METHODOLOGY TO DEVELOP ROAD SAFETY INDEX AND EVALUATION FOR THIRD WORLD COUNTRIES

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ABSTRACT

Road traffic injuries remain an important public health problem at global, regional and national levels. It is estimated from the WHO report (2009) that over 90% of the world's fatalities on the roads occurs in low income and middle income countries, which have less than half of the world's vehicles. Road safety being a complex topic to study, the problem itself is underestimated in many countries, especially in developing countries where the issue is challenging. In recent years, the interest in the use of indicators and indices are rapidly increasing along with its measurement followed by evaluation. RSI is one such index used to develop a methodology to identify road and its infrastructure deficiencies related to road safety. This is a handy tool which can be made available readily to obtain the road performance which can be evaluated and audited. The methodology developed here is through qualitative approach and leads to the interventions to establish safer roads with a better level of service (LOS). Various parameters / indices which are measurable qualitative / quantitative are identifies underlining the phrase "We can't manage what we can't measure" by Robert Kaplan (Harward Business School). This study can be used as a readymade tool to know the road safety index, which demands the improvement measures, if necessary. In India, perhaps this is the first of its kind to assess the rating of an existing road.

Key words: Road Safety Index (RSI), Vulnerable Road User (VRU), Value Score Charts (VSC), Accident trends & Micro analysis, Accident Cost & Economic loss, level of service (LOS).

I. INTRODUCTION

The safe design of road infrastructure is a key part of a comprehensive road safety plan. Road safety auditing provides a vital role in checking that roads which have been designed and built to the highest safety standards. Practical road safety auditing provides solutions to safety problems and also brings together safety audit procedures to be followed by the agency, local authorities and other organizations involved in safety aspects.

Based on the local conditions and adopted methodologies for the planning and design, the road user safety suffers to a larger extent until and unless a scientific and rational method is evolved in assessing the road safety and suggest measures for implementation. So, it is very important to identify the road safety audit parameters with reference to a given set of conditions and aggregate these parameters. The various identified parameters are aggregated to a composite road safety index after developing a methodology, with the help of a questionnaire. Weighted averages of each factor are obtained and aggregated. The rating of a given road, based on priority (number of accidents taking place) can be obtained using the qualitative approach. Knowing the field condition, the road safety rating can be arrived and compared to the standard which was developed earlier. The index will speak on the road safety performance. The work examines the real road safety problems, together with number of successful solutions supported by comprehensive evidence.

India is one of the most accident-prone countries in the world with a record rate of more than three lakh road crashes every year. The rate of fatality is as high as sixty thousand, which contemplates a need for immediate rectification of this critical situation. Despite India having less than 1% of the world's vehicles, the country accounts for 6% of the total road accidents across the globe and 10% of road fatalities. Accident record of the country was among the worst in the world as per CRRI-Study report, (Feb 2005). Road accidents have registered a sharp increase recently following rapid growth in vehicle ownership, construction of high-speed roads and expressways. With greater demand for faster road transportation, accident rates could go up further unless both traffic rules and road safety measures are enforced strictly. A review on the road crash analysis world over implies that the human factor attributes to the majority of accidents. A similar instance has been observed in India, with an authenticated report [(2)] saying that the contribution by the human for the road crashes is about 82%, while 12% is due to the bad road conditions, whereas the vehicle factor contributes to about 5% and the rest due to environmental factors. However, the driver is solely responsible for the prevention of such road crashes unless and otherwise the vehicle is incorporated with intelligent devices. Large extent of casualties reported in

India is mainly due to the two wheelers ie.38% whereas pedestrian casualties are about 42%. This is a scenario observed in urban roads whereas in the rural highways, trucks are responsible for the major road crashes.

Table 1: Accident rates per million populations

City	Population (millions)	Accident rate/million population
Bangalore	8.1	14.58
Delhi	15.0	7.252
Mumbai	17.8	15.729
Chennai	7.92	6.81

(Ref: Traffic Police, Bangalore, India)

Table 1 indicates that the accident rates per million population, which is an indicative measure of the unsafe urban area. Bangalore records the second highest road crashes rate per million populations.

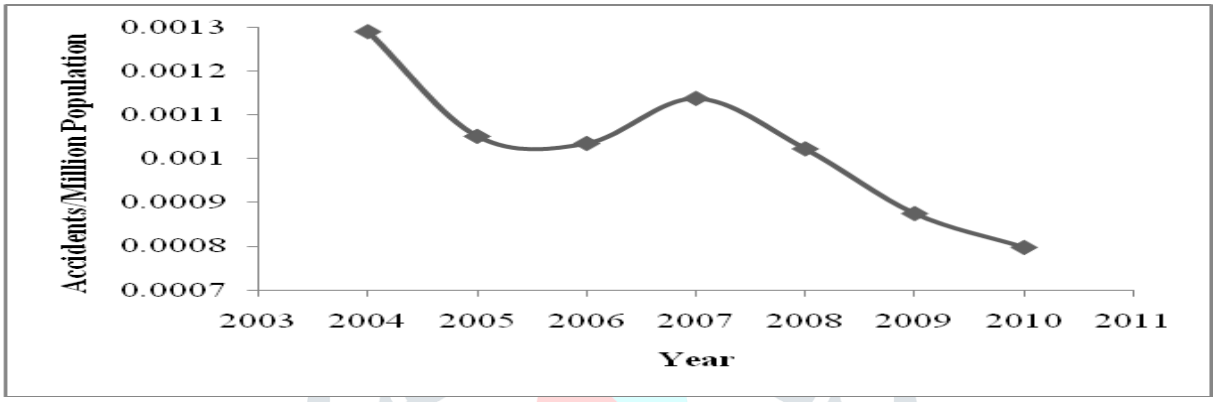


Figure 1: Road crash rate / Million population over the years (Bangalore)

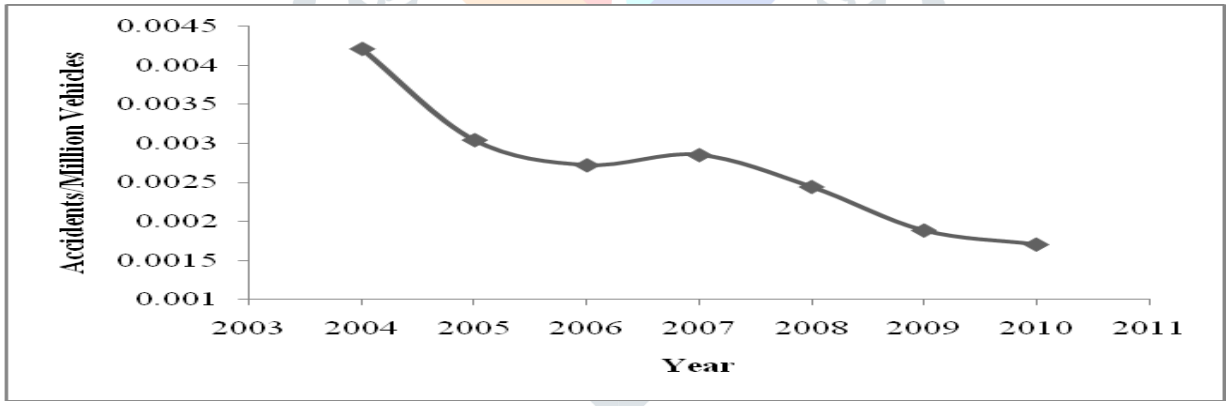


Figure 2: Road crash rate / Million Vehicles over the years (Bangalore)

However, considering the rate of road crashes/million vehicles over the years, Bangalore registers a decreasing trend.

1.1 Objectives

1. Identification, measurement and aggregating the various road safety indicators to a composite index namely RSI.
2. To develop relative weightages and value score charts for various indices.
3. Measurement and validation of RSI by taking trial stretches case studies to rate the road under question
4. Interventions for improvements
5. Before and after studies

1.2 Methodology

1. Identification, definition and effectiveness of indicators/parameters
2. Assigning and validating relative weights for each indicator.
3. Development of standard value score charts (Vsi)
4. Data collection and analysis
5. Aggregating the indicators to a composite index
6. Suggest interventions to improve the low rated roads and improve the RSI
7. Score charts are presented to the authorities / local bodies to attend the issues
8. To understand the system through before and after studies

Out of several factors available which affects the road safety, it is very difficult to arrive at a consensus about the exact one which can be measured quantitatively or qualitatively. Hence it is very essential to consider all of them with their relative importance for measuring RSI. These large number of factors are grouped into 6 categories namely, General, Road way characteristics, intersections, traffic characteristics, pedestrian facilities and miscellaneous. The methodology includes the development of relative weights for the 6 broad categories which contain the identified indicators.

2.0 METHODOLOGY DEVELOPMENT

Various factors contribute to the road crashes and the audit explores a methodology of identifying strong factors for which the measurements can be obtained in terms of developing weightages for each attribute. With the help of the weightages, trend charts are developed as indicated in subsequent chapters. A road under question can be assessed for its safety and its ranking can be arrived to indicate the extent of safety.

Out of the several types of indicators available, it is very difficult to arrive at a consensus regarding the one of most suitable indicators. Hence it is very essential to consider all of them with their relative importance for measuring the RSI. These factors are grouped to six categories namely – General (No. of curves, carriage way width, on street parking, bus stop location and median), Roadway characteristics (potholes/km, speed breakers/km, gradient), Intersections (type, visibility, no. of intersections/km), Traffic signs & markings (signs and signages, pavement markings), Pedestrian facility (footpath/shoulders), and Miscellaneous (roadside trees, adv boards, electric and telephones, roadside illumination). The methodology includes in the development of relative weightages and value score charts of individual factors under each indicator and aggregation of these factors to obtain RSI.

2.1 Relative Weights for indicators

About 100 traffic engineering experts in the country are given questionnaire to indicate the relative importance of each indicator in percent and their weighted average is computed. This is indicated in figure 3. Statistical checks indicated that the coefficient of variation for the relative weightages is not very significant which justifies the consistency in the collection of the data.

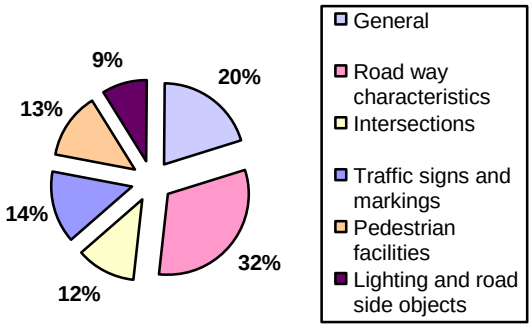


Figure 3: Relative weightage diagram

2.2 Value Score Trend Charts

A scientific questionnaire is designed as indicated and the value scores awarded by the experts are used for preparing the charts. (Road safety and traffic engineering experts constituted by Road research institutes & laboratories, academicians, practicing engineers and consultants numbering 100). Based on these value scores, trend charts are developed as indicated below. For each factor (0-100), experts assign values between 0-100 and the evaluated values are being averaged. The data sheet for obtaining the value scores are presented in Table 2 and value score charts are given in figure 4(a) to 4(p).

Table 2: Data sheet for obtaining value scores

No. of horizontal curves/km (a)						Speed (b)						On-street parking causing interference(c)						Bus-stop location from intersection (d)					
5	4	3	2	1	0	Within speed limit	10%more	20%more	30%more	40%more	50%more	No parking	0˚	30˚	45˚	60˚	90˚	80-100m	60-80m	40-60m	20-40m	0-20m	0m

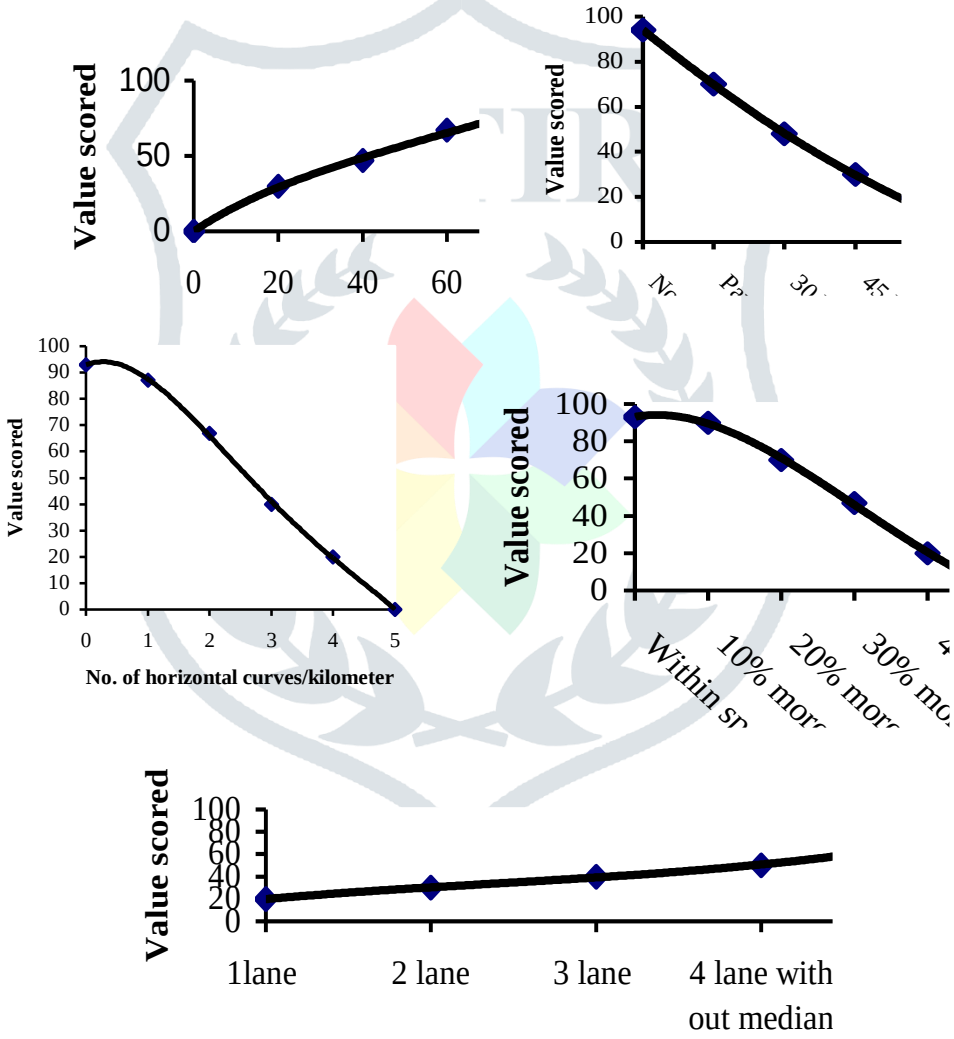
Intersection visibility (h)						Potholes/km (i)						Gradient (j)						Shoulders (k)					
Excellent	Very good	Good	Fair	Bad	Poor	8-10	6-8	4-6	2-4	0-2	0	16-20%	12-16%	8-12%	4-8%	0-4%	0%	2-2.5m	1.5-2m	1-1.5m	0.5-1m	0-0.5m	No shoulders

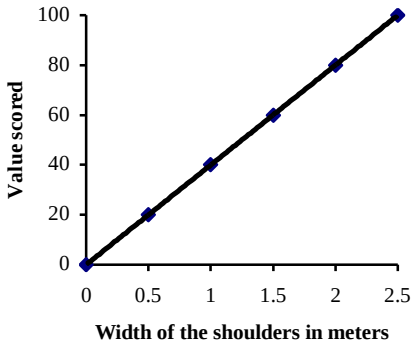
Carriage-way width (e)						No. Of intersections /km (f)						Speed-breakers/km (g)					
Median & 4-lane	Median, 4-lane& parking	No median & 4-lane	No median & 3-lane	No median & 2-lane	No median & 1-lane	5	4	3	2	1	0	5	4	3	2	1	0

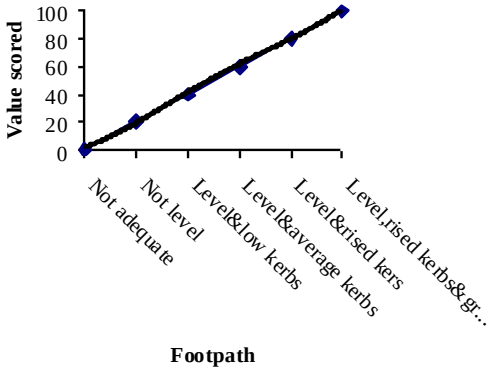
Pavement Marking (l)						Sign & Signages (m)						Median & its height(n)					
A	B	C	D	E	F	Adequately	Placed at strategic points	No adequate signs	Placed at wrong locations	Using wrong signs	No signs	With grill of 1.5m	Grill of 0.7m	Only median of 60cm.	Median of 30cm.	Median of 15cm.	No median

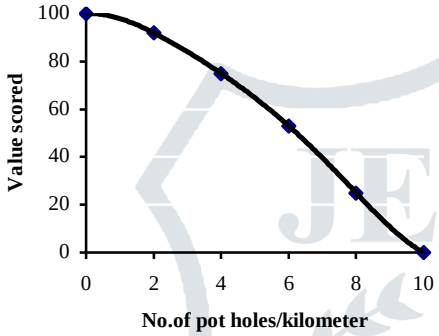
Foot-path (o)						Type of intersection(p)					
G	H	I	J	K	L	M	N	O	P	Q	R

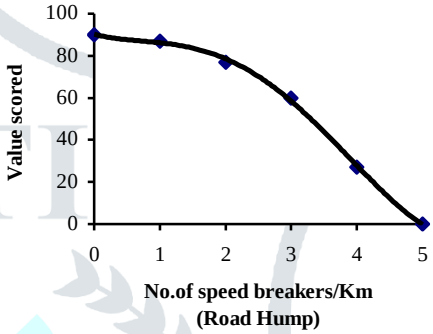
A-edge marking, centerline marking, lane marking, zebra crossing & stop line.
B- Centerline marking, lane marking, zebra crossing & stop line, C- lane marking, zebra crossing & stop line.
D- Zebra crossing & stop line, E- stop line, F-No marking, G-level, raised kerbs, with grills, H-level & raised Kerbs, J- level & low kerbs.
K-not leveled, L-no adequate footpath, M- intersection with island, free left & island, N- intersection with island & free left.
O- intersection with island & controlled left, P- perfect right angle, Q- T-junction, R- skew junctions.

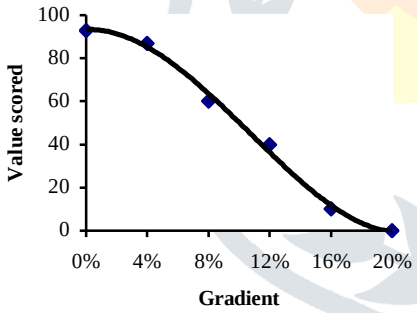


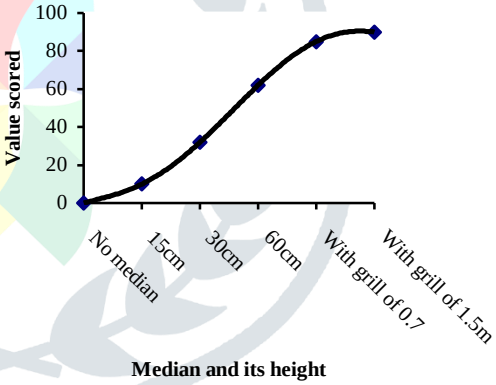

Value scored
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
Width of the shoulders in meters

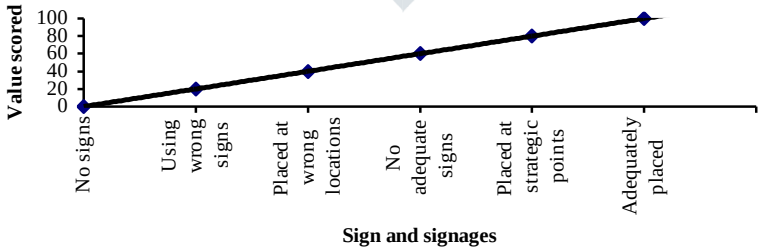

Value scored
100
80
60
40
20
0
Not adequate
Not level
Level&low kerbs
Level&average kerbs
Level&rised kers
Level,rised kerbs&gr...
Footpath

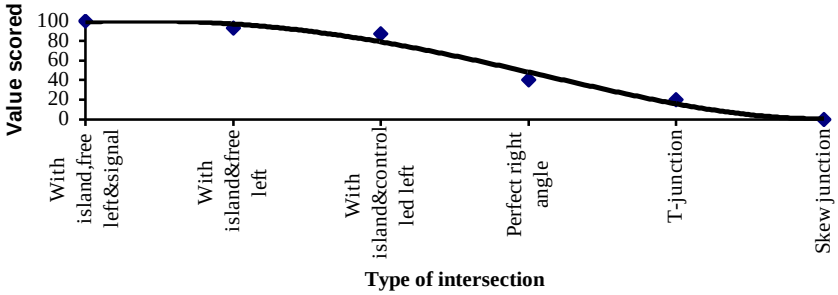

Value scored
100
80
60
40
20
0
0
2
4
6
8
10
No.of pot holes/kilometer

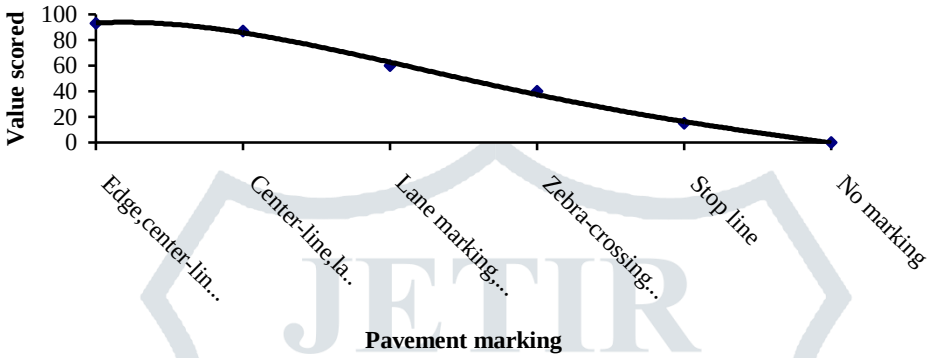

Value scored
100
80
60
40
20
0
0
1
2
3
4
5
No.of speed breakers/Km
(Road Hump)


Value scored
100
80
60
40
20
0
0%
4%
8%
12%
16%
20%
Gradient


Value scored
100
80
60
40
20
0
No median
15cm
30cm
60cm
With grill of 0.7
With grill of 1.5m
Median and its height


Value scored
100
80
60
40
20
0
No signs
Using wrong signs
Placed at wrong locations
No adequate signs
Placed at strategic points
Adequately placed
Sign and signages





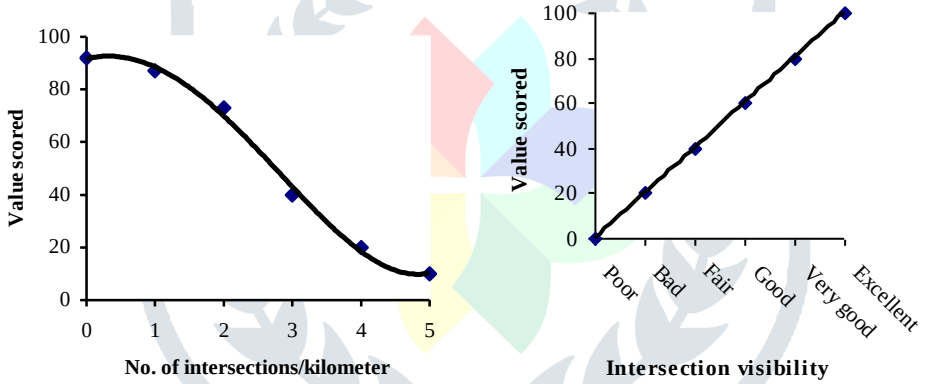


Figure 4 (a) to (p): Value score charts for individual factors

2.3 Aggregation of factors for road safety index

Aggregation of the various factors is possible mathematically using the equation given below.

$$RSI = \frac{\sum_{i=1}^{i=n} Wi * Vei}{\sum_{i=1}^{i=n} Wi * Vsi}$$

Where 'n' is number of groups that define the overall factors to contribute accident.

'W_i' is the relative weightage allocated with i^{th} service characteristics.

'V_{ei}' is the value score for i^{th} service characteristics of the existing situation

'V_{si}' is the value scores for i^{th} service characteristics.

As indicated in the study when the safety index (SI) requirements being met (resulting in the higher values of the index) or otherwise the poor condition of index requiring immediate concern/improvement.

2.4 Computation of Road Safety Index

Considering the absolute value score for the excellent and safe condition of the road, based on the local operating conditions, the value of $\sum (W_i * V_{si})$ is computed to be 100.The numerator is computed on the basis of observations made for each factor in the field for a given road. The value scored for each factor is assessed after measuring each sub-heads and referring the chart for $V_{ei.}$

3.0 EVALUATION OF ROAD SAFETY INDEX- A CASE STUDY

To evaluate and validate the mathematical model developed to obtain RSI, typical roads in Bangalore where accidents are frequented, were taken. The selected stretch of the roads measured 1km. A typical worksheet is presented as below:

3.1 Case study: Mysore Road - B U Gate to RVCE

All the factors were measured and the value scores were obtained from the charts. As per the calculations, the total values scored for each among the six categories are as below.
General-58.00
Road way characteristics-86.67
Intersections-43.33
Traffic signs and markings-50
Pedestrian facility-60
Miscellaneous-60

$$RSI = \frac{\sum_{i=1}^{i=n} Wi * Vei}{\sum_{i=1}^{i=n} Wi * Vsi}$$

$$\frac{[(0.2x58.00) + (0.32x86.67)+(0.12x43.33)+(0.14x50)+(0.13x60)+(.09x60)]}{100}$$

=0.65 i.e. 65.00 Percent

Table 3: Gradation of roads based on RSI

RSI in %	Level of Service
0.80-1.00	Excellent
0.60-0.80	Good
0.40-0.60	Satisfactory
0.20-0.40	Poor
0-0.20	Very poor

Using the equation and substituting the values obtained from the charts, the RSI will be 0.65. The present status of the road taken for the case study is graded as **good** as per the gradation of roads indicated in Table 3. However, the level of service can be brought to excellent by improving various measures as indicated in the Table 4. The above measures if implemented, will improve the RSI to 0.84(84%), which transforms the road to **excellent** and safe condition for operation.

Table 4: RSI values before and after improvements

No	Name of the Road	Existing		Improved		Improvement measures
		RSI	LOS	RSI	LOS	
1	Mysore Road - (B U Gate to RVCE)	0.65	Good	0.84	Excellent	Removal of on street parking, adequately placing the signs and signages, road markings, illumination, shoulder of 2 m wide, removal of roadside advertisement boards

2	Shankaramath Road – (Pavithra Paradise to Pertol Bunk)	0.57	Satisfactory	0.79	Good	Removal of on street parking, providing 30cm height median, potholes filling, reducing speed breakers to one, providing level raised kerbs with grills, pruning tree branches, signs and signages, road markings
3	Shadashivanagar – (Windsor Manor to Sadashivanagar PS)	0.73	Good	0.87	Excellent	Potholes filling, removal of speed breakers, signs and signages, lane marking, level & raised kerbs with grills, pruning tree branches
4	Ulsoor Road – (Manipal Towers to Ulsoor road end)	0.71	Good	0.86	Excellent	Providing 0.3 m height median, removal of on street parking, shifting bus stops, providing signs and signages, lane marking
5	Bangalore University Road – (Mysore Road entrance to Civil Department)	0.31	Poor	0.79	Good	Providing 2 lanes, proper location of bus stop, filling pot holes, reducing speed breakers to one, improving visibility at intersection, providing level and average kerbs, pruning trees branches, sign and signages, Road marking.

4.0 CONCLUSIONS

An attempt has been made by the authors to develop a methodology to aggregate the road safety parameters on to a common base scale by developing value score charts, after interviewing 100 traffic engineering experts in the country. The equation developed is a simple tool to measure the RSI for the existing roads and assess them through index for its safety. It is possible to improve each affected factor of RSI.

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