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Ranking Road Safety Hazardous Location: A Case Study of Chhorepatan–Machhapuchhre Viewpoint Road Section

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Abstract

The importance of road safety, involving pedestrians, cyclists, motorcyclists, and drivers adhering to rules and strategies to prevent accidents and fatalities, is emphasized, especially in Nepal, where road fatalities remain a pressing issue. The study focuses on the Chhorepatan – Machhapuchhre Viewpoint Road Section, which faces increasing traffic density and hazards. It proposes a six-stage methodological framework, incorporating the Analytical Hierarchy Process (AHP) and field surveys, to rank hazardous locations based on safety parameters, resulting in a Safety Hazardous Index (SHI). The research aims to identify and prioritize key safety factors by correlating SHI values with crash records, potentially serving as a model for assessing road sections in similar conditions.

Keywords: Safety Hazardous Index; Condition Rating; Analytical Hierarchy Process; Weightage of safety factors

1. Introduction

Road safety is a paramount concern that demands our steady attention. It's a collective responsibility involving pedestrians, cyclists, motorcyclists, and drivers, all of whom must adhere to rules and employ strategies to safeguard lives. The comprehensive goal is to fortify roadways, mitigating the severity of accidents, injuries, and fatalities.

Road safety hazards are things that make it more likely for accidents, injuries, or even death to happen on the road. These hazards can come from different sources, like how the road is built, the weather, how people behave, and the condition of vehicles. There can be dangerous road conditions, people driving too fast, drivers not paying attention, confusing intersections, pedestrian crossings that are not safe, cars that are not well-maintained, and chaotic construction zones. To make the roads safer, people who use them need to be aware of these hazards and do things to prevent accidents. This includes following traffic rules, driving carefully depending on the road conditions, and paying attention to potential dangers.

Government agencies responsible for the roads also play an important role. They need to maintain and improve the roads and set safety rules to protect everyone on the road.

In our modern society, where transportation networks constitute life's arteries, the well-being of road users holds paramount importance. Ensuring road safety is an expression of ethical virtue and has continued throughout the economy. Thus, pinpointing and appraising hazardous zones on roadways with precision assumes critical significance in supporting road safety. The thesis titled "Ranking Road Safety Hazardous Locations: A Case Study of Chhorepatan – Machhapuchhre Viewpoint Road Section" delves deeply into road safety within a specific geographic context, seeking to unravel the art of identifying and ranking immediate danger along a challenging thoroughfare. Through an exhaustive exploration of the Chhorepatan–Machhapuchhre Viewpoint Road Section, this study aspires to furnish invaluable insights into road safety enhancement, refining safety regulations, and making roads universally secure.

Regrettably, road safety has emerged as a pressing issue in Nepal, where countless innocent lives are snuffed out each year, and many more endure injuries or permanent disabilities. According to the World Health Organization (WHO), Nepal

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witnessed a staggering 4,654 road fatalities in 2020 alone, highlighting an alarming trend that refuses to subside. Despite raising awareness campaigns, both public and private, the misfortune of road accidents in Nepal persists.

Notably, the Chhorepatan–Machhapuchhre Viewpoint road segment grapples with escalating traffic volumes, rendering safety hazards increasingly probable. This 12.6-kilometer stretch, part of the Siddhartha Highway, navigates through a terrain filled with sharp curves, straightaways, bridges, culverts, and merging points. Yet, it also contains conflict zones and accident-prone areas. While comprehensive crash statistics may not always be readily available, this thesis tries to bridge the gap by examining risk factors intrinsic to various road characteristics and assigning them weighted values within the risk assessment framework. This innovation gets around the need for extensive databases and paves the way for a more proactive approach to road safety.

1.1 Problem Statement and Objective of the Study

Research indicates that identifying hazardous locations on roads is challenging due to limited comprehensive crash data. The Chhorepatan–Machhapuchhre viewpoint road, designed to alleviate congestion, has become unsafe post-construction, lacking safety features like traffic signals, signs, crosswalks, and pedestrian passes, posing significant risks. Urgent action is imperative to address this critical issue and enhance road safety. This study concludes the following two objectives:

- To identify road elements and prioritize the safety factors for this element using AHP.
- To rank the road hazardous location by determining the Safety Hazardous Index.

2. Literature Review

In response to declining collision data quality in North American jurisdictions, Leur and Sayed (2022) introduced the Road Safety Risk Index (RSRI), a subjective evaluation method. The RSRI relies on a driver-based assessment of potential road safety risks, encompassing road features, hazard exposure, collision likelihood, and consequences. It employs a systematic process during drive-through evaluations. It offers adaptable guidelines for road types, demonstrating reliability through observer consistency and validity by comparing results to objective safety measures. While the RSRI effectively identifies high-risk areas, aids road safety analysis, and informs improvement strategies, its subjective nature may raise accuracy concerns, particularly regarding assessing the human element in road safety.

Sharma and Pradhananga (2022) present a six-stage methodology using the Analytical Hierarchy Process (AHP) and field surveys to address road safety risks in Nepal, focusing on the Kathmandu Ring Road due to urbanization-related hazards. By computing the Safety Hazardous Index (SHI) for the Kalanki Koteshwor Road Section, their study facilitates a comparative assessment of the importance of risk factors and their correlation with crash records, offering insights into critical safety elements. This research not only aids in prioritizing safety measures but also provides a valuable template for evaluating safety risks in other road sections and devising targeted safety improvement strategies based on SHI values.

In their Kalanki Koteshwor Ring Road Section study, Shakya and Marsani (2020) propose a six-stage methodology utilizing the Analytical Hierarchy Process (AHP) and field surveys to rank hazardous road locations based on safety parameters. The Safety Hazardous Index (SHI) is calculated, revealing that the 'Ch.12+600 km to Ch.14+600 km' section is the most perilous, with an SHI of 12.38, while the 'Ch.10+600 km to Ch.12+600 km' section is the least hazardous with an SHI of 9.30. This ranking serves as a valuable tool for prioritizing safety improvements within budget constraints, pinpointing areas requiring immediate attention for road safety enhancements. It underscores the method's reliability when accident data is scarce or inaccurately documented.

Habibian et al. (2011) present an auditing-based methodology designed for identifying and ranking hazardous road locations, specifically in scenarios where crash data is lacking, focusing on rural two-lane two-way roads. The methodology divides a road into six elements, assigning safety factors to each. It employs the Analytical Hierarchy Process (AHP) and expert input to determine their relative contributions to road safety. After auditing and ranking roads based on these elements, a Safety Index (SI) is calculated to identify hazardous locations with lower SI values. This approach empowers road safety authorities to prioritize data collection and target safety improvements, even without crash data, rendering it a valuable tool for assessing and enhancing road safety. Future research could validate the framework using areas with available crash data and adapt it to local conditions through recalibration with input from local experts.

3. Methodology

3.1 Study Area

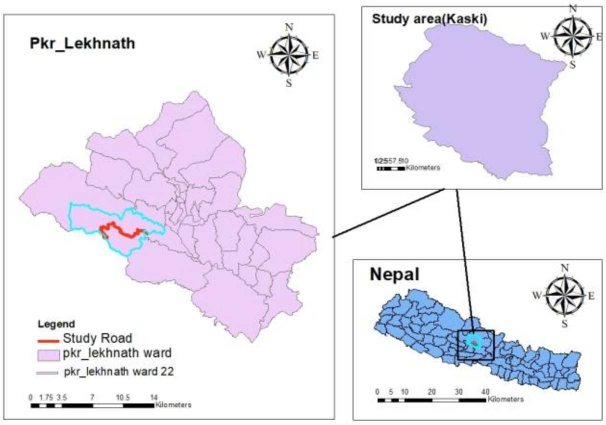

Figure 1: Study area location

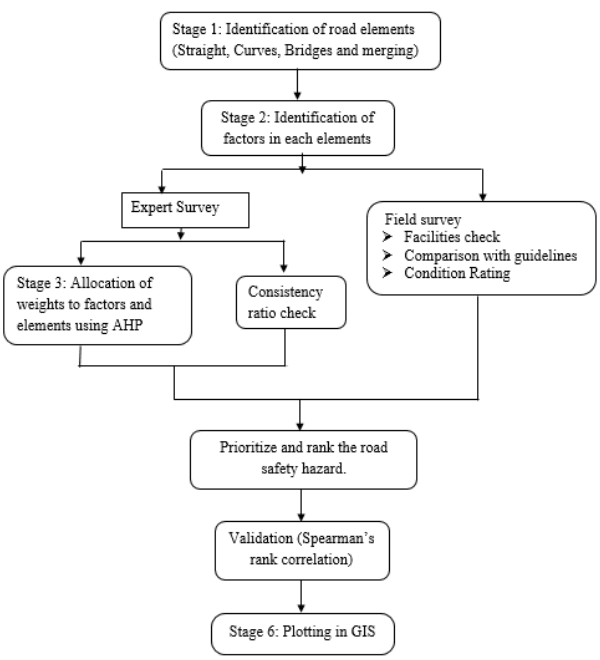

Figure 2: Flow Chart of Methodology

Siddhartha highway is a 181 kilometers (km) road that starts from Pokhara and ends in Siddharthanagar. It is categorized as a National Highway category (code H10 renamed NH047). It has been improved in order to minimize traffic congestion. Thus, it serves as the major transport link road. The starting section of this highway, Pokhara Chhorepatan to Machapuchhere viewpoint, as shown in the figure, is selected as the study area, which is 12.6 km long.

3.2 Overview of Methodology

The recommended framework for attaining the goals of the study "Ranking of Safety Hazardous Locations" is divided into six steps.

3.2.1 Stages 1 and 2: Identification of road elements and safety factors for each element

Based on a literature review of hill roads, highways and district roads on AHP and with field visits, four types of indicator parameters: Straight, Curve, Merge, Bridges and side road land use were considered, which are shown in Table 1.

3.2.2 Stage 3: Allocation of weights to factors using AHP

In the decision-making process, relative weights are crucial, and they are determined for each criterion at each level of the hierarchy once the criteria have been defined and the importance of setting priorities and maintaining consistency is established. To achieve this, a scale of measurement is necessary, and the 1-to-9 scale has been favored due to its close resemblance to our ability to differentiate between the strengths of preferences or dominance among objects. Saaty's Intensity of 1-to-9 Importance Scale (Table 2) is commonly used for this purpose. Expert input is essential for pairwise comparisons, which involves evaluating two criteria simultaneously, simplifying the evaluation process by focusing the evaluator's attention on the two available options.

After the pairwise comparison is completed, the relative weight matrices (RWM) will be constructed and the matrixes will be:

$$
\begin{array}{c|cccc|c|c|}
 & C1 & C2 & \ldots\ldots & C_n & & A_{ij} \\
C1 & 1 & w1/w2 & \ldots\ldots & w1/wn & & w1 \\
C2 & w2/w1 & 1 & \ldots\ldots & w2/wn & & w2 \\
. & .. & .. & .. & .. & = & \\
. & .. & .. & .. & .. & & \\
C_n & wn/w1 & wn/w2 & \ldots\ldots & 1 & & wn
\end{array}
$$

Then, the process is followed by calculating the matrix eigenvector, Aij and consistency index test (CI) of the criterion. For the matrix eigenvector, Aij multiplies the n elements in each row, takes the nth root, and prepares a new column for the resulting values. Then, divide each number by the sum of the resulting values of the new column.

Table 1: Parameters considered

1. Straight Segments:	A. Cross-section elements (Carriageway, Shoulder, Drainage) B. Pavements Maintenance condition C. Speed limit and no overtaking signs D. Road Markings E. Roadside hazards F. Pedestrian safety countermeasures G. Vehicle flow
2. Curves	A. Delineation(chevrons), Speed advisory signs, reflectors B. Pavement maintenance condition C. Roadside hazards D. Combination of horizontal and vertical curves E. Lateral offset to vertical obstruction s F. Operation speed G. Cut slope H. Design consistency I. Cross-section elements (Carriageway, Shoulder, Drainage)
3. Bridges and Culverts	A. Horizontal or lateral clearance B. Bridge Barriers C. Load limit signs and speed limit sign D. Pavement maintenance condition E. Guard rails and approach protection F. Carriageway Drainage
4. Merge and Intersections:	A. Roadside condition (Drainage, Shoulder condition) B. Lighting poles and reflective signs C. Traffic calming measures D. Pedestrian safety countermeasures E. Road furniture (Road marking, signs and signals) F. Visibility distance G. Design consistency
5. Side Road land use	A. Lighting poles and reflective signs B. Information signs (Hotels, Restaurants, Health post) C. Access to land use, shoulder width, Road marking D. Pavement Maintenance Condition E. Spacing of the rest areas.

Eigen vector, $A_{ij} = \frac{\sum_{i=1}^{n} \quad (\frac{w1}{w2}*....*\frac{w1}{wn})^\wedge(\frac{1}{n})}{\sum \quad [\sum_{i=1}^{n} \quad (\frac{w1}{w2}*....*\frac{w1}{wn})^\wedge(\frac{1}{n})]}$

Eigenvalue, $\lambda i = \frac{\sum_{j}^{n} \quad (\sum_{i=1}^{n} \quad Aij)wj}{Aij}$

Consistency index, $CI = \frac{\lambda - n}{n-1}$

Table 2 Safty's Rating Scale

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

The consistency index was then compared with random index (RI), shown in Table 5. The ratio of the consistency index to the random index is called Consistency ratio (CR). If the CR exceeds 10%, the judgment is considered inconsistent and should be excluded or repeated.

Table 3: Random Index for different dimensions of RWM (Saaty and Wong 1983)

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

3.2.3 Stage 4: Field Survey

The entire survey route was split into 2 km sections so that the priority index could be created and changes could be made as needed. The road length under study featured a variety of phases, including horizontal curves, vertical curves, and other features like pedestrian facilities and bridges. These portions are examined independently because the degree of the problems varies from one to the next. This is carried out in the following steps:

- Reconnaissance Survey
- Facilities Check
- Comparison with guidelines
- Severity Analysis/ Rating

Table 4: Condition rating of road safety factors

SN	State of condition	Value
1	Excellent condition	0
2	Good condition	0.10-0.24
3	Average condition	0.25-0.49
4	Poor condition	0.50-0.74
5	Very poor condition	0.75-1.00

3.2.4 Stage 5: Ranking the road safety hazardous locations

Utilizing the following calculations, the Safety Hazardous Index was created by adding the weight of the safety factors and the condition rating of each factor from stages 3 and 4.

Safety hazardous Index at straight sections:

$$SHIs = \sum (Wsfs \times Rsfs)$$

Safety hazardous Index at curve sections:

$$SHIc = \sum (Wsfc \times Rsfc)$$

Safety hazardous Index at bridge sections:

$$SHIb = \sum (Wsfb \times Rsfb)$$

Safety hazardous Index at intersections:

$$SHIi = \sum (Wsfi \times Rsfi)$$

Safety hazardous Index at Roadside land use:

$$SHI_l = \sum (Wsf_l \times Rsf_l)$$

where SHIs, SHIc, SHIb, SHIi, SHI_l = Safety Hazardous Index for straight, curve, bridge, intersections and roadside land use, respectively.

Wsfs, Wsfc, Wsfb, Wsfi = Weight of safety factors at straight, straight, curve, bridge, and intersections respectively.

Rsfs, Rsfc, Rsfb, Rsfi, Rsfl = Condition rating of safety factors at straight, straight, curve, intersections and bridge, and Roadside land use, respectively.

Further, the Safety hazardous index for the entire road section (SHIrs) of 2km will be obtained by summating the SHI of all elements.

$$SHIrs = SHIs + SHIc + SHIb + SHIi + SHIl$$

This is performed for each 2 km long Chhorepatan – Machhhapuchhre viewpoint Road Section. It will be observed that locations with higher SHI ratings will have more dangerous safety conditions. To install road safety infrastructure for at least a 2 km length in a two-lane road while considering the limited available road safety budget, the Chhorepatan – Machhapuchhre viewpoint Road's dangerous sites will be ranked.

3.3.5 Stage 6: Plotting in GIS:

The road section is prioritized as a calculated safety hazardous index. The safety hazards black spot location is ranked and the hazardous location is plotted using GIS software.

3.3.6 Stage 7: Recommendations for preventive actions

After identifying the hazardous places along the research area, the necessary countermeasures or preventative measures are to be suggested depending on the budget at hand and the prioritization of countermeasures.

4. Results and Discussion

After the consistency check of the weight provided by 20 experts, only 7 were found to have a consistency index within the acceptable range of 0.10. Now, after the consistency test of experts, the relative weight is calculated and finally, the average weight of all accepted experts for each parameter in each section is calculated. The weight calculated from the pairwise comparison using AHP is tabled below in Table 5.

Now, the condition rating of the field is calculated using the field survey and a rating is given for each element in each section.
After this the SHI (Safety hazardous index of all the elements is calculated. SHI for every 2 km road section was calculated by combining the average weights of experts and the condition rating obtained by road survey. Finally, ranking was done with the SHI value obtained.

Table 5. Average weight summary

1. Straight Segments:	
A. Cross-section elements (Carriageway, Shoulder, Drainage)	0.1099
B. Pavements Maintenance condition	0.1678
C. Speed limit and no overtaking signs	0.1139
D. Road Markings	0.1175
E. Roadside hazards	0.2026
F. Pedestrian safety countermeasures	0.1490
G. Vehicle flow	0.1391
2. Curves	
A. Delineation(chevrons), Speed advisory signs, reflectors	0.1272
B. Pavement maintenance condition	0.1128
C. Roadside hazards	0.1251
D. Combination of horizontal and vertical curves	0.0830
E. Lateral offset to vertical obstructions	0.0861
F. Operation speed	0.0828
G. Cut slope	0.1090
H. Design consistency	0.1157
I. Cross section elements (Carriageway, Shoulder, Drainage)	0.1586
3.Bridge and Culverts:	
A. Horizontal or lateral clearance	0.1374
B. Bridge Barriers	0.1826
C. Load limit signs and speed limit sign	0.1379
D. Pavement maintenance condition	0.1926
E. Guard rails and approach protection	0.2053
F. Carriageway Drainage	0.1440
4. Merge and Intersections	
A. Road side condition (Drainage, Shoulder condition)	0.1901
B. Lighting poles and reflective signs	0.1112
C. Traffic calming measures	0.1063
D. Pedestrian safety countermeasures	0.1172
E. Road furniture (Road marking, sign and signals)	0.1199
F. Visibility distance	0.1846
G. Design consistency	0.1703
5. Side Road land use	
A. Lighting poles and reflective signs	0.1445
B. Information signs (Hotels, Restaurants, Health post)	0.2478
C. Access to land use, shoulder width, Road marking	0.1874
D. Pavement Maintenance Condition	0.2199
E. Spacing of the rest areas	0.2003

Table 6: Calculated SHI

1. Straight Segments:	
A. Cross-section elements (Carriageway, Shoulder, Drainage)	1.30
B. Pavements Maintenance condition	3.37
C. Speed limit and no overtaking signs	1.18
D. Road Markings	1.22
E. Roadside hazards	1.80
F. Pedestrian safety countermeasures	1.23
G. Vehicle flow	3.23
2. Curves	
A. Delineation(chevrons), Speed advisory signs, reflectors	2.6203
B. Pavement maintenance condition	3.1009
C. Roadside hazards	2.2943
D. Combination of horizontal and vertical curves	1.4973
E. Lateral offset to vertical obstructions	1.3544
F. Operation speed	1.2478
G. Cut slope	2.2443
H. Design consistency	1.6915
I. Cross-section elements (Carriageway, Shoulder, Drainage)	3.0562
3. Bridge and Culverts:	
A. Horizontal or lateral clearance	1.4441
B. Bridge Barriers	3.6885
C. Load limit signs and speed limit sign	1.3128
D. Pavement maintenance condition	1.7604
E. Guard rails and approach protection	1.8066
F. Carriageway Drainage	1.1275
4. Merge and Intersections	
A. Roadside condition (Drainage, Shoulder condition)	1.368
B. Lighting poles and reflective signs	0.767
C. Traffic calming measures	0.328
D. Pedestrian safety countermeasures	0.312
E. Road furniture (Road marking, signs and signals)	0.317
F. Visibility distance	0.467
G. Design consistency	0.570
5. Side Road land use	
A. Lighting poles and reflective signs	0.867
B. Information signs (Hotels, Restaurants, Health post)	1.263
C. Access to land use, shoulder width, Road marking	0.937

D. Pavement Maintenance Condition	1.011
E. Spacing of the rest areas	1.101

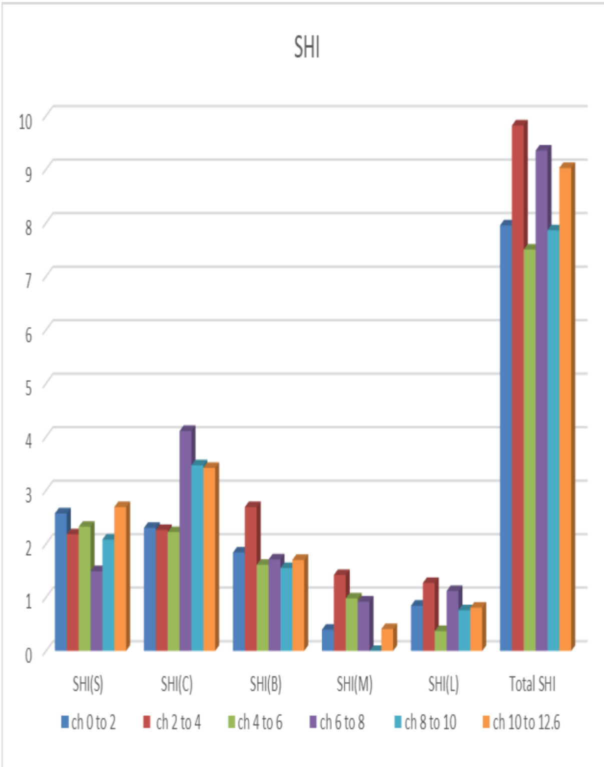

Figure 3: Safety Hazardous Index (SHI) for each road element and total SHI of 2 km road section-wise.

Here, chainage 2+000 to chainage 4+000 km was found to have a high SHI value of 9.82, which denotes this section is more vulnerable.

4. Conclusion

Hence, for the calculated SHI, we conclude that the road sections 2 – 4 km and 6-8 km are the most vulnerable sections of the road with SHI = 9.82 and

Table 7: SHI for each 2 Km road section

SN	Chainage, Km					
SHI	**0-2**	**2-4**	**4-6**	**6-8**	**8-10**	**10-12.6**
SHI(S)	2.57	2.18	2.32	1.49	2.08	2.69
SHI(C)	2.30	2.26	2.22	4.11	3.47	3.42
SHI(B)	1.84	2.69	1.61	1.71	1.55	1.70
SHI(M)	0.39	1.42	0.98	0.92	-	0.40
SHI(L)	0.84	1.27	0.37	1.12	0.76	0.81
	7.95	9.82	7.50	9.35	7.86	9.028

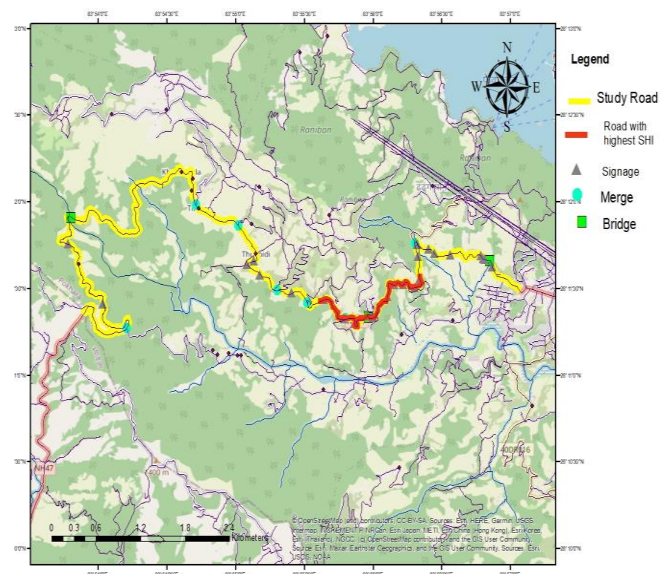

Figure 4: Location with the highest SHI

SHI = 9.35, respectively, which suggests this section to be treated as fast and first. Also, Cross section elements (Carriageway, Shoulder, Drainage), pavement maintenance conditions, and Pedestrian safety countermeasures are important for straight sections in the curve section. A combination of horizontal and vertical curves, Operation speed, cut slope, and Design consistency are important factors to consider. For the case of bridges and culvert Guard rails and approach protection, Carriageway drainage is considered an important factor to be looked after. Similarly, for merge roadside conditions, pedestrian safety measures, and visibility distance are focused factors. Also for side road land use Spacing of rest area, access widths are considered most.

Since every road safety measure may not be applicable and implemented in these sections due to lack in budget and consideration, this methodology can be acted as a first aid implication measures for agencies to detect the hazardous location and study the details and assign the limited budget which help in road safety and reduce the crash numbers.

5. Recommendation

- For the better safety of the road I recommend examining how well the safety features work. We should think about intelligent transportation systems. Some of these technologies include signs that indicate speed limit changes based on conditions, cameras to police traffic laws, and emergency services call buttons in the event of an accident.
- We should analyze the costs and benefits of various safety measures and evaluate the policies and programmes related to safety over the long run.
- For further study, consider human factors (Cognitive and psychological aspects related to the mental process involved in knowing, learning, and understanding things) that lead to the accident. Also, it can examine cultural and economic determinants.

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