Journal of Traffic and Transportation Engineering 12 (2024) 187-195
doi: 10.17265/2328-2142/2024.04.003

Development of Accident Prediction Model under Mixed Traffic Conditions: A Case Study

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Abstract: Accident prediction models are developed under mixed traffic conditions. Two models have been developed. The first model is a city based traffic accident prediction model. City population and vehicle ownership are the two parameters used to develop the model. A case study of Surat city in Gujarat is taken up. Total accident occurred in the city are regressed with population and vehicle ownership. Second model is the urban arterial based accident prediction model. Past accident record of ring road of Surat city shows that there are eight different locations on a ten kilometer stretch of ring road where the accidents took place consistently. These locations are picked up as accident spots. As there are many contributing factors and causes to road accidents. A comprehensive study of road safety found that human error was the sole cause in 57% of all accidents and was a contributing factor in over 90%. Keeping this in view a new term driver-pedestrian index is used to develop this model. Regression function of Microsoft excel is used for model development. Both the models are checked with R-statistics and t-statistics further the models are validated by using statistical goodness of fit (chi square test). Hence these models can be used to predict number of accidents in future subjected to the same geometric standards. Keeping this in mind improvement measures can be taken up by the district authorities.

Key words: Traffic, accidents, regression, population and vehicle ownership, driver-pedestrian index.

1. Introduction

Road traffic accidents and their causalities on human being have been the major scourge in both developed and developing societies in the latter half of the twentieth century. Traffic accident is one of the major social problems adversely affecting the welfare and prosperity of developing countries [1]. The incidence of road traffic accidents (RTA) is raising world-wide [2]. As per the commission for Global Road Safety [3], the road traffic accidents kill an estimated 1.3 million people and injure 50 million people per year globally, and global road fatalities are forecast to reach 1.9 million by 2020. Now a days it is proved that number of accident cases in urban areas are increasing day by day. Due to rapid growth of urbanization, there is a significant growth in number of vehicles. Increased socio-economic status of the people living in urban areas partially reflects on vehicle ownerships, which finally manifest in traffic congestion, encroachment, reduction in vehicular speed, unnecessary delay and significance increase in number of accidents [4]. In heterogeneous traffic condition, chances of traffic accidents are very high. Forecast for the year 2020 suggests that road accidents as a cause of death or disability would lie at third place out of hundred separately identified causes (WHO 1999).

2. Literature Review

Hajoti et al. [5] carried out detailed quantitative analysis on traffic incidents on an Australian road network. The study has considered number of variables to see the considerable effect on incident duration and frequency. Results show that breakdown of vehicles, multiple vehicle crash and debris were the major source of incidents. It was found that incident frequency dropped sharply during weekends whereas rainfall increased the number of incidents. Many researchers

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have used regression analysis to predict the incident duration. Garib et al. [6] presented regression model for estimating freeway incident congestion. The incident duration prediction model showed that 81 percent of variation in incident duration can be predicted by number of lanes affected, number of vehicles involved, truck involvement, time of day, police response time, and weather condition. Hadi and Aruldhas [7] developed an accident model by road-grades. Road length, annual average daily traffic (AADT), lane and shoulder width, types and width of median, existence of curve, grade and number of intersections and speed limit were considered as independent variables. Study concludes that widen the median width on four-lane roads enhanced safety and roads with two-way and left turn median were safer than non-separation roads. Hong et al. [8] developed accident prediction models for four type of urban road categories which was based on number of lanes, road levels and existence of median barrier. Traffic volumes, number of intersections, connecting roads, pedestrian traffic signals, existence of median barrier were selected as independent variables in a regression analysis. The result reveal that in case of two lane roads, the number of intersections and pedestrian traffic signals were significant variables whereas in case of four lane roads existence of median barrier and number of connecting roads were significant. Cela et al. [9] used multiple linear regression analysis to find the most significant variables related to the road conditions, time and the main cause which have likely contributed to high rates of accidents in urban areas. Sikdar and Bhavsar [10] showed that median opening is one of the responsible causes of road accidents because the vehicles travel in the wrong direction (in the opposite carriageway) for a short stretch to avoid travelling the extra distance to take a U-turn at the next median opening.

2.1 Accident Scenario in India

In India more than 142,485 persons were killed and 511,394 were injured in about 0.5 million accidents in the year 2011 [11]. There is an accident every 65 seconds in India and in every 4 minutes one person dies on the road. The average annual growth of road accidents at national level is 0.6 percent during last ten years. Table 1 shows the accident statistics in India for the period from 2001 to 2011 with accident severity which is the number of persons killed per 100 accidents.

Table 1 Number of accidents and number of persons involved: 2001 to 2011.

Year	Number of Accidents		Number of Persons		Accident Severity*
	Total	Fatal	Killed	Injured	
2001	405,637	71,219 (17.6)	80,888	405,216	19.9
2002	407,497	73,650 (18.1)	84,674	408,711	20.8
2003	406,726	73,589 (18.1)	85,998	435,122	21.1
2004	429,910	79,357 (18.5)	92,618	464,521	21.5
2005	439,255	83,491 (19.0)	94,968	465,282	21.6
2006	460,920	93,917 (20.4)	105,749	496,481	22.9
2007	479,216	101,161 (21.1)	114,444	513,340	23.9
2008	484,704	106,591 (22.0)	119,860	523,193	24.7
2009	486,384	110,993 (22.8)	125,660	515,458	25.8
2010	499,628	119,558 (23.9)	134,513	527,512	26.9
2011 (P)	497,686	121,618 (24.4)	142,485	511,394	28.6

(P): Provisional Source: Information supplied by the provinces (Police Department)
Figure within parentheses indicate share of fatal accidents to total accidents.
* Accident Severity: Road Accident Deaths/100 Accidents

Table 2 Growth of Persons Killed in Road Accidents in selected Countries.

Country	1980	1990	1997	2001	2002	% Variation between 1997-2002
Austria	2003	1391	1105	958	956	-13.48
France	13672	10289	7989	8160	7655	-4.18
Germany	15050	7906	8549	6977	6842	-19.96
Hungery	1630	2432	1373	1239	1429	4.07
Italy	9220	6621	6198	6682	6736	8.68
Japan	11388	11227	9640	10060	9575	-0.67
Netherland	1996	1370	1076	993	987	-8.27
USA	51099	44529	41967	42196	42815	2.02
India	24000	54100	76977	80888	84674	6.1

(Source: Handbook on Transportation and road Accidents Statistics, NATPAC, September-2006)

Detailed analyses of global accident statistics indicate that fatality rates per licensed vehicle in developing countries are very high in comparison with the industrialized countries. Table 2 shows the comparison between the number of persons killed in industrialized countries and India. It clearly shows that India is far ahead from other developed countries in terms of persons killed in road accidents even with over 130,000 deaths annually; India has overtaken China and now has the worst road traffic accident rate worldwide.

2.2 Vehicle Ownership

The growth rate of vehicles is the backbone of economic development and the Indian automotive industry is the second fastest growing in the world. About 8 million vehicles are produced annually in the country today. In 2011, the country reported 141.80 million registered motor vehicles, a motorization rate of 22 vehicles per 1000 population [11], in comparison, the United States, the world’s most motorization nation reported 675 vehicles per 1000 population.

The motorization rate in India is lower than many developing (Brazil- 222 per 1000 population, South Africa 153 per 1000 population) countries throughout the world.

Over the last three decades, motor vehicle numbers have been doubling every ten or fewer years in India as against a 2 % - 5 % annual growth rate in Canada, the United States, the United Kingdom and Japan [12]. While motorization rate in India is lower than many developing countries-both in absolute term and relative to size of population, over the last decade, India is experiencing one of the highest motorization growth rates in the world. Motor vehicle growth rate has been largely concentrated in the major cities with Chandigarh being at first place with 82 cars per 1000 population and Delhi holds second rank with 52 cars per 1000 population whereas the average vehicle ownership in the country is 22 vehicles per 1000 population.

2.3 Study Area Profile

Surat is eighth most populous city (urban agglomeration) of India as per the 2011 census (www.censusindia.gov.in) and also one of the fastest growing city. It became a metropolis in 1991, along with eleven other major cities across the country. The statistical data show that during the last eight decades, the city population has grown up from 0.15 million in 1921 to 4.46 million in 2011. The city has registered an annualized GDP growth rate of 11.5 per cent over the past few fiscal years.

2.4 Accident Scenario in Surat City

Accident scenario in Surat city is shown in Table 3 and Table 4 shows total accident and accident deaths in some other metropolitan cities of India with nearly same or higher population. It explicitly shows that accident severity in Surat is 16 which is near to the other metropolis like Hyderabad, Nagpur, Pune and Jaipur.

Table 3 Accident scenario of Surat city.

Year	Types of accidents			Total
	Fatal	Serious	Minor	
1999	173	489	436	1098
2000	138	369	408	915
2001	116	392	359	867
2002	139	425	375	939
2003	144	418	385	947
2004	168	481	397	1046
2005	253	527	345	1125
2006	196	544	386	1126
2007	219	525	408	1152
2008	247	551	424	1222

(Source: District police station)

Table 4 Road Accident Profile of selected Metropolitan cities of India (2009).

S. No.	Name of City	Total No. of				Accident Severity*
		Fatal Accidents	All Accidents	Persons Killed	Persons Injured	
1.	Ahmedabad	188	2179	200	2232	9.2
2.	Bengaluru	715	6872	742	5705	10.8
3.	Bhopal	244	3719	272	3152	7.3
4.	Chennai	602	5177	618	4377	11.9
5.	New Delhi	2272	7516	2325	6936	30.9
6.	Hyderabad	465	2990	481	2908	16.1
7.	Indore	394	4724	419	3817	8.9
8.	Jaipur	389	2007	415	1840	20.7
9.	Kanpur	477	1178	533	999	45.2
10.	Mumbai	607	29327	628	6567	2.1
11.	Pune	383	2157	394	1839	18.3
12.	Surat	207	1357	217	1117	16.0

* Accident Severity: Road Accident Deaths/100 Accidents.

3. Model Development

3.1 City based Accident Prediction Model

The model can consist of several independent or explanatory variables. In this study, two variables population and number of vehicle of the study area are concerned important for the development of accident model.

Total accident data, population data and number of vehicle data for the city of Surat for a period from 2001 to 2008 are shown in Table 5.

These data were used to develop a multiple linear regression model between the number of accidents and other two variables as shown in equation (1).

$$Y = 401.73 + 108.23\,(X_1) + 271.72\,(X_2) \quad (R^2 = 0.98) \qquad (1)$$

where,

Y = Total number of accidents in a year

X_1 = Population in million in a year,

X_2 = Number of vehicles in million.

The model has an R-square of 0.98, which means that 98 % of the variation in the data explained by the regression line. The t- test also indicates that the model is significant and can be used for the prediction of the number of accidents. Figure 1 also indicates that almost no difference between the predicted and observed value of accidents.

Table 5 Accident, population and per capita no. of vehicle data of Surat city (2001-2008).

Year	Fatal accident	Serious accident	Minor accident	Total accident	Population in million	Number of Vehicles (in million)
2001	116	392	359	867	2.4	0.723
2002	139	425	375	939	3.0	0.803
2003	144	418	385	947	3.1	0.882
2004	168	481	397	1046	3.4	0.975
2005	253	527	345	1125	3.6	1.109
2006	196	544	386	1126	3.7	1.191
2007	219	525	408	1152	3.8	1.295
2008	247	551	424	1222	4.2	1.362

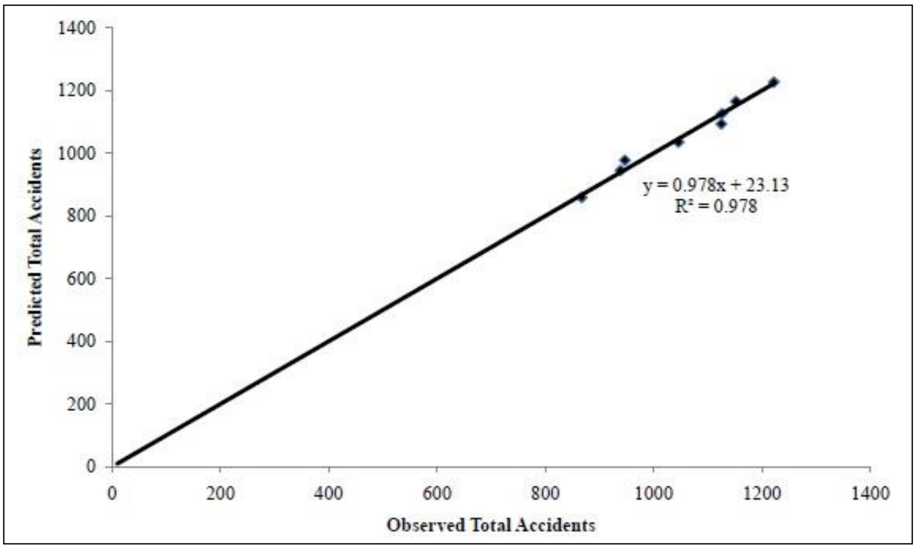

Fig. 1 Comparison of observed and predicted accidents.

The model is further validated by chi-square test. It is assumed that there is a no significant difference between the observed and estimated number of accidents. The calculated chi-square value for the set of data is 2.28 which is less than the table value of 29.14 at significance level of 0.01 and 14 degree of freedom. Therefore, we accept the null hypothesis that there is no significant difference between the observed accident and estimated accident data.

3.2 Urban Arterial based Accident Prediction Model

A 10 kilometer stretch of the ring road of Surat city has been selected for the study. This is the major arterial road of the city divides old city to the new city. Accident records over the past six years show that there is a high fatality of accident (Table 7) on this road as compared with other arterial roads also there is a high traffic volume on this road (Table 8). Accident records over a period of six years shows that there are eight different locations namely Athwa gate, Majura gate, Udhna gate, Textile market, Vrushabh Petrol Pump, Sahara gate, Falsawadi and Delhi gate having consistent accident records. These locations have been selected as accident spot on a 10 kilometer stretch of ring road of Surat city and are shown in Figure 2. Accident data of these locations are collected from the respective police stations and are shown in Table 7.

Traffic volume studies are also carried out at the mid-block section of these locations and are represented in Table 8. A model was developed for an urban arterial consisting accident data, traffic volume and driver pedestrian index as the variables. Detail categorization of accident data at these locations are shown in Table 9.

Table 7 Accident records at ring road of Surat city (2003 to 2008).

S. No.	Location	Total Accidents Occurred					
		2003	2004	2005	2006	2007	2008
1	Athwa gate	8	13	10	12	10	11
2	Majura gate	11	12	7	10	12	12
3	Udhna gate	10	11	6	10	12	10
4	Textile Market	11	13	19	18	31	21
5	Vrusabh Petrol Pump	4	10	3	2	4	7
6	Sahara gate	10	10	5	9	11	14
7	Falsawadi	10	6	5	8	14	14
8	Delhi gate	9	15	10	5	3	7

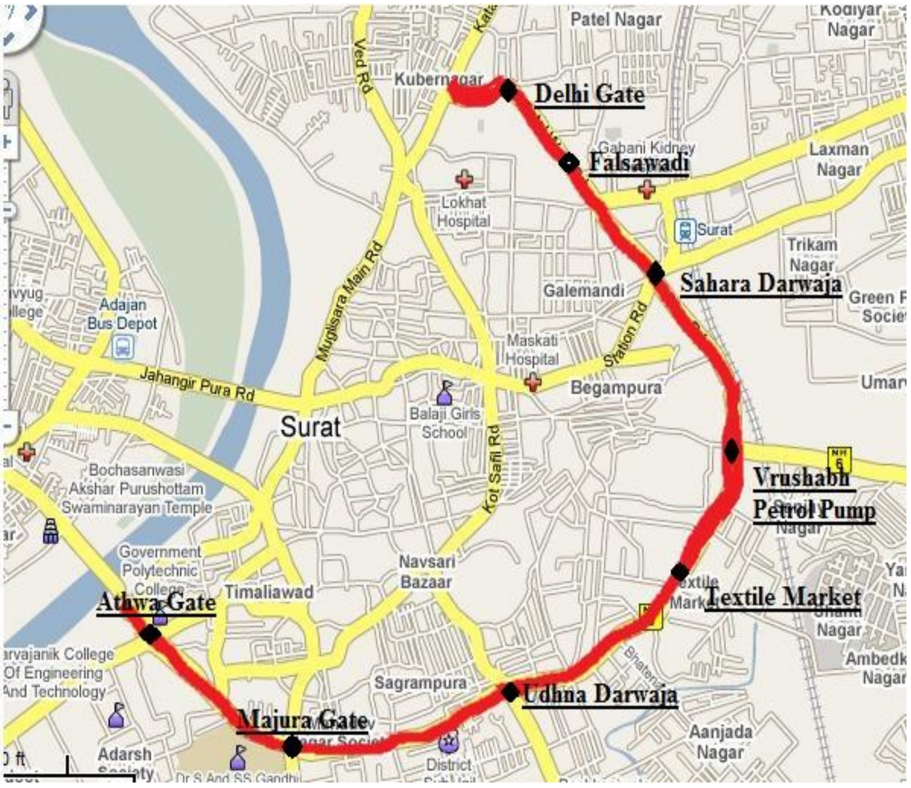

Fig. 2 Black spots at ring road section.

Table 8 Hourly traffic volume data at the respective locations on ring road.

Location	2W	3W	4W	Bus	LCV/HCV	Cycle	Others	Total
Athwa gate	6497	5175	1569	145	480	284	116	14266
Majura gate	5909	4150	1362	123	372	412	150	12479
Udhna gate	3523	4433	619	60	347	343	150	9474
Vrushabh petrol pump	7293	4695	1953	154	495	333	94	15017
Textile market	7773	5040	2090	91	832	329	94	16249
Sahara gate	8554	5330	2240	199	484	359	77	17241
Falsavadi	8282	5250	2151	207	473	296	88	16747
Delhi gate	9648	5701	2384	180	711	357	63	19045

Table 9 Accident data at different spots on ring road section in 2008.

Sr No	Location	Fatal Day	Fatal Night	Serious Day	Serious Night	Minor Day	Minor Night	Total Accidents
1	Athwa gate	5	2	3	0	1	0	11
2	Majura gate	6	0	3	1	1	1	12
3	Udhna gate	1	0	5	2	2	0	10
4	Textile Market	2	0	7	2	6	4	21
5	Vrushabh Petrol Pump	1	2	0	0	1	3	7
6	Sahara gate	5	3	3	3	0	0	14
7	Falsawadi	3	1	4	0	3	3	14
8	Delhi gate	0	0	3	1	0	3	7

Table 10 % Role of driver.

Percentage Accident range	% role of driver
1.0-10.0	20
11.0-20.0	50
21.0-30.0	70

Table 11 Rating index of driver and pedestrian.

% role of driver	Rating
1.0-20.0	1
21.0-40.0	2
41.0-60.0	3
61.0-80.0	4
80.0-100.0	5

There are many contributing factors and causes to road accidents. A comprehensive study of road safety [13] found that human error was the sole cause in 57% of all accidents and was a contributing factor in over 90%. A new terminology "Driver-Pedestrian Index" is introduced in this study which is a measure of driver role as a major cause of accident. The index is measured on an arbitrary scale of 1 to 5 by giving the appropriate rating to the percentage role of driver. The percentage role of driver is calculated based on the percentage of accident measured at a spot. The rating of driver-pedestrian index is shown in Table 10 and 11.

Based on the above criteria the driver-pedestrian index calculated at different spots is tabulated in Table 12.

Similarly the number of accident and traffic volume reported at a spot is given a rating on a scale of 1 to 5. Accident and traffic volume range and their corresponding rating are shown in Table 13.

The combined rating of accident, traffic volume and driver-pedestrian index as calculated above are tabulated in Table 14. A multiple linear regression model is developed adopting accident as a dependent variable, traffic volume and driver-pedestrian index as independent variables rating.

The accident prediction model for an urban arterial is expressed as:

$$Y = -2.61 + 0.49(X_1) + 1.27(X_2) \quad (R^2 = 0.91) \qquad (2)$$

where,

Y = Accident rating.

X_1 = Volume rating.

X_2 = Driver-pedestrian index.

The t- test also indicates that all the coefficients are significant the model is significant and can be used for the prediction of the number of accidents. Figure 3 shows the comparison between observed and model predicted accident rating and is well defined by a straight line with R-square as 0.91. Further the model is validated with chi-square test while taking the average number of accident corresponding to the predicted accident rating. It is found that calculated chi-square value for the set of data is 1.17 which is less than the table value of 29.14 at significance level of 0.01 and 14 degree of freedom. Therefore, we accept the null hypothesis that there is no significant difference between the observed accident and estimated accident data.

Table 12 Calculation of driver – pedestrian index.

Sr. No.	Location	Total accident	Percentage accident	% of driver role	Driver – pedestrian Index
1	Athwa gate	11	11.46	50	3
2	Majura gate	12	12.50	50	3
3	Udhna Gate	10	10.42	50	3
4	Vrushabh Petrol Pump	7	7.29	20	1
5	Textile Market	21	21.88	70	4
6	Sahara Gate	14	14.58	50	3
7	Falsawadi	14	14.58	50	3
8	Delhi Gate	7	7.29	20	1

Table 13 Range and rating of accident and traffic volume.

Accident range	Accident rating	Volume range (vph)	Volume rating
07-09	1	7,500-10,000	1
10-12	2	10,001-12,500	2
13-15	3	12,501-15,000	3
16-18	4	15,001-17,500	4
19-21	5	17,501-20,000	5

Table 14 Accident, traffic volume and driver-pedestrian index at the respective locations.

Location	Accident rating	Volume rating	Driver and pedestrian index
Athwa gate	2	3	3
Majura gate	2	2	3
Udhna Gate	2	1	3
Vrushabh Petrol Pump	1	4	1
Textile Market	5	4	4
Sahara Darwaja	3	4	3
Falsavadi	3	4	3
Delhi Gate	1	5	1

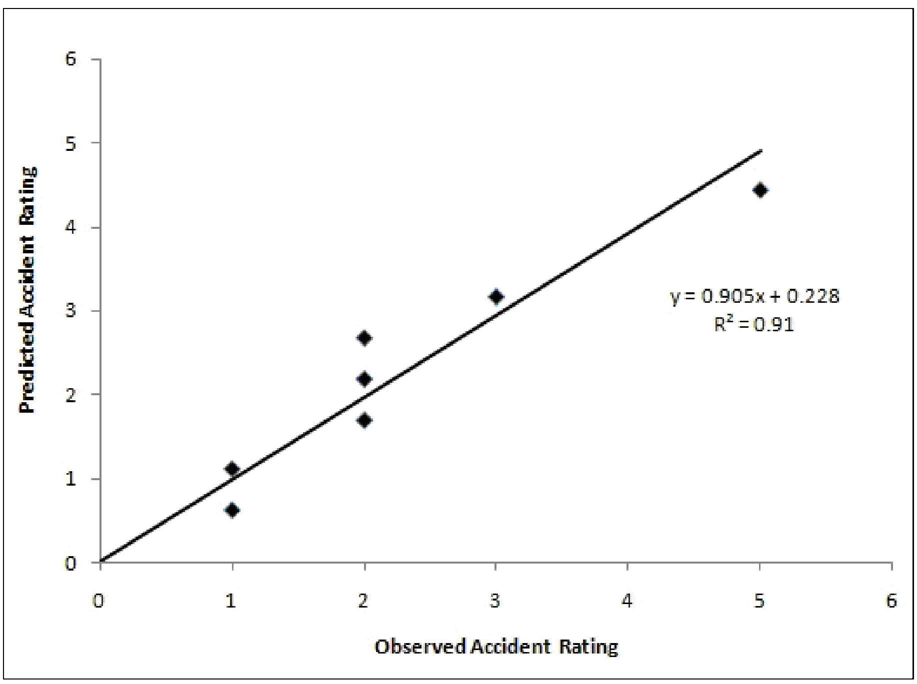

Fig. 3 Comparison between observed and model predicted accident rating.

4. Conclusion

The accident prediction model based on population and number of vehicles also the urban arterial based accident prediction model has a very good R-square value of 0.98 and 0.91 respectively. This indicates that there is a perfect correlation between independent and dependent variables. These parameters are found significant at 1 percent level of significance and therefore they are statistically good. The t- test also indicates that the model coefficients are significant and can be used for the prediction of the number of accidents in future and improvement measures can be taken up. However, the transferability of this model to other cities of similar size needs to be checked. As a future scope of work, models can be prepared based on several explanatory variables like road geometry features, time of accident, accident places both commercial or residential weather conditions and many others.

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