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Identification of Crash Risk Index for Urban Road: A Case Study of Ahmedabad City.

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***Abstract*- Road Safety is one of the crucial subject in transportation engineering. This study deals with the estimation of crash risk index for urban Arterial Street by safety levels considering Accident. Accident analysis covers the 8km stretch with 9 locations, in which the more accidents are occurs. The traffic classified volume count, spot speed, gradient, Road width, footpath width; geometrical conditions are the factors affecting the accident. Traffic accident data for three years (2013-2015) are used in development and testing the model. The regression model of Crash Risk index i.e. an estimated score to rank the sites by using different road features is developed with R^2 value and t vale using the above parameters with the help of statistical tools.**

***Index Terms*- Accident, Crash risk index, traffic, Safety**

I. INTRODUCTION

The road accidents deaths and injuries are global phenomena but more sever situation in mixed traffic condition as prevailing on Indian multilane highways. Concept of quality management and sustainable safety have gained ground in the past two decades and may have been among the factors that led policymakers and project managers to realize the need for purely safety-oriented tools. Road Safety Audit (RSA) is one of the best tools for improvement of road safety; in which experts attempt to identify potentially dangerous features on the highway environment and urban roads as well and suggest remedial measures. (Dr. S. S. Jain 2011.)

Traffic accident prevention has been a consensus all the time around the World and in last several years large amount of money has been spent for traffic accident prevention. Reduction of social and economic costs also associated with accidents and collisions in road transportation. Identification of sites requiring investigation for possible safety treatments is one of the most important aspects of infrastructure safety management. Road authorities need road safety management programs, designed to improve road safety performance for the system users. Most of the safety management programs include study of accident-prone locations. Significant accident history must exist and be identified before road improvements are recommended. Even though there are several reasons why accidents are not a good measurement for describing the traffic safety condition. The reasons include (1) many accidents are never reported to the police. The share reported varies from site to site and between different road user groups, (2) the number of accidents at a specific site is usually small. Small accident numbers go hand in hand with large random variations. Many years have to be included to get a good picture of the situation. This means that many factors are changed during the period of observation and (3) often a countermeasure is introduced at a site because the number of reported accidents there has been large. A drop in the number of accidents may be attributed either to a successful countermeasure, or to the fact that the period before the measure was introduced had a randomly high number of accidents.

Road safety audit is one of the road safety engineering programs widely used. Experience has shown that an effective road safety engineering program requires three times as much effort being put in to black spot programs as is put in to road safety audit and can yield benefits in terms of reduction in likelihood crashes, severity of crashes, reduction in need for costly remedial works etc. To carry out road

safety audit, it is essential to know the characteristics and risk by considering the fundamental elements that can describe road safety in a quantifiable manner. Risk index is an estimated score to rank the sites using different road features to formulate the exposure, probability and consequence components. Development of risk index produces a technique to support road safety analysis and can be useful to rank the sites and for in depth study of road safety audit. (Venkata Ganesh Babu Kolisetty 2004.)

II. CRASH RISK FACTORS FOR ROAD TRAFFIC ACCIDENTS

A safe road traffic system can be defined as the one that accommodates and compensate for human vulnerability and fallibility (Muhlrad and Lassarre, 2005). During the last decades, many resources have been spent by automotive industry for the improvement of road user's protection (both drivers and pedestrian). Several activities also led to the enhancement of the safety level that a vehicle may offer by means of numerous new technologies: ITS system, airbags, active safety systems like advanced brake systems, the ESC (Electronic Stability Control) are just some examples. However, these efforts seem to be not enough for a consistent reduction of traffic fatalities and crashes if they are conducted independent of an improvement of road infrastructure safety at all the stages of its lifetime: planning, design, construction and operation.

By introducing different tools such as Road Impact Assessment, Road Safety Audits and Inspections and Black Spots Management, an integrated concept of safety, also within the road infrastructure field, was promoted and developed (Perandones and Ramos, 2008). The possibility of informing drivers about the risk associated to the road segment they are travelling is aimed at preventing future road accidents, especially where road infrastructure must be improved and previous fatalities occurred (ETSC, 2001; Perandones & Ramos, 2008). A risk factor is any factor that, all else being equal, increases the probability of sustaining an accident or worsens the severity of injuries (ETSC, 2001)**.** Previous studies have identified a number of risk factors influencing the possibility of being involved in a crash. Many of these parameters are summarized in Table 1 (Elvik et al, 2009; ETSC, 2001; Perandones and Ramos, 2008).

Table 1: Main factors affecting road safety

FACTORS	DESCRIPTIONS
ACCIDENT and ROAD USER BEHAVIOUR	Speed; Fatigue; Overtaking man oeuvres; Alcohol; Travelling in darkness; Age of drivers; Use of seat belts;
ROAD CONDITIONS	Road surface; Inadequate visibility; Road Alignment; Defects in road design; Road junctions; Super elevation; Defects in road maintenance; Private accesses; Consistency;
ROAD INVENTORIES	Road width, footpath width, no of lanes,
VEHICLE FACTORS	Vehicle defects; Vehicle number and size; Technical conditions;
TRAFFIC FACILITY	Classified volume count, Perfect rate of traffic sign; Serviceability rate of traffic marking; Traffic accident emergency rescue;

III. RISK INDEX: OBJECTIVE AND METHODOLOGY

First stages of this research attempt to find a sub-set of variables, among the most important factors related to road safety (see Table 1),for the Estimation of crash the Risk Index. This measurable parameter can be used for assessing and monitoring the risk level of a road segment. The possibility of giving this information to road users is addressed to the improvement of the active safety (accident mitigation), with the final purpose of solving road safety problems before they may become traffic accidents. The proposed integrated approach is based on the identification of the following six classes of factors, which can contribute to an accident occurrence:

- Number of previous occurred accidents. The safety level of a road infrastructure can be evaluated by means of the number and the severity of accidents that occurred during time. The analysis of historical data is a useful tool that allows road management operators to define the priority of maintenance intervention where the accident rate is high (Hautzinger et al, 2007). Historical accident data are an important

indicator of roads safety performance for the identification of high-accident locations. A high-accident location is a road section (or intersection) characterized by a number of accidents greater than a specified fixed threshold during a recent period (typically 1 to 3 years). However, if no accident occurred in a road section in the past several years, it is not correct to think that it will never experience an accident; for this reason it seems to be necessary to investigate on other hazardous factors that can determine the risk level of a road segment. (Harwood et al., 2000).

- Density of intersections/lateral accesses on the road section which covers the classified volume count and spot speed of the composition of the vehicles. the Direct access to roads can significantly increase accidents: previous studies show that a roadway segment with 10 driveways per kilometer can experience 75% more accidents than a segment with 4 driveways per kilometer (Cafiso et al., 2005) Furthermore, the joint effect of roadway access and geometry, such as the combination of private access and horizontal curvature, intensifies the effect of access on the accident rate.
- Road surface anomalies and irregularities. Many bituminous roads are characterized by serious damages and distresses especially as regards surface performance. Several previous studies identified a correlation between the crash rate and road surface properties (friction, texture). Surface friction, developed at the tire-pavement contact, largely depends on pavement surface properties. Friction is an essential component of traffic safety because it provides the grip that a tire needs to maintain vehicle control and for stopping in emergency situations (especially in wet conditions). It is related to pavement texture and, consequently, accident ratio depends both on texture and friction (Vaiana et al., 2012).
- Problems related to horizontal road signs. Generally, deficiencies in horizontal signs are referred to edge lines missing or inadequate, centerline missing or inadequate, and no-overtaking line missing, especially where passing sight distance is not provided. The accident risk is primarily affected by no overtaking line missing: in this case the number of crashes can increase of 50% (Wilkie and Fergus,2003). Moreover, an increase in injury accidents risk of about 8% was registered for edge lines missing, the rate of increase was of 13% for centerline missing (Wilkie and Fergus, 2003).
- Problems related to vertical road signs. A traffic signal can be defined as an object placed along the roadway in an attempt to aid or control the driver, transmitting an unambiguous, quick and clear message to road users (Ramos et al., 2008). Road signs that have the greatest effect on traffic safety are warning signs, since they call attention to hazardous situations (Montella, 2005). In a previous work, the relative risk factor for missing or ineffective curve warning signs on severe curves was fixed to10% (Wilkie and Fergus, 2003).

In order to consider the influence of each variable on the global level of risk, the following expression was used for the Estimation of crash Risk Index. The Regression analysis is used to find the index:

$Y= a_1x_1+a_2x_2+a_3x_3+a_4x_4+a_5x_5+a_6x_6+b$

$$\sum_{i=1}^{n} CRI = pi * Yi * \alpha i$$

……...(1)

Where αi (i=0.9 to 0.1) represents the weight to be assigned to the each class of event ,Pi is probability percentile obtained from the regression analysis, Yi_i is a quantitative estimation obtained by the numerousness of each event occurred in an area of interest. x_i may change according to the number of occurrences of the single type of event and it can assume the following values given in below table

In particular, the 6 no of variables are included for the estimation of crash risk index, also the inventories like road surfaces, no of lanes and signs & signals, road markings. the traffic data to be collected by conducting the surveys and road inventory survey.

According to the selected analytical formulation, the Crash Risk Index (CRI) has a range between 0 and >200. Five levels of risk have been

defined. Each level is determined on the basis of the CRI value obtained by equation (1), as reported in Table 2.

Table 2: Level of risk associated to CRI values

Crash Risk index	**0 < RI<50**	**50 <RI<100**	**100 <RI<150**	**150<RI < 200**	**>200**
	Very low	Low	Medium	High	Very High

The index is equal to zero if there are no occurrences related to the factors listed previously.

IV. STUDY AREA

Growth of road transport in Ahmadabad city is very fast. There is heavy volume and many big problem of traffic on urban road. The heavy vehicles and passengers are moving on the BRTS route in the Morning and evening peak hours.. The Study is carried out on the stretch of BRTS route from RTO to SHIVRANJANI.

- A case study of Ahmadabad city – RTO circle to SHIVRANJANI intersection.
- The stretch is 8.8km long and 40m wide.
- It covers;
  1. One underpass
  2. Three flyovers
  3. Three major signalized intersections
  4. One round – about.

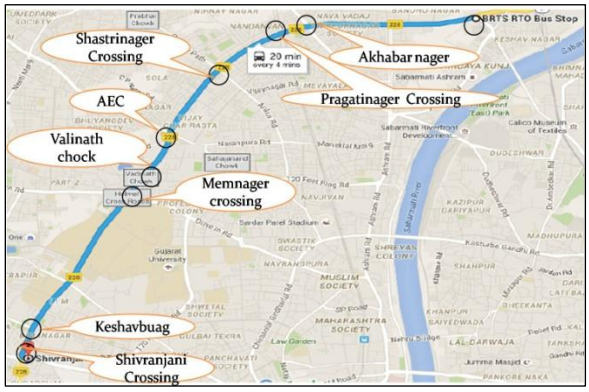

Figure 1: Study Area

V. DATA COLLECTION

Estimation of risk index and road safety audit depends upon the characteristics of the data, particularly their type, quantity, quality and how the data is collected. The data that need to be acquired and the sources of such data must be identified as a matter of utmost importance.

The accident situation in general is very serious and more worrisome in large cities which accounts for maximum number of accidents. In most of the cases crashes occurs either due to carelessness or due to lack of road safety awareness of the road user. For this purpose the estimation of Risk index in road safety carried out on the stretch: "A corridor of 132 feet ring road from RTO circle to Shivranjani intersection." Ahmedabad is the largest city in the state of Gujarat and the seventh largest city in India. The data collected for the study are FIR collections from respective police stations, Classified Volume Count, spot speed, Roadway inventory and required other probable parameters. Accident data for the period 2013-2015 are obtained from different police stations on the study area corridor.

Following data is to be collected for the estimation of crash risk index:

- Accident data are collected from respective police stations which covers the whole stretch.
  - Ranip (RTO) (RTO – Ranip T cross road)
  - Naranpura (Ranip T cross road – AEC)
  - University (AEC – starting of Helmet crossing)
  - Vastrapur (Helmet crossing – IIM intersection)
  - Satellite (IIM intersection – Shivranjani) ,for analysis, last 3 years accident data has been considered here.
- Length of section, Width of road, footpath width, Road condition, Signs and signals, Markings, Gradient are collected using road inventory data.
- Traffic volume and Spot Speed are collected by manual method of survey and vediography.

Based on the available data crash risk index can be estimated and road safety audit is conducted on those sections, which are having higher risk. A list of safety deficiencies and recommendations to the identified deficiencies can be reported by the road safety audit.

VI. DATA ANALYSIS

The chart below shows the graphical representation of accidents occurred at each locations of study area in the form of compositions.

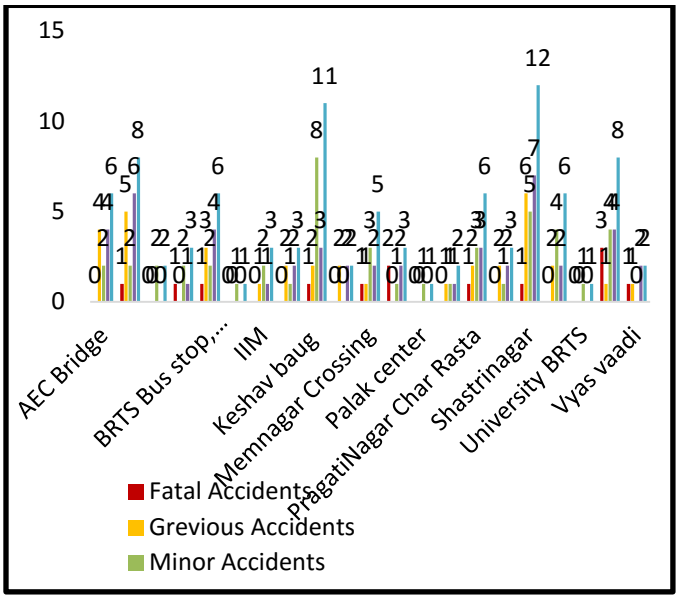

Figure 2: Composition of Accident of whole stretch

Accidents are classified with respect to time of day and night, Nature of Accident, Classification of Accident, Causes of Accident, Road feature, Road conditions, Intersection type and control, weather conditions etc. During day time visibility is more and numbers of trips are also more that's why the speed of vehicles is more regulated than night time.

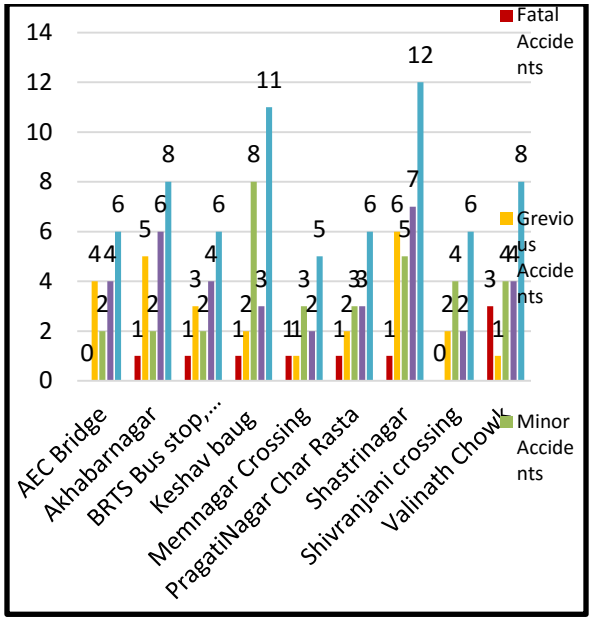

Figure 3: Composition of accidents in selected Locations

VII. CORRELATION BETWEEN DEPENDENT AND INDEPENDENT VARIABLES

Correlation analysis of collected influential safety parameters had been done. Here, dependent variable is taken as an Accident and independent variables are taken as Classified volume count, Spot seed, Gradient, Road width, length of section, footpath width. Derived correlation between independent and dependent variables are found good correlation

VIII. FINDINGS

The regression models is developed for predicting total accidents. The linear regression models developed will take the following form:

$$Y = mX + b$$

Where,
Y= number of total accidents
X=independent variables
m & b are the parameter estimates
The goodness of models is examined on the basis of three statistical values i.e. coefficient of determination R2, t-statistics and F-statistics. The models developed with parameter estimation and different statistics are presented in Table 4. It is observed from the table that for model of total accidents, R2 value is closer to 1 i.e 0.836062 anf F value is 0.849981 and equation Y is obtained as per

regression analysis i.e.

$$Y = -0.000195X1 + 0.2112X2 - 2.934X3 + 503.218X4 + 7.6896X5 + 2617.82X6 - 11.7273$$

Table 4: Multiple Linear Regression (MLR) Analysis

	Coefficients	***t Stat***
Intercept	-11.72732217	-0.6398358
X_1(cvc)	-0.000195054	-0.2742082
X_2(speed)	0.211250927	0.4734034
X_3(gradient)	-2.934862362	-1.0360228
X_4 (road width)	503.218178	0.7241632
X_5(length of section)	7.689638462	0.888172
X_6(footpath width)	2617.826061	0.7247941

This test site was selected because it is characterized by many problems related to safety: i) the presence of a high number of uncontrolled accesses on the roadway; ii) a high number of occurred previous accidents, especially in particular black points (intersections, roundabouts, etc.); iii) many deficiencies in road pavement (potholes, irregularities) and signs. Data availability and robustness are key factors for ensuring the quality of risk analysis, for this reason, a detailed investigation was carried out on each factor taken into account for Crash the Risk Index calculation. Many official sources of data, including both local governments and national administrations, were consulted. An accident data analysis was carried out by manual method for the period 2013-2015. Most frequent accident types are both right and left–angle turning 45%), rear-end (30%) and head-on crashes (16.5%).

As per equation no (1), and table 2 i.e. level of risk associated below as per location .Crash Risk Index was to be carried out. A set of weights α_i and the relative Y_i were selected as shown in Table 5.

Table 5: Estimated crash risk index

Probability (%)	**Y**	**level Weightage**	**location**	**CRI= P*Y*W**	**Estimated Risk level**
6.25	5	0.9	RTO	28.125	Very low
18.75	6	0.8	Akhbarnagar	90	Low
31.25	6	0.7	Pragatinagar	131.25	Medium
43.75	6	0.6	Shastrinagar	157.5	High
56.25	8	0.5	AEC	225	Very high
68.75	8	0.4	Valinath chawk	220	Very high
81.25	11	0.3	Memnagar	268.125	Very high
93.75	12	0.2	Keshavbaug	225	Very high
96.25	12	0.1	Shastrinagar	115.5	Medium

As per the regression analysis, The proposed set of weights and levels of occurrence was used for crash the Risk Index calculation on the nodes of the test site (see Fig.1). A validation procedure was carried out by a systematic comparison between data obtained from the Road Safety Inspection (RSI) of the test site and the estimated crash Risk Index in selected road segments. As it is possible to see a satisfactory matching between the sets of data was reached, confirming the validity of the proposed method.

IX. COCLUTIONS

In this study a methodology for evaluating Road safety performance was assessed and a new road network Crash Risk Index for assessment the test site was proposed. Many variables affecting accidents occurrence were investigated; in particular six factors were selected for the Crash Risk Index calculation among those proposed by scientific literature: number of previous occurred accidents; density of intersections/lateral accesses on the road section; road surface anomalies and irregularities; problems related to horizontal road signs; problems related to vertical road signs; deficiency of the roadside and safety barriers. A system architecture based on a user generated content paradigm was built for evaluating the Crash Risk Index and informing drivers about the risk associated to the road segment travelled, in order to make the transportation system more safe and comfortable.

The proposed methodology was validated by means of a study on a road test-site, a sub-set of input parameters for the Crash Risk Index calculation was

selected. The values of the Crash Risk Index estimated for some particular road segments were compared to the qualitative analysis obtained by a Road Safety Inspection of the same test site. Results showed that the methodology allows to reach a satisfactory matching between the two sets of data. Further investigation is needed for a wider application of the proposed method on several road types.

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