

# GIS based Road Safety Audit of State Highways in Thrissur

Bincy B J<sup>1</sup>, Archana S<sup>2</sup>

<sup>1</sup>PG Research Scholar, Dept of Civil Engineering, Jyothi Engineering College, Kerala, India

<sup>2</sup>Assistant Professor, Dept of Civil Engineering, Jyothi Engineering College, Kerala, India

\*\*\*

**Abstract** - In India the number of road crashes is raising at frightening rate. There is one death in every four minutes due to road crashes in India. Hence it is necessary to improve the road safety by conducting a detailed Road Safety Audit (RSA) in order to identify road safety issues and to make necessary improvements. This will eventually delay any rehabilitation or repair process making the road conditions the worst and risky. This project work focus on conducting a detailed Road Safety Audit and qualitatively estimates potential road safety issues on two road stretches and also proposes a systematic approach to do the road safety audit on a highway and to do effective and efficient data mining, for deriving knowledge driven decisions in the ranking of highway sections based on their risk. The approach will help to perform safety evaluation of sections and to identify the crash potential locations. Further output of the work is the development of a mathematical model for classification of highway sections based on road safety audit.

**Key Words:** Road Safety Audit, Factor analysis, Data mining, Road safety model, Geographic Information system

## 1. INTRODUCTION

A Road Safety Audit (RSA) is that the formal safety performance examination of existing or future road by a multidisciplinary team. It qualitatively estimates and reports on potential road issues of safety and identifies opportunities for enhancements in safety for all road users. Every year, more than one million people across the world become the victims of road traffic injuries. To combat the number of injuries and fatalities, road safety audits have become an increasingly popular approach to improve safety on roadways. Road safety audits are versatile because they can be used to evaluate existing roadways and also roadways in the planning and construction processes. Road safety audits measure a proactive means for transportation agencies to diagnose safety deficiencies before crashes and injuries occur. Public agencies with a desire to enhance the safety performance of roadways underneath their jurisdiction will be excited concerning the concept of RSAs. Road safety audits will be employed in any section of project development from planning to construction. The RSA method is qualitative in nature thus there

are restricted quantitative studies of the advantages gained through road safety audit recommendations on existing roadways. In this study Road safety audit is conducted in the State Highways in Thrissur as a tool to assist and quantify the road characteristics with road crashes.

## 2. METHODOLOGY

Two study stretches were selected for conducting road safety auditing. It is the State Highway SH 74(17 KM) and SH 50 (15 KM). For conducting the road safety audit road sections are divided on the basis of geometry (500m each section). Crash spot is identified based on the accident details collected from the police stations. The study stretch is selected based on the past five year crash data. Based on the road safety manual, check list is prepared. While conducting the road safety audit the parameter considered are shown in Table 1

**Table -1:** Check List

Description	Observations
Roadway width (m)	
Type of terrain	
Shoulder width	
Shoulder condition	
Fit of horizontal and vertical curve	
Volume (Veh/3min)	
Pavement condition	
Road markings	
Sight distance problems	
Type of sign and condition	
Protection for pedestrians and bicycle	
Presence of road side hazard	
Post mounted delineators	

Parking	
Street light	
Speed(kmph)	
No of curve	
No.of intersection	
Accident number	

### 3. STUDY AREA

In order to find out the deficiencies in the road stretch a road safety inspection is conducted on the two study stretches were selected for conducting road safety auditing. It is the State Highway SH 74(17 KM) and SH 50 (15 KM). Recent crash data shows that occurrence of accident in these road stretch is very high. highway 74.Vazhakode to Pazhayannur is a State Highway in Kerala that starts in Vazhakode and ends in Alathur. This road connects important towns Chelakkara and Pazhayannur. The study stretch sis of 17 Km road stretch. For conducting the road safety audit road sections are divided into different section on the basis of geometry (500m each section).Crash spot is identified based on the accident details collected from the police stations. This is a road stretch with a number of horizontal and vertical curves and combined curves. Since crashes in this road stretch is high, therefore it is selected as one of the study area.

Ottupara to Vellarakkad is another State Highway in Kerala, that starts in Chavakkad and ends in Wadakkanchery. Recent crash data shows that crashes on this road stretch is very high, hence 15 Km road stretch from Ottupara to Vellarakkad is chosen as the study area. Road Safety Inspections (RSI) are carried out to identify traffic hazards related to the road environment characteristics and propose interventions to mitigate the detected hazards and done under the guide lines of IRC codes [17].

#### 3.1 Road Inventory Survey

Through the data collection all the relevant in formations are collected. For this project the data is mainly collected from two sources. That is the crash data is collected from the police station and the primary data is collected through road inventory survey. Road Safety Inspections are carried out to identify traffic hazards related to the road environment characteristics and propose interventions to mitigate the detected hazards. Data is collected on the basis of prepared checklist.

### 4. DATA TRANSFORMATION

Data transformation is the process of converts the data into appropriate forms for conducting analysis. The data set used in the study contain both continous values and discrete values. There for the discrete values has to be classified accordingly, which is shown in Table 5.4 The table shows the classification values for the corresponding attributes.

Table -2: Description and type of variables

Attribute	Description	Rating
Width of road	Width of road (m)	Continuous
Shoulder width	Width of shoulder(m)	Continuous
Horizontal and vertical Curves	Expressed in numbers	Continuous
Street light	Expressed in numbers	Continuous
Traffic volume(Veh/3 Min)	1 = With in limit, 2 = Exceeded limit	Discrete
Visibility	1 = Proper, 2 = Poor	Discrete
Fitness of horizontal and vertical curve	0 = No curve, 1 = Good fit, 2 = Very sharp curve, 3 = Sharp bend immediately after summit curve / Sag curve with bend	Discrete
Speed	Expressed in m/s	Continuous
Presence of road side hazard	1 = No obstruction, 2 = Fixed objects/ road side stalls, 3 = Poles/ column, trees in hazardous condition	Discrete
Pavement Characteris-Tics	1 = Smooth condition, 2 = Relatively smooth, slight break and rut, 3 = Rough, breaks, rut, potholes, 4 = Rough, severe breakage, rut, pot holes	Discrete
Intersection	0 = No intersection, 1 = Single minor road, 2 = Two minor/ Single major road, 3 = Two major road	Discrete
Pavement markings	1 = Proper, 2 = Partially removed, 3= Completely remove	Discrete
Sign boards	1 = Proper, 2 = Faded sign boards 3 = Not provided where traffic is high, 4 = No warning at hazardous situations	Discrete

## 5. CRASH ANALYSIS

The increase in motorization accompanied with expansion of road network has brought with it the challenge of addressing the adverse influence of road traffic accidents. Road accidents are a global cataclysm with ever raising trend which pose a public health and development challenge and greatly affect the human capital development of every nation. Five tear crash details is collected from the police station and based on that crash analysis is done.

### 5.1. LOCATION BASED CRASH ANALYSIS

The Fig. 1. showing the sample of location based crash analysis. It shows the number of crashes occurred in the first 6 section ie, from the chainage (0- 3Km). Similarly the number of crashes occurred in the whole section is find out based on the crash details collected from the police station. From that the sections were maximum number of crashes are identified. Occurrence of accident in these road stretch is very high due to the presence of many sharp contributing the spate of accidents and had made it into an accident prone area. Most of the motorist especially unfamiliar drivers fail to notice the curve and end up crashing. Most of the crashes at this location happened due to high speed and often it turned out of human error also. From the crash analysis it can be found out that the sections with steep and combined curves are crash prone spots, and it is mainly due to poor visibility. In some stretches the bus stops are provided very closer to intersection.

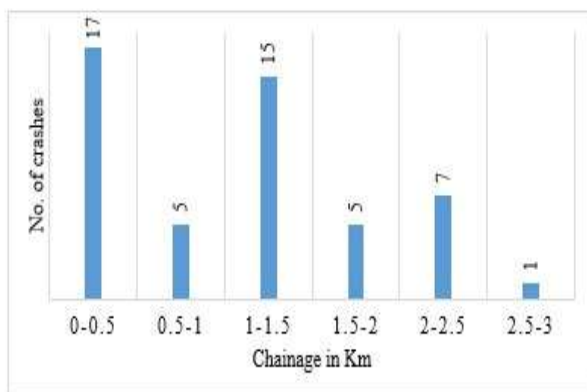


Fig -1: Location based crash analysis

### 5.2 SEVERITY BASED CRASH ANALYSIS

The Fig.2 showing sample of the severity based crash analysis. It represents the accident severity for the first 0 to 3Km chainage. Similarly the crash severity for the whole study area is found out with the help of accident data collected from the police station and the details collected from the local people.

From the analysis it is observed that most of the accident occurred is of grevous type and the highest is in Nelluvai,

Vazhakode, Uthuvady. Fatal accident is high in Vazhakode, Kanjirakkode and Erumapetty.

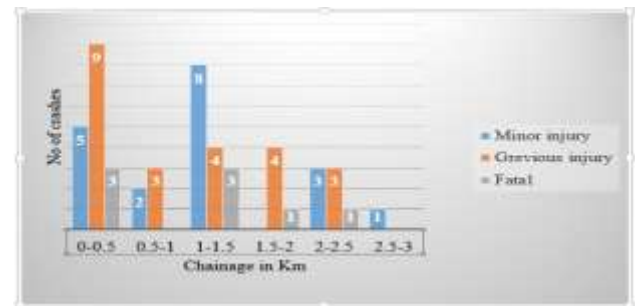


Fig -2: Severity based crash analysis

The collection and use of accurate and comprehensive data related to road crashes is very important to road safety management. The various factors which leads to road crashes are studied and the locations with most number of occurrence of accidents are identified.

## 6. MODELING

A model help to explain a system and the effects of different components (independent variable) with that the predictions and behavior can be understand. The quality of the study will depend on how well the mathematical model developed on the theoretical side agree with the actual conditions. In this study it aim to model a relationship between the weighted severity index and the various parameters selected for the study.

### 6.1 CORRELATION

Correlation analysis is done in order to identify top correlated attributes Spearman rank correlation. Correlation analysis is a method of statistical evaluation used to study the strength of a relationship between two, numerically measured, continuous variables. If correlation is found between two variables it means that when there is a systematic change in one variable, there is also a systematic change in the other.

Table -3: Correlation table

Variables	Correlations
Visibility	0.599**
No. of curves	0.335**
Intersection	0.587**
Presence of road side hazard	0.329**
Pavement condition	0.518**
Sign board	0.634**
Pavement markings	0.436**
Fitness of curve	0.288*
Shoulder width	0.250*
** Correlation is significant at the 0.01 level	
* Correlation is significant at the 0.05 level	

## 6.2 FACTOR ANALYSIS

Factor analysis is a method of data reduction. It does this by seeking underlying unobservable (latent) variables that are reflected in the observed variables (manifest variables). There are many different methods that can be used to conduct a factor analysis (such as principal axis factor, maximum likelihood, generalized least squares, unweighted least squares), There are also many different types of rotations that can be done after the initial extraction of factors, including orthogonal rotations, such as varimax and equimax, which impose the restriction that the factors cannot be correlated, and oblique rotations, such as promax, which allow the factors to be correlated with one another. Simple structure is pattern of results such that each variable loads highly onto one and only one factor. Rotated factor matrix contains the rotated factor loadings (factor pattern matrix), which represent both how the variables are weighted for each factor but also the correlation between the variables and the factor which is shown in Table 4. Because these are correlations, possible values range from -1 to +1.

**Table -4:** Rotated component matrix

Parameter	Component 1	Component 2	Component 3
Visibility	0.781	-	-
Intersection	0.771	-	-
Pavement condition	0.720	-	-
Pavement markings	0.681	-	-
Fitness of curve	-	0.845	-
No. of curves	-	0.633	-
Sign board	-	0.503	-
Shoulder width	-	-	0.759
Presence of road side hazard	-	-	-0.585

Here in this case the first five features can be grouped together i.e., Visibility, Intersection, Pavement characteristics, Conditions of road markings, Fitness of curve and it can be named Roadway characteristics (RC). The second component includes Fitness of curve, number of curves, condition of sign board and it comes under Curve characteristics and Sign conditions (CC). The third component includes shoulder width and Presence of road side hazard and it can be called as road side features component include Shoulder width and Presence of road side hazard and it can be called as road side features (RS). Therefore Roadway characteristics (RC)

$$RC = 0.781 * \text{Visibility} + 0.771 * \text{Intersection} + 0.720 * \text{Pavement condition} + 0.681 * \text{Road Markings}$$

Eqn.[1]

$$\text{Curve characteristics and Sign conditions (CC)}$$

$$CC = 0.845 * \text{Fit of curve} + 0.633 * \text{Number of curve} + 0.503 * \text{Signboard}$$

Eqn[2]

$$\text{Road side features (RS)}$$

$$RS = 0.759 * \text{Shoulder width} - 0.585 * \text{Presence of road side hazards}$$

Eqn[3]

## 6.3 ANALYSIS OF DATA USING WSI METHOD

Five years accident data were analyzed to obtain the most accident prone locations using WSI method by assigning scores based on the number and severity of accidents at that particular location in the last five years. Weighted Severity Index (WSI),  $WSI = (1 \times MI) + (4 \times GI) + (41 \times K)$

Where, K - No of fatality  
GI - is the number of grievous injuries  
MI - is the number of minor injuries

**Table -5:** Ranking of road stretches based on WSI

Rating	Classification value	Condition of road stretch
0-4	1	Low Risk
5-41	2	Medium Risk
> 41	3	High Risk

There for the regression analysis is done on the basis of weighted severity index as the independent parameter.

## 6.4 REGRESSION MODELING

In statistics, linear regression is a linear approach for modelling the relationship between a scalar dependent variable and one or more explanatory variables (or independent variables). The case of one explanatory variable is called simple linear regression. For more than one explanatory variable, the process is called multiple linear regression. In linear regression, the relationships are modeled using linear predictor functions whose unknown model parameters are estimated from the data. Such models are called linear models. Values of R<sup>2</sup> is between 0 and 1. In this case two third data is taken for regression analysis. The coefficient of determination, R<sup>2</sup>, is used to analyze how differences in one variable can be explained by a difference in a second variable. R<sup>2</sup>, is the square of the correlation coefficient. It gives an idea of how many data points fall within the results of the line formed by the regression equation which is shown in Table 6

**Table -6:** Regression coefficients

Model	Unstandardized B	T	Sig.
Constant	0.102	4.226	0.000
RC	0.256	9.481	0.000
CC	0.193	2.341	0.024
RS	0.225	3.234	0.002

$$\text{Class of road} = 0.102 + (0.256 * RC + 0.193 * CC + 0.225 * RS) \quad \text{Eqn[4]}$$

The higher the coefficient, the higher percentage of points the line passes through when the data points and line are plotted. A higher regression coefficient indicates a better goodness of fit for the observations. The usefulness of R<sup>2</sup> is its ability to find the likelihood of future events falling within the predicted outcomes. While conducting the regression analysis the R<sup>2</sup> value obtained is 0.773 as shown in Table 7. Higher the value of R square, better the model. The obtained value of R<sup>2</sup> is 0.773 it means 77.3 percent of the points should fall within the regression.

**Table -7:** Summary of R<sup>2</sup>

Model	R	R <sup>2</sup>
1	0.879	0.773

### 6.5 MODEL VALIDITY

Remaining one third data is checked for validity. Along with these data 5Km stretch of another State Highway in Thrissur is added and the validation is checked. Then the average root mean square error is calculated. The obtained root mean square error for the model is 0.21.

### 6.6 APPLICATION OF RSM

Let's take a road stretch with the following condition. The corresponding values of each parameter is substituted in the regression model. Using this model the ranking of the road stretch can be find out. The features of this segment is shown in Table 8.

- Poor visibility
- Intersection with two major road
- Partially removed pavement markings
- Pavement with slight break and rut
- Sharp curve
- Stretch with 3 curves

- No sign board
- Shoulder width is 2.1m
- No road side hazard

**Table -8:** Application of RSA model

Factors	Factor score	Classification values
Poor visibility	0.781	2
Intersection with two major road	0.771	3
Pavement relatively smooth with slight break	0.720	2
Partially removed markings	0.681	2
Sharp curve	0.845	2
Number of curves is 3	0.633	3
No sign board	0.503	4
Shoulder width	0.759	2.1
No road side hazard	-0.585	1

$$RC = 0.781 * 2 + 0.771 * 3 + 0.720 * 2 + 0.681 * 2 = 6.67$$

$$CC = 0.845 * 2 + 0.633 * 3 + 0.503 * 4 = 5.6$$

$$RS = 0.759 * 2.1 * (-0.585) * 1 = 1.02$$

Road safety model (RSM) obtained is

$$RSM = 0.102 + (0.256 * RC + 0.193 * CC + 0.225 * RS) \quad \text{Eqn[5]}$$

Road safety model(RSM) obtained is  $RSM = 0.102 + (0.256 * RC + 0.193 * CC + 0.225 * RS)$

By substituting the corresponding values of these road sections into the road safety model the rank of the road will obtain i.e.  $\text{Class of road} = 0.102 + (0.256 * 6.677 + 0.193 * 5.601 + 0.225 * 1.0089) = 3.119 \approx 3$   
Hence road is classified as High Risk

### 7. GIS TOOLS FOR ROAD SAFETY MANAGEMENT

Geographic Information System (GIS) is a specific integrated system of hardware, software and analysis tools designed to capture, store, manipulate, analyse, manage, and present all types of spatial or geographical data. In a general sense, GIS is a tool which has been employed for integration of spatial and non-spatial data. GIS applications allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations. Road network map along with attribute data pertaining to the study area were created in ArcGIS

environment. Accident spots derived from weighted severity (WSI) method were prioritized in GIS, to obtain the most vulnerable accident spots in the study area. Based on the regression model with rating based on Weighted Severity Index as independent parameter each section of road is classified and displayed in ArcGIS. Both the road stretches in the study area are coming under Thalipilli Taluk. Hence the Open street map of road shape file of Thalipilli Taluk is taken from Q-GIS. Then the map is imported to Arc GIS. Afterwards the road stretches are segmented based on length. The attribute tables are added to it, which include the information collected regarding each section, which is shown in Fig. 3

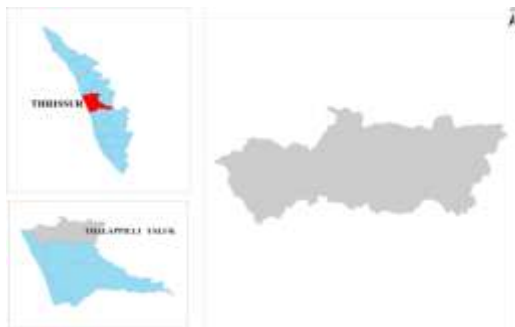


Fig -3: Thematic representation of study area in ArcGIS

### 7.1. Thematic Representation of Vazhakoode to Pazhayannur In ArcGIS

Into thematic map corresponding attribute table of Weighted Severity Index of Vazhakoode to Pazhayannur road stretch is added which is shown in Fig. 4

- Low Risk - Green
- Medium Risk - Yellow
- High Risk - Red

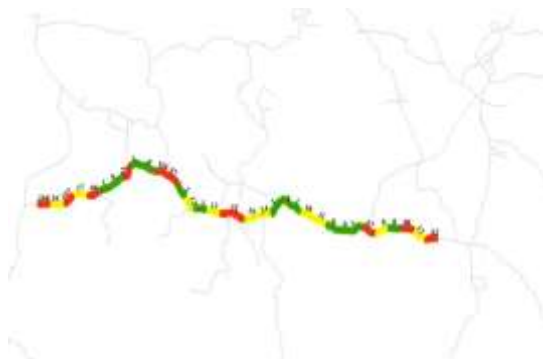


Fig -4: Weighted severity index of Vazhakoode to Pazhayannur stretch

### 7.2. Thematic Representation of Ottupara to Vellarakkad In ArcGIS

Similarly into thematic map corresponding attribute table of Weighted Severity Index of Ottupara to Vellarakkad road stretch is added and is shown in Fig.6



Fig -5: Weighted severity index of Ottupara to Vellarakkad stretch

From the analysis of Vazhakode to Pazhayannur stretch it is clear that there are 11 sections which are classified as High Risk, 10 sections classified as Moderate Risk and 13 sections were classified as Low Risk. Finally the ranking of each section are represented with suitable colour for each segment. In this road stretch 7 section with most vulnerable condition were identified and are classified as High Risk, 12 sections were classified as Moderate Risk sections and 11 sections were classified as Low Risk stretches.

### 7.3. Suggestions for Improvement of Study Stretch as Per IRC Codes:

Based on the results the sections which comes under high risk classification can be improved by on the basis of recommendations provided in IRC codes

Vazhakode Junction Vazhakode junction is a Y intersection. Leaving a large unmarked area at the junction will cause wavering of vehicles and increase accident potential. As per IRC SP 66: 1976 when an intersection were two major and a minor roads meets[17].The major road has to given the priority. Therefor the entry from the minor road is controlled by STOP or GIVE WAY signs and stop line markings

Vazhakode Valavu it is a steep vertical curve. A number of crashes are occurring at this spot every year. The bus stop is also situated with in this curve. There are problem of inadequate visibility may arise on the inside of the curve because of the presence of tall mosque nearby. The factors affecting safety at a vertical curve are the rate of grade, the length of grade, and the frequency of grade changes. The first two factors influence the extent of speed differential between the vehicles. Therefor speed limit sign boards should be kept within this section.

Uduvadi In this road stretch there are two sharp horizontal curves and also the natural objects (trees) very adjacent to the road section. On the inside of horizontal curves, visibility can be improved by cutting back the obstructions to sight, lowering the height of hedges. Sharper the curve, greater is the proneness to accidents. Trees allowed to remain should be painted in white colour for a height of 1.25 m above roadway level with 300 mm middle band in black colour to warn road users of their presence [16]. For better night visibility, it will also be preferable to fix on their face a piece of red reflectorised tape, disc or paint.

Near Nelluvai region there are paddy fields. A number of culverts are provided in this stretch, also the road width in this stretch is lesser than the required. During night times vehicles may fall on the paddy fields due to lack of delineators. Wherever widening of single lane to two-lane carriageway is undertaken, the widening/reconstruction of narrow culverts equal to full formation width should be simultaneously taken up. For this purpose, it would be preferable to include the provision for culverts in the estimate for widening of road itself. However, wherever this is not possible, bold warning sign boards on both sides of narrow culverts should be installed.

In kanjirakkode there are two intersections and a steep curve. No warning signs are provided in this stretch. Since it is a staggered intersection with 6 major conflicts and 12 minor conflict points the number of intersections should be reduced to the barest minimum. On rural highways, the intersections should not be spaced closer than 750 m. [17] On urban arterials, the corresponding minimum distance should be 500 m. Therefore approaches to intersections should be provided with properly laid out guidance system in the form of signs and pavement markings.

Erumapetty Junction It is a junction where two minor roads meet with two major road. Priority intersections like an intersection between major and minor roads where the major road has the priority for movement while the entry from the minor road is controlled by STOP or GIVE WAY signs and stop line markings. Sign boards with speed limit should be erected and also necessary warning signs should be provided.

## 8. CONCLUSION

The outcome of a road safety audit is the identification of any road safety deficiencies and formulation of recommendations aimed at removing or reducing the deficiencies. From the analysis it can be identified that intersections and curves are the major features leading to crashes. A curvilinear alignment with long curves is better from the point of safety and aesthetics. As a normal rule, sharp curves should not be introduced at the end of long tangents since these can be extremely hazardous. Visibility is an important requirement at intersections. To avoid

collisions, it is essential that sufficient sight distance is available along the intersecting roads and their included corners, to enable the operators of vehicles simultaneously approaching the intersection to see each other in time. The study attempts to find out the causative factors for accident and suggests measures to prevent accidents in future.

## REFERENCES

- [1] Agarwal, P. K., Patil, P. K., and Mehar, R. (2013). "A methodology for ranking road safety hazardous locations using analytical hierarchy process." *Procedia Social and Behavioral Sciences*, 104, 1030–1037.
- [2] Aghasi, N. H. M. (2019). "Application of GIS for urban traffic accidents: A critical review." *Journal of Geographic Information System*, 11, 82–96.
- [3] Bagi, A. S. and Kumar, D. N. (2012). "Road safety audit." *IOSR Journal of Mechanical and Civil Engineering Ver. 1*, 1(6), 1 – 7.
- [4] Deshpande, P. (2014). "Road safety and accident prevention in India: a review." *International Journal of Advanced Engineering Technology*, 5(2), 64–68.
- [5] Geurts, K., Brijs, T., and Wets, G. (2003). "Clustering and profiling traffic roads by means of accident data."
- [6] Grosskopf, S. E., Kazemi, T., Hughes, J., and Alumsawi Bani Hashim, S. (2012). "Road safety assessments and road safety audits on the existing Abu Dhabi internal road network." *SATC 2012*.
- [7] Huvarinen, Y., Svatkova, E., Oleshchenko, E., and Pushchina, S. (2017). "Road safety audit." *Transportation Research Procedia*, 20, 236–241.
- [8] Khalilikhah, M. and Heaslip, K. (2016). "The effects of damage on sign visibility: An assist in traffic sign replacement." *Journal of Traffic and Transportation Engineering (English Edition)*, 3(6), 571–581.
- [9] Khera, D. and Singh, W. (2014). "A review on injury severity in traffic system using various data mining techniques." *International Journal of Computer Applications*, 100(3).
- [10] Lopez, G., de Ona, J., Garach, L., and Baena, L. (2016). "Influence of deficiencies in traffic control devices in crashes on two-lane rural roads." *Accident Analysis & Prevention*, 96, 130–139.

- [11] Mehar, R. and Agarwal, P. K. (2013). "A systematic approach for formulation of a road safety improvement program in india." *Procedia-Social and Behavioral Sciences*, 104, 1038–1047.
- [12] Moradkhani, F., Ebrahimkhani, S., and Sadeghi Begham, B. (2014). "Road accident data analysis: a data mining approach." *Indian Journal of Scientific Research*, 3(3), 437–443.
- [13] Sayed, M. and Mhaske, S. (2013). "Gis based road safety audit." *International Journal of Scientific Engineering and Research (IJSER)*, 1(2), 21–23.
- [14] Szenasi, S. and Janko, D. (2017). "A method to identify black spot candidates in built-up areas." *Journal of Transportation Safety & Security*, 9(1), 20–44.
- [15] Wei, L. "Enhancing road safety management with gis mapping and geospatial database.
- [16] IRC: 27- 1984, Report Contarning Recommendations of the Regional Workshops on Highway Safety.
- [17] IRC: 66-1976, Recommended Practice for Sight Distance On Rural Highways. [3] IRC SP-088,2010,Manual on Road Safety Audit,.