Urban Road Crash Fatality Impact Index for Areas of Surat

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Abstract: A road crash refers to any accident involving of at least one road vehicle, occurring on the road open to public transit using different modes. Intentional acts (terrorism, war) and natural disasters are excluded. Road crashes will be acquiring higher rank among non-natural deaths around the globe. The fatalities in urban road crash incur major economic, social and cultural loss to the society. Present work aims to evaluate these losses by computing an 'Urban Fatality Impact parameter(s)' that would indicate the severity of the fatalities for the area based on different variables involved. The research builds on a study carried out in the Surat city. The city has the population of about 5 million and spread of the urban area of about 327 Sq km. Encompassing road lengths of more than 2500 km. The records of road crash for past ten years under six police station administered areas were examined. The "***Fatality Impact Index***" may have itself several applications like identification of most vulnerable cities for road traffic injuries and fatality, most required improvement locations, so that the development of transit facilities give an overall high value of return and would also diminish the losses due to road crashes. The present work is based on a study carried out to understand the fatality and road crash occurring on the streets of Surat – specific attention is given for cases of Varachha and Salabatpura police station areas. The initial details include over understanding these areas, road inventories, type of accidents through records of police stations and analysis thereof. In the next course of work, a collection of further data and analysis for different police station limits will be carried out to attain the aim of developing an Index for various areas of Surat as well as of the city.

The yearly average of all variables for all was found and using the Urban Road Crash Fatality Impact Index (URCFII) formula index values for areas under the command of six police stations were obtained with the allocation of ranking these areas. It can be stated that the impact of urban road crash fatality does not only depend on the number of people died in the road accidents but also on the total number of accidents, nature of these accidents, number and type of vehicles involved and the severity index of the area. The multi variable regression model not only proves the research hypothesis but also provides the magnitude of this relation. The number of two wheeled and four wheeled vehicles are the leading cause of fatalities in urban road fatalities as well the losses incurred due to them, while on another hand the other large vehicles have comparatively minimum impact, so increase in the number of large vehicles as such public transportation would decrease the losses incurred due to urban road fatalities. Furthermore, it was found that the involvement of pedestrians in cases of road crashes was also high, that indicates a lack of proper pedestrian movement facilities in Surat, provision of good pedestrian movement in the urban transportation scenario would decrease the impact of urban fatalities. Amongst the study area, the region of Khatodara has the maximum URCFII implying maximum losses due to road accidents. The URCFII index derived because of the research was undertaken could be applied to different cities/ areas may show diverse useful applications as identification of most vulnerable cities for road traffic injuries and fatality, most required improvement locations and so on. If similar work is carried out in other parts of the city, a comparative analysis can also be performed and maintained to identify most road fatality risk bearing city areas towards focusing upon in a city.
Keywords: Fatality, Fatality impact, Road Crashes, Urbanization

Study area

With the aim of studying the urban road crashes, the urban area of Surat city (Gujarat, India) was selected. The study area was confined into the command areas of 6 major police stations, namely: Khatodara Police Station, Mahidarpura Police Station, Rander Police Station, Salabatpura Police Station, Udhna Police Station, and Varachha Police Station. The study area represented approximately 270.647 sq km of the area of Surat city that makes up for about 80% of total area of Surat city. In all accident records from 5 zones of Surat city were collected and analysed. Table 1 summarises the study area on which the research work was carried.

Table 1 Study Area Summary

№	Station Name	SMC Zone	Area (sq km)	Population (Persons)	Density (persons/sq km)
1.	Khatodara	Southwest	111.912	3,47,080	3101.37
2.	Rander	West	51.279	2,87,144	5599.64
3.	Mahidarpura	Central	8.18	4,13,641	50567.36
4.	Salabatpura	Central	8.18	4,13,641	50567.36
5.	Udhna	South	61.764	3,20,087	12311.04
6.	Varachha	East	37.525	7,11,516	41879

(**Source**: Surat Municipal Corporation, 2016)

Variable definitions

The chapter defines various variables that were used in the computation of mathematical model for validating the hypothesis of the research work; the following units would set all such variables.

Total Accidents (TA)

The Total accidents can be defined as the total number of accidents occurred in the command area of the police station during the period of one calendar year.

Two-wheeler Count (TW)

The two-wheeler counts can be defined as the total number of two wheeled motor vehicles involved in the road accidents either as a first vehicle or second vehicle during the accidents occurred in the command area of the police station during the period of one calendar year.

Four-wheeler Count (FW)

The Four-wheeler counts can be defined as the total number of four wheeled motor vehicles involved in the road accidents either as a first vehicle or second vehicle during the accidents occurred in the command area of the police station during the period of one calendar year.

Other Wheeler Count (OW)

The Other Wheeler counts can be defined as the total number of vehicles other than the two and four wheeled vehicles involved in the road accidents either as a first vehicle or second vehicle during the accidents occurred in the command area of the police station during the period of one calendar year.

Accident Type Index (ATI)

The Accident type index can be defined as the numeric account of type/nature of road accident occurred in the command area of the police station during the period of one calendar year. The ATI is the algebraic sum of all indexes representing various types of accidents individually; the numbers of accidents of a particular kind are multiplied with an impact factor to obtain the index value of this kind of accident, similarly the index values of all kinds of accidents are found, and their algebraic sum gives the ATI. The Table 2 shows the assumed impact factors to be used for various types of accidents.

Table 2 Impact factor for various types of accidents

Nature of Accident	Impact Factor
Overturning	1
Head on collision	0.9
Hit and run	0.8
Rear end Collision	0.7
Brushing	0.6
Right angled collision	0.5
Skidding	0.4
Right turned collision	0.3

Pedestrian Involvement (PEDAS)

The Pedestrian involvement can be defined as the total number of pedestrians involved in the road accidents occurred in the command area of the police station during the period of one calendar year.

Fatality (FATAL)

The Fatality can be defined as the total number of fatal accidents (involving the death of people) occurred in the command area of the police station during the period of one calendar year.

Severity Index (SI)

The severity index is a ratio of Fatality by Total accidents; it is the probability of occurrence of a fatal accident in the command area of the police station during the period of one calendar year.

$$\text{Severity Index} = \text{Fatality/Total Accidents}$$
$$= \text{FATAL/TA}$$

Road crash data was collected from the Crime writer office of the Police Stations. The Police station administration provided summarised copies of FIR from the ‘Khaitan book’ and ‘Bhala book’. The required data that were selected or computed as variables were entered into a separate excel sheet to obtain the refined set of data that could be used for linear regression. The method of multivariable linear regression was chosen to formulate the mathematical model for the study; the linear regression model was computed on IBM-SPSS software.

Research hypothesis

The **impact of fatality is directly proportional to the severity index**, as an increase in severity index (SI) would indicate the increase in a total number of deaths, and death impacts economic, social and emotional loss to the society and nation as on the whole. So, to study the impact of the death/fatality in the case of urban road crashes mathematically, a Severity index is investigated due to their direct relation. This hypothesis assumes that there is certain proportion of relationship between the severity index (SI) and other assumed variables like TW, FW, OW, PEDAS, ATI, and FATAL. The method of mathematical modelling via multi variable linear regression was adopted to find the proportion of relation between severity index and assumed variables and viability of the above-stated hypothesis. The next sections would use parts of output generated on SPSS. Below is the employed methodology for the exercise.

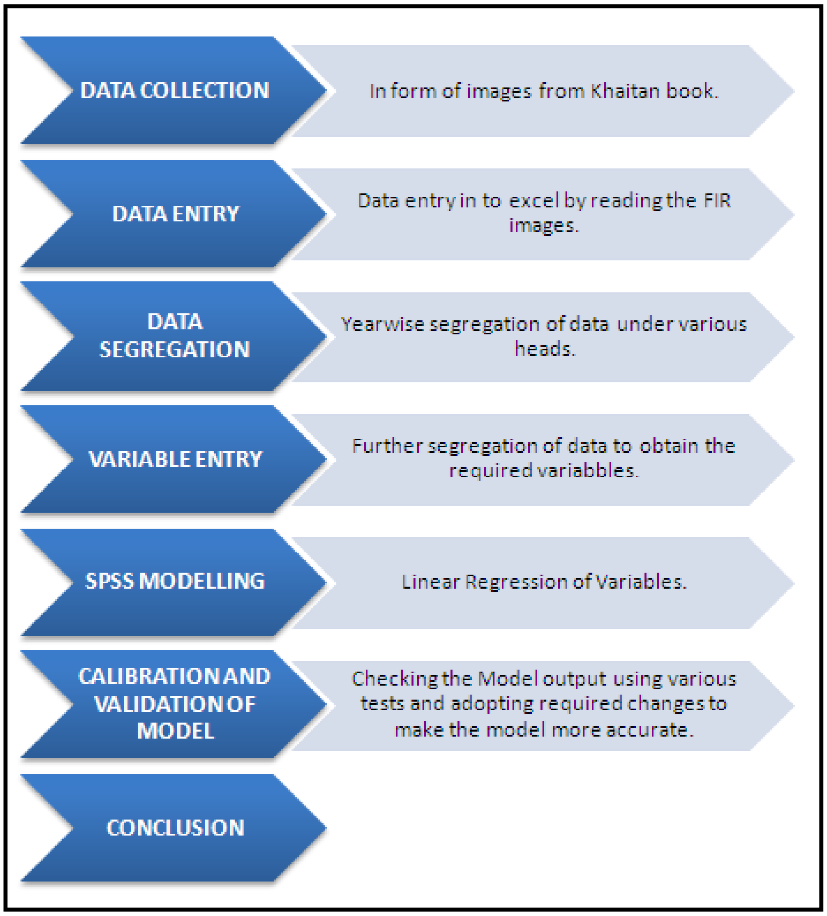

Figure 1 Research Methodology

Validation of Mathematical Model

Seven models in all were computed considering various combinations of variables assumed, all the models were tested on following tests, and the most accurate model was found. All the variables that were supposed were identified valid through IBM-SPSS output so further modelling can be done considering all variables.

R^2 Test

Based on adjusted R^2 the most accurate model is 'Model 7' having the value of adjusted R as 0.667., i.e. the model is 66.7% accurate and has relatively less amount of redundancy amongst the independent variables. Further tests would be performed on 'Model 7' only.

Table 3 R^2 Summary of models

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.383[a]	.146	.132	.1370835
2	.387[b]	.150	.121	.1379599
3	.387[c]	.150	.106	.1391402
4	.387[d]	.150	.090	.1403554
5	.388[e]	.151	.075	.1415388
6	.390[f]	.152	.060	.1426909
7	.840[g]	.705	.667	.0849545

a. Predictors: (Constant), TA

b. Predictors: (Constant), TA, TW

c. Predictors: (Constant), TA, TW, FW

d. Predictors: (Constant), TA, TW, FW, OW

e. Predictors: (Constant), TA, TW, FW, OW, ATI

f. Predictors: (Constant), TA, TW, FW, OW, ATI, PEDAS

g. Predictors: (Constant), TA, TW, FW, OW, ATI, PEDAS, FATAL

h. Dependent Variable: SI

ANOVA Analysis

Based on ANOVA test, Model-7 (refer Table 4) is accurate since it has a large F and almost zero significance.

Table 4 ANOVA Summary

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.193	1	.193	10.287	.002[a]
	Residual	1.128	60	.019		
	Total	1.321	61			
2	Regression	.198	2	.099	5.198	.008[b]
	Residual	1.123	59	.019		
	Total	1.321	61			
3	Regression	.198	3	.066	3.408	.023[c]
	Residual	1.123	58	.019		
	Total	1.321	61			
4	Regression	.198	4	.049	2.512	.052[d]
	Residual	1.123	57	.020		
	Total	1.321	61			
5	Regression	.199	5	.040	1.986	.095[e]
	Residual	1.122	56	.020		
	Total	1.321	61			

6	Regression	.201	6	.033	1.645	.152[f]
	Residual	1.120	55	.020		
	Total	1.321	61			
7	**Regression**	**.931**	**7**	**.133**	**18.430**	**.000[g]**
	Residual	**.390**	**54**	**.007**		
	Total	**1.321**	**61**			

a. Predictors: (Constant), TA
b. Predictors: (Constant), TA, TW
c. Predictors: (Constant), TA, TW, FW
d. Predictors: (Constant), TA, TW, FW, OW
e. Predictors: (Constant), TA, TW, FW, OW, ATI
f. Predictors: (Constant), TA, TW, FW, OW, ATI, PEDAS
g. Predictors: (Constant), TA, TW, FW, OW, ATI, PEDAS, FATAL
h. Dependent Variable: SI

Henceforth, after considering all the tests, Model-7 is selected as the most accurate model. After the Validation of the models, Model-7 was chosen for continuing the modelling process. The summary of all types can be referred in Table 5.

Table 5 Model summary Coefficients

Model		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
		Beta			Lower Bound	Upper Bound
1	(Constant)		7.782	.000	.257	.434
	TA	-.383	-3.207	.002	-.005	-.001
2	(Constant)		7.500	.000	.250	.432
	TA	-.290	-1.292	.201	-.005	.001
	TW	-.110	-.490	.626	-.005	.003
3	(Constant)		7.428	.000	.249	.433
	TA	-.289	-1.279	.206	-.006	.001
	TW	-.105	-.433	.666	-.006	.004
	FW	-.009	-.057	.955	-.006	.005
4	(Constant)		7.338	.000	.248	.434
	TA	-.291	-.695	.490	-.008	.004
	TW	-.105	-.422	.674	-.006	.004
	FW	-.008	-.048	.962	-.006	.006
	OW	.001	.004	.997	-.008	.008
5	(Constant)		7.262	.000	.247	.435
	TA	-.411	-.604	.548	-.013	.007
	TW	-.115	-.453	.653	-.006	.004
	FW	-.019	-.103	.919	-.007	.006
	OW	-.017	-.054	.957	-.009	.008
	ATI	.154	.225	.822	-.011	.014
6	(Constant)		7.173	.000	.247	.439
	TA	-.219	-.239	.812	-.015	.012
	TW	-.147	-.533	.596	-.007	.004
	FW	-.056	-.258	.797	-.009	.007
	OW	-.048	-.142	.888	-.010	.008
	ATI	.124	.178	.860	-.012	.014
	PEDAS	-.104	-.315	.754	-.010	.007
7	**(Constant)**		**10.677**	**.000**	**.249**	**.364**
	TA	**-.863**	**-1.568**	**.123**	**-.015**	**.002**
	TW	**.138**	**.829**	**.411**	**-.002**	**.005**
	FW	**-.127**	**-.971**	**.336**	**-.007**	**.002**

	OW	**.001**	**.004**	**.997**	**-.005**	**.005**
	ATI	**-.058**	**-.141**	**.889**	**-.008**	**.007**
	PEDAS	**-.156**	**-.794**	**.431**	**-.007**	**.003**
	FATAL	**.979**	**10.058**	**.000**	**.024**	**.036**

Total Accidents (TA)

TA has a coefficient of -0.8639 which means they have an inverse proportion to SI, which is, in fact, true because SI is the ratio of FATAL by TA, so the model predicts the correct scenario. It can also be interpreted that the TA shares a huge share of impact almost 86.4% on the severity that means a decrease in TA would reduce the overall losses. The scatter plot is shown in Figure 2 also shows the high negative relationship between SI and TA.

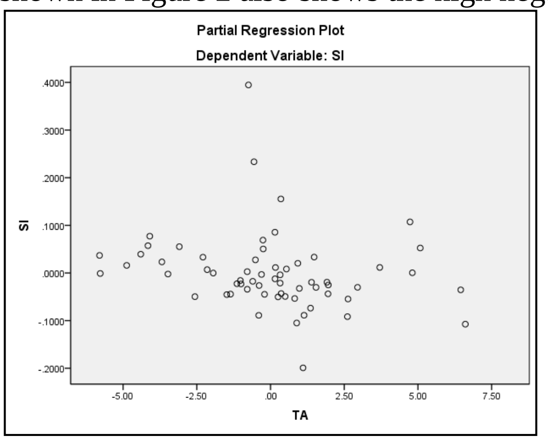

Figure 2 Partial Regression Plot SI vs. TA

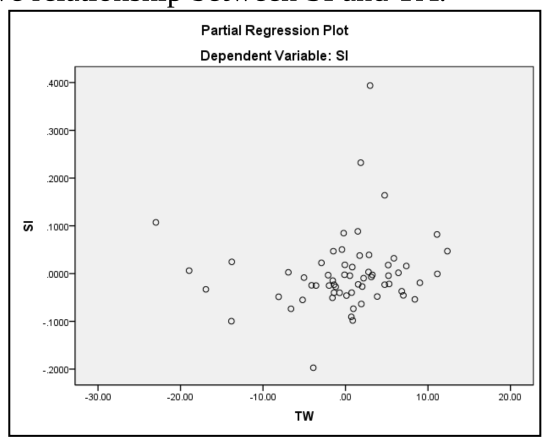

Figure 3 Partial Regression Plot SI vs. TW

Two-wheelers (TW)

TW has a coefficient of 0.138 which means it has a direct proportion SI, so the model suggests that the number of two wheelers involved in the urban road crashes are a leading cause of the fatalities (approximately 14%). So, with an increase in some 2- wheeled motor vehicles the amount of damage would also increase. The Scatter plot shown in Figure 3 shows a trusting relationship between the variables. Also, the clustering of data along the positive gradient shows a strong relation between TW and SI.

Four-wheeler (FW)

FW has a coefficient of -0.127 which means it has an indirect proportion SI, so the model suggests that the number of four wheelers involved in the urban road crashes are one of the leading causes of the fatalities (approximately 13%). So, with an increase in some 4- wheeled motor vehicles the amount of damage would also increase. The Scatter plot shown in Figure 4 shows an adverse relationship between the variables. Also, the clustering of data along the negative gradient shows a strong relation between FW and SI.

Other-wheeler (OW)

OW has a coefficient of 0.001 which means it has a direct proportion SI, so the model suggests that the number of other wheelers involved in the urban road crashes is not a primary cause of the fatalities (approximately 0.1%). So, increase to bigger vehicles like buses can reduce the overall fatalities on urban roads. The Scatter plot shown in Figure 5 is showing a clustering terms between the variables; also, the scattering of data along the positive gradient shows a negative relation between OW and SI.

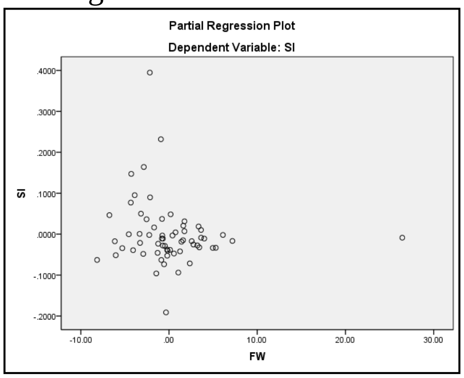

Figure 4 Partial Regression Plot SI vs. FW

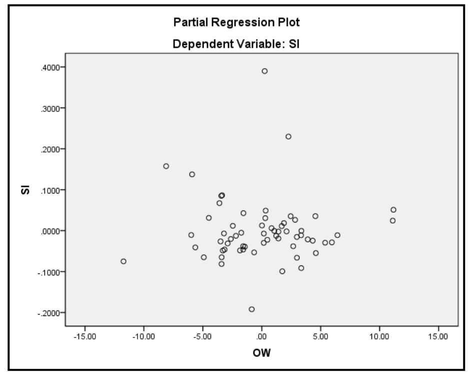

Figure 5 Partial Regression Plot SI vs. OW

Accident Type Index (ATI)

ATI has a coefficient of -0.058 which means it has an indirect proportion SI, so the model suggests that the nature of accidents urban roads are a primary cause of the fatalities (approximately 6%). The Scatter plot shown in Figure 6 shows a negative relationship between the variables. Also the clustering of data along the negative gradient shows a strong relation between ATI and SI.

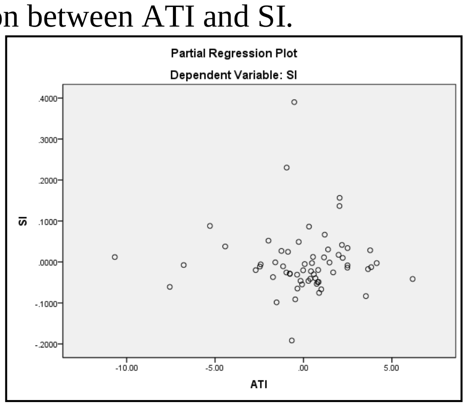

Figure 6 Partial Regression Plot SI vs. ATI

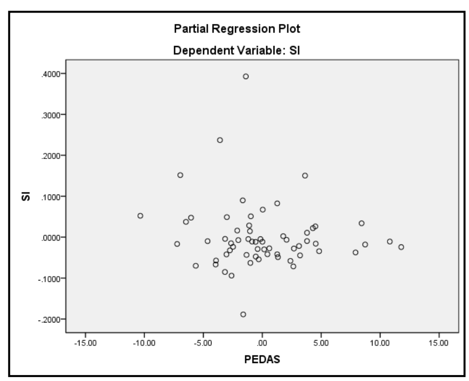

Figure 7 Partial Regression Plot SI vs. PEDAS

Pedestrians (PEDAS)

PEDAS has a coefficient of -0.156 which means it has an indirect proportion SI, so the model suggests that the numbers of pedestrians involved in urban road crashes are a leading cause of the fatalities (approximately 16%). It can also be implied that absence of pedestrian traffic facilities is a primary cause of urban fatalities. The Scatter plot shown in Figure 7 shows a negative relationship between the variables. Also, the clustering of data along the negative gradient shows a strong relation between PEDAS and SI.

Fatality (FATAL)

TA has a coefficient of 0.979 which means they have a direct proportion to SI, which is, in fact, true because SI is the ratio of FATAL by TA, so the model predicts the correct scenario. It can also be interpreted that the Fatality shares a huge share of impact almost 97.9% on the severity that means an increase in FATAL would increase the overall losses.

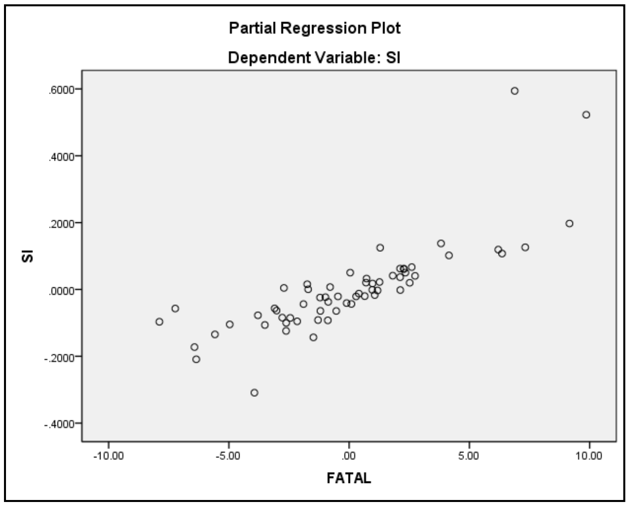

Figure 8 Partial Regression Plot of SI vs. FATAL

Nearly 100% impact of fatality also proves the research hypothesis valid that the severity index can be used a mathematical tool to study death impact. The scatter plot also shows a strong positive relationship. So, a Modulus equation of the defined model can be accurately used to measure the public road crash fatality impact.

Urban Road Crash Fatality Impact Index

The ranking Index is hence defined as "The Urban road crash fatality impact index (URCFII) can be defined as a parameter index to measure the scaled comparative losses faced due to fatalities in urban road crashes" that works out to be:

URCFII= 0.390 - 0.8639(TA) + 0.138(TW) - 0.127(FW) + 0.001(OW) - 0.058(ATI) - 0.156(PEDAS) + 0.979(FATAL)

Computation of URCFII for the study area

The yearly average of all variables for all was found and using the URCFII formula index values for all stations were found, all the data is summarised in Table 6 and ranks the police stations command areas based on fatality impact.

Table 6 URCFII Data Summary

Station	TA	TW	FW	OW	ATI	PEDAS	FATAL	URFII	Rank
Khatodara	57.57	37.85	20.14	26.85	46.10	23.28	14.14	77.69	1
Rander	51.55	40.00	16.60	24.10	41.48	22.90	8.20	66.19	2
Udhna	51.07	25.15	6.84	30.46	39.91	27.30	8.30	63.19	3

Salabatpura	44.36	19.45	6.72	23.54	31.65	29.36	9.09	57.20	4
Mahidarpura	40.00	20.30	6.20	21.70	32.02	24.30	8.20	51.84	5
Varachha	34.45	19.18	7.00	19.00	26.36	19.81	6.54	44.34	6

Concluding Remarks

It can be stated that the impact of urban road crash fatality does not only depend on the number of people died in the road accidents but also on the total number of accidents, nature of these accidents, number and type of vehicles involved and the severity index of the area. The multi variable regression model not only proves the research hypothesis but also provides the magnitude of this relation. The number of 2 wheeled and four wheeled vehicles are the leading cause of fatalities in urban road fatalities. It also largely contributes to the other losses. On another hand the other large vehicles have a comparatively minimum impact, so increase in the number of large vehicles as such public transportation would decrease the losses incurred due to urban road fatalities.

Furthermore, it was found that the involvement of pedestrians in cases of road crashes was also high, that indicates a lack of proper pedestrian movement facilities in Surat, provision of good pedestrian movement in the urban transportation scenario would decrease the impact of urban fatalities to a great extent. Amongst the study area, the region of Khatodara has the maximum URCFII implying maximum losses due to road accidents. The URCFII index derived because of the research was undertaken could be applied to different cities/ areas may show diverse useful applications as identification of most vulnerable cities for road traffic injuries and fatality, most required improvement locations and so on. If similar work is carried out in other parts of the city, a comparative analysis can also be performed and maintained to identify most road fatality risk bearing city areas towards focusing upon in a city. Threshold values of the model are not identified and the same may be considered a limitation of the present work.

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