30.9	1
Hazardous road furniture conditions	24.1	3
Hazardous road environment condition	14.2	4

Consistency Ratio= 5.7%

Here in table 4.12, hazardous carriageway sections and hazardous road side conditions are given equal priority by this respondent. So the rank values of both criteria are assigned as 1.

Similarly for the same criteria (level 02 of table 3.1) when compared along the intersections, following are the decision matrix and priority table obtained from the respondent as shown in table 4.13 and 4.14 respectively.

Table 19: Decision matrix along Intersections

Criteria (level 02)	Hazardous Carriageway conditions	Hazardous roadside conditions	Hazardous road furniture conditions	Hazardous road environment condition
Hazardous Carriageway conditions	1	1	3	1
Hazardous roadside conditions	1	1	1	1
Hazardous road furniture conditions	1/3	1	1	1
Hazardous road environment condition	1	1	1	1

Table 20: Priorities along Intersections

Categories	Priority (relative weightage)	Rank
Hazardous Carriageway conditions	33.1	1
Hazardous roadside conditions	24.1	2
Hazardous road furniture conditions	18.8	4
Hazardous road environment condition	24.1	2

Consistency Ratio= 5.7%

In the similar manner priority table was calculated for all other sub criteria of level 03 in table 3.1 were calculated. From one individual response, a total of 16 different decision matrix were developed from 63 questions asked. Each individual decision matrix provides a priority table with independent ranks. 20 responses were analyzed to draw the results. Results of the priorities from each individual responses were averaged and the mean value was taken for further consideration. Responses which were not mathematically consistent were discarded during analysis process.

Consistency analysis of each matrix showed that the acceptable value of CR was not exceeded. It means that the matrixes fulfil the formal criterion of the AHP method. Therefore, the local priorities were used to determine the final ranking of factors with regard to their importance. The final values of relative weights determined from each individual responses were obtained and the mean value of these relative weights were calculated. The final mean values thus obtained are shown in tabular form as shown below.

Table 21: Mean weights of Safety Factors

S.No.	Name of Safety Factors	Straight Section (SFS)	Curved Section (SFC)	Intersection (SFI)
1	Hazardous surface Conditions	0.5	0.604	0.171
2	Hazardous Structural Conditions	0.5	0.395	0.828
3	Hazardous Shoulder conditions	0.385	0.475	0.487
4	Hazardous Drainage Conditions	0.614	0.525	0.512
5	Hazardous Road Guidance conditions	0.236	0.214	0.528
6	Hazardous Pedestrian Infrastructure conditions	0.270	0.308	0.286
7	Hazardous Vehicle Restraint System	0.243	0.266	0.170
8	Hazardous Vegetation condition	0.246	0.210	0.120
9	Inappropriate lighting Conditions	0.214	0.397	0.219
10	Hazardous Island conditions	-	-	0.277
11	Inappropriate Traffic signs & signals	0.424	0.301	0.231
12	Inappropriate Road Marking	0.219	0.181	0.272
Total of Weights		3.992	3.995	4.101

4.3 Field Condition Rating

The study road section starts from Kotre Bridge at the border of Kaski and Tanahun District of Gandaki Pradesh and passes through various settlement areas (built-up area, and small emerging towns in Tanahun district and ends at station office of Marsyandi powerhouse at Aabukhaireni municipality. The road section under study passes from Shukla Gandaki Municipality, Myagde Rural Municipality, Vyas Municipality, Bandipur Municipality, and passes through Aabukhaireni Municipality in Tanahun District. The road passes through various agricultural fields, market zones, built up areas and provides connectivity to major settlements, market centers and agricultural production pockets of Tanahun District. Salient Features of the Study section is presented in the table below.

Table 22: Salient Features of the Study Section

Name of the Highway	Prithvi Highway (H04)
Name of the section	Muglin Pokhara Road Section
Province	Gandaki
District	Tanahun
Municipalities /Rural Municipality	The alignment of the study section passes through two municipalities and three rural municipalities namely, Aabukhaireni Rural municipality, Bandipur Rural municipality, Vyas Municipality, Myagde Rural municipality, Shukla Gandaki Municipality of Tanahun District.
Start Point	Kotre Bridge, Kotre, Tanahun (Border of Kaski and Tanahun District)
End point	Marsyangdhi hydropower station, powerhouse Aabukhaireni, Tanahun district
Total Length	70 kilometers
Road Standard	National Highway (H04), class II
Right of way	50m (25m on either side from Centre line of the road)
Surface Type	Bituminous
Road Stereotype	Two lane undivided

For ranking of hazardous locations, safety hazardous index is developed using the weights of safety factors and condition rating of these safety factors. The safety hazardous index is developed separately for each identified safety hazardous locations within the route. For this development of safety hazardous index, it is necessary to determine the rating of safety factor conditions first. So, Rating of safety factors is determined for each according to the present condition of safety factors. For this the identified potential safety hazardous locations were restudied and condition rating was done. Condition rating was assigned values between 0 - 1. Table 3.7 presented above show the condition rating and values assigned for the safety conditions of the hazardous locations at actual field. For field scoring of the safety factors, the actual field condition was divided into 12 above mentioned safety factors and deviance in any one of these criteria was assigned with a score 0.8. If one of the above safety criteria is found to be in deviation with standard conditions then the value assigned will be 0.8 and the values were added with each deviation of the safety parameter with standard condition. As mentioned above, in the table altogether 15 spots along the study section were found to be potentially hazardous section, ranking is carried out as below. As an example of the process scoring of Bhimad Chowk is carried out below.

Bhimad Chowk is identified as potential hazardous location for having insufficient shoulder width, insufficient sight distance, lack of guard rails at the edges, insufficient street lighting for night driving, lack of interchanges and inappropriate road guidance system, absence of appropriate road marking signs and signals. So, these deficiencies accounts for inappropriate shoulder condition, hazardous road guidance system, hazardous street lighting conditions and hazardous road markings. So this spot is assigned with a condition scoring of 0.32. Here it was observed that this spot has deviance from standard conditions on 4 different heading of above illustrated safety factors. This implies 0.8*4= 0.32. As per table 3.7 this spot is in average condition. Similarly, all other spots were scored accordingly. Table below presents the score and state of the condition of these potential safety hazardous locations.

Table 23: Condition Rating of Identified locations

S.No	Name	Score value	State of condition
1	Seraphat	0.24	Good Condition
2	Bhimad Chowk	0.32	Average Condition
3	Chhirkeni	0.5	Poor condition
4	Nirmal Basti	0.24	Good Condition
5	Dhayere	0.24	Good Condition
6	Jamune	0.32	Average Condition
7	Kamalbari	0.32	Average Condition
8	Deurali	0.24	Good Condition
9	Bimalnagar	0.40	Average Condition
10	Yampa	0.48	Average Condition
11	Baradi	0.48	Average Condition
12	Satrasayephat	0.4	Average Condition
13	Dhaaptar	0.32	Average Condition
14	Markhichowk	0.32	Average Condition
15	Taalghar	0.4	Average Condition

4.4 SHI Values and Ranking of Hazardous Locations

The safety hazardous index (SHI) is now developed by using the relative weights of safety hazardous conditions and condition rating of those hazardous conditions in the field. This safety hazardous index is developed separately to evaluate safety conditions of all those identified potential safety hazardous locations. Ranking of these road safety hazardous locations is done by the evaluation of the values obtained from individual safety hazardous index. Safety Hazardous index for hazardous locations at straight sections curved sections and intersections are calculated by using the equations. Eq. (6), Eq. (5) and Eq. (6) mentioned above. For easier study they are illustrated below also.

$$SHIS = \Sigma\ WSFS \times RSFS \qquad \text{Eq. (6)}$$

$$SHIC = \Sigma\ WSFC \times RSFC \qquad \text{Eq. (7)}$$

$$SHII = \Sigma\ WSFI \times RSFI \qquad \text{Eq. (8)}$$

The final result obtained is tabulated as below.

Table 24: Ranking Order of identified locations

S.No	Name	SHI value	Rank
1	Yampa	0.852	1
2	Baradi	0.773	2
3	Chhirkeni	0.712	3
4	Satrasayephat	0.670	4
5	Kamalbari	0.573	5
6	Bimalnagar	0.549	6
7	Markhichowk	0.471	7
8	Taalghar	0.470	8
9	Jamune	0.450	9
10	Deurali	0.319	10

S.No	Name	SHI value	Rank
11	Nirmal Basti	0.296	11
12	Dhayere	0.236	12
13	Seraphat	0.220	13
14	Bhimad Chowk	0.213	14
15	Dhaaptar	0.210	15

Thus the identified potential safety hazardous locations are ranked as per their safety hazardous index value.

4.5 Comparison of Hazardous locations along with Crash data

Crash Statistics obtained from District Traffic Police Office Damauli was used for this purpose. Crash history of three consecutive fiscal years from 2016-2019 A.D. was analyzed. Equivalent Property Damage Only Index (EPDO Index) method was used to identify and rank the crash locations. This comparison is considered necessary in order to cross- verify whether the hazardous sections identified from SHI index are in fact identified as hazardous ones from crash records analysis or not. Crash Data analysis was conducted independently using the records from Damauli Traffic police office to create a comparison platform. Table below presents the list of hazardous locations and corresponding rank identified by EPDO index method

Table 25: Ranking Order of Hazardous Road Locations

Safety Hazardous locations	Average EPDO Index value	SHI Index value	Rank (SHI value)
Yampa	9.5	0.852	1
Baradi	9.5	0.773	2
Chhirkeni	9.5	0.712	3
Satrasayephat	8.409	0.670	4
Kamalbaari	9.5	0.573	5
Bimalnagar	8.3	0.549	6
Markhichowk	8	0.471	7
Taalghar	9.5	0.470	8
Jamune	9.5	0.450	9
Deurali	8	0.319	10
Nirmal Basti	8.75	0.296	11
Dhayere	8	0.236	12
Seraphat	8.642	0.220	13
Bhimad Chowk	6.6(safe)	0.213	14
Dhaaptar	8	0.210	15

Comparing the safety hazardous locations as per EPDO index value and SHI index values as presented in table 4.19. It is evident that locations identified by EPDO index method that needs detailed safety analysis and thus identified as hazardous one is also identified AHP method. Both methods presented Yampa and Baradi as the most hazardous locations and Dhaaptar as the least hazardous one. Some Locations were identified with same EPDO index value. However, based on SHI index their ranking values are different. The minimum EPDO value that warrants a detailed safety analysis was obtained 7.95

Bhimad Chowk is considered safe by EPDO method. However, the road features of that particular section lack guard rails and barriers to protect errant vehicles from leaving the road, shoulder width and pedestrian infrastructures are lacking. Thus, it is considered hazardous.

5. Conclusion and Recommendations

5.1 Conclusion

This research aimed to identify and rank road safety hazardous locations without using crash record statistics with respect to “road” features. As per the objective of this research, identification and ranking of hazardous road locations was carried out.

Among the road related parameters considered in this study, Surface Conditions, Structural Conditions, shoulder conditions and drainage conditions respectively were considered most important along straight sections whereas road surface conditions, shoulder conditions and drainage conditions respectively were considered important along curved sections in terms of safety conditions. Among intersections, Structural conditions, road guidance system and drainage conditions were considered more important from safety point of view.

This study identified Yampa and Baradi as the first and second most hazardous section with SHI scoring of 0.852 and 0.773 respectively and Dhaaptar as the least hazardous one with a SHI of 0.210. A total of fifteen different places were identified as road safety hazardous locations within a span of 70km based on the deficiencies on road cross sectional elements and some other physical parameters of the road.

5.2 Recommendation

This research study was conducted to identify road safety hazardous locations in terms of risk associated with road features. So, parameters related to driver – vehicle features were not considered which the limitations of this study are. It is recommended to include driver behavior and vehicle condition parameters in addition with road environment parameters. It is also recommended to derive driver- vehicle relationship, and driver- road environment relationship with respect to crashes first before including driver and vehicle factors as research parameters. In terms of future research, it is recommended to develop a risk rating model incorporating some other risk factors using the same concept in this study. Such model can be used as a tool to identify safety hazardous locations on newly constructed roads and roads with no crash data available.

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