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CRASH PREDICTION FOR PRIORITIZATION OF INTERSECTIONS FOR SAFETY IMPROVEMENT: CASE STUDY OF KATHMANDU VALLEY

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Abstract

Every year globally 1.3 million people lose their lives from road traffic crashes (RTAs). Similarly, increasing rate of RTAs has been observed in Nepal including Kathmandu valley. This study is focused on the analysis of crash trends and respective site specific geometric features of urban road intersections in Kathmandu valley. Seventeen major intersections based on the data availability and traffic volume, are considered for the analysis of crash type. Previous crash data and traffic volume records of one year have been analysed. Common types of three and four legged intersections were taken for the study. Classified traffic volume at those intersections were converted into the Annual Average Daily Traffic. Evaluation factors for the crash analysis were determined by using predictive method. Crash frequency, crash rate, critical crash rate and crash prediction methods were used for ranking of the intersection. Priority for the safety improvement is prepared based on the results of this study.

Keywords: *Crashes; Intersections; Ranking; Predictive Methods; Prioritization; Safety Improvement*

1. Background

Overall development of the country depends on the transport infrastructure and efficient transport service. In fact, road infrastructure is one of the indicator of a nation to be developed. Therefore the infrastructure of road network in a country should be efficient and adequate. The facilities in the road network should be such that the mobility of transport and people should be safe and reliable. “Each year nearly 1.3 million people die as a result of a road traffic collision— more than 3000 deaths each day - and more than half of these people are not travelling in a car. Twenty to fifty million more people sustain non-fatal injuries from a collision, and these injuries are an important cause of disability worldwide” (United Nation, 2011). Ninety percent of road traffic deaths occur in low- and middle-income countries, which claim less than half the world's registered vehicle fleet. Road traffic injuries are among the three leading causes of death for people between 5 and 44 years of age. Unless immediate and effective action is taken, road traffic injuries are predicted to become the fifth leading cause of death in the world, resulting in an estimated 2.4 million deaths each year (United Nation, 2011). This is, in part, a result of rapid increases in motorization without sufficient improvement in road safety strategies and land use planning. The economic consequences of motor vehicle crashes have been estimated between 1% and 3% of the respective Gross National Product (GNP) of the world countries, reaching a total over $500 billion. Reducing road casualties and fatalities will reduce suffering, unlock growth and free resources for more productive use. Intersection crashes are one of the major issues in Kathmandu valley road networks. Even the small crashes may create large congestion and blockage of traffic flow during peak hours or even beyond. The number of crashes occurring in major intersections are increasing yearly (MTPO, 2016). The number of crashes at major intersections are recorded and it shows that total of 3621 crashes occurred at intersection in the year 2013. It increased to 3915 in the year 2014 and to 4330 in 2015.

2. Literature Review

The statistics on road crashes globally suggests that over 1.17 million people die in road crashes. There are 65% of deaths involving pedestrians 35% among them are children. More than 10 million get incapacitated annually (Mehar & Agrawal, 2013). It is expected that road crashes will be the fifth major cause of death in the year 2030(World Health Organization, 2013). Intersection-related crashes are associated with high proportion of crashes involving drivers, occupants, pedestrians, and cyclists. A significant portion of total fatal crashes usually occur at intersections. In order to enhance the safety of intersections, significant attention is needed to ensure safe movement of road users. Many researchers have come out with the causes, effects and recommendations to vehicular crashes in Ghana and elsewhere. For instance, Ayeboo (2009), identified that the numerous crashes on our road networks have been linked to various causes which include over speeding, drink driving, wrong over taking, poor road network and the rickety vehicles which ply on our roads. Furthermore, Thapa (2013) has identified many causes of road crashes in Nepal which include unnecessary speeding, lack of proper judgment of drivers, inadequate experience, carelessness, wrong overtaking, recklessness, over loading, dazzling and defective light, unwillingness to alight from motion objects (vehicles, motor cycles, human being and uncontrolled animals), skid and road surface defect, level crossing and obstruction. Other factors are inadequate enforcement of road laws and traffic regulations, use of mobile phones when driving, failure to buckle the seat belt and corruption (Thapa, 2013).

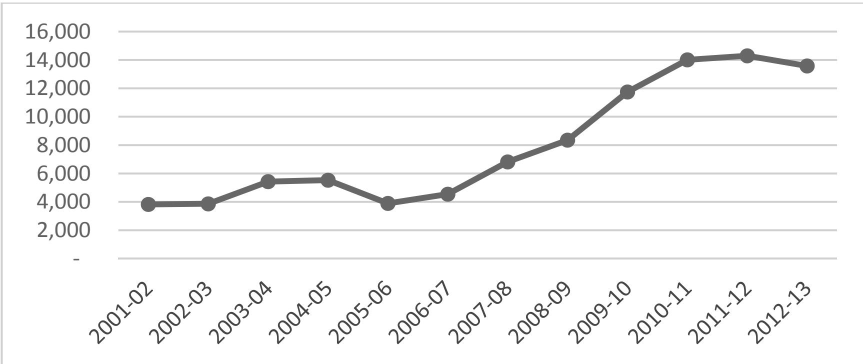

Fig1: Road Accident Trends in Nepal

Source: Status Paper on Road Safety in Nepal, (Thapa, 2013)

The rate of fatality are also in increasing trend from 2013/14 and crossed 2000 in 2014/15 as shown in figure 2.

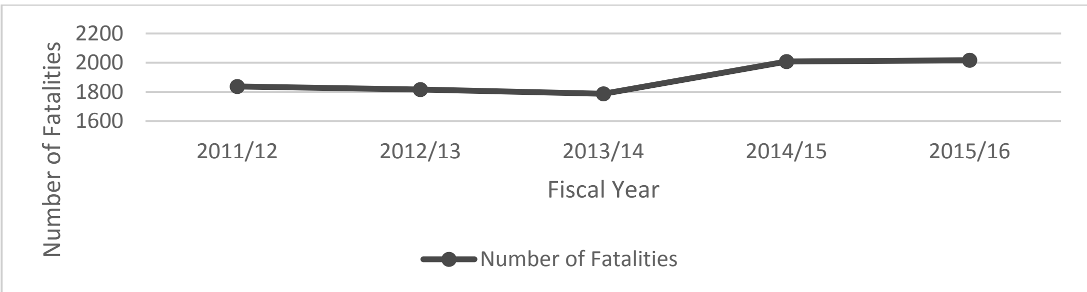

Fig 2: Trend of Fatalities in Road Crashes

Source: MTPO (2016)

Challenges in Crash Reduction

To reduce the crash on road intersections channelization is one of the most effective measures. It provides positive guidance to the driver and as the result simplifies the movements and reduces the room for error, reduces confusion, separates and localizes the conflict points. According to HSM (AASTHO, 2009), at intersections, each of these elements presents challenges:

- **Control:** The path through the intersection is typically unmarked and may involve turning
- **Guidance:** There are numerous potential conflicts with other vehicles, pedestrians, and cyclists on conflicting paths and
- **Navigation:** Changes in direction are usually made at intersections, and road name signing can be difficult to locate and read in time to accomplish any required lane changes.

In the process of negotiating any intersection, drivers are required to:

- Detect the intersection
- Identify signalization and appropriate paths; Search for vehicles, pedestrians, and bicyclists on a conflicting path;
- Assess adequacy of gaps for turning movements;
- Rapidly make a stop/go decision on the approach to a signalized intersection when in the decision zone; and,
- Successfully complete through or turning manoeuvres.

Predictive model in Highway Safety Manual

The highway safety manual provides safety performance functions (SPF) for the intersections and roadways divided into rural two lane two-way roads, rural multilane highways and urban and suburban arterials. The SPFs provide the predicted total crash frequency for base condition and for the effect of individual geometric design and traffic control features. Basic elements of accident predictive models of HSM (AASTHO, 2009) are listed as follows:

Safety Performance Functions (SPFs)

Safety Performance Functions (SPFs) are regression equations that estimate the average crash frequency for a specific site type (with specified base conditions) as a function of annual average daily traffic (AADT) and, in the case of roadway segments, the segment length (L). Base conditions are specified for each SPF and may include conditions such as lane width, presence or absence of lighting, presence of turn lanes etc.

Accident Modification Factors (AMFs)

Accident Modification Factors (AMFs) represent the relative change in crash frequency due to a change in one specific condition (when all other conditions and site characteristics remain constant). AMFs are the ratio of the crash frequency of a site under two different conditions

Calibration Factor (C)

Calibration factor (C) is multiplied with the crash frequency predicted by the SPF to account for differences between the jurisdiction and time period for which the predictive models were developed and the jurisdiction and time period to which they are applied by HSM users. While the functional form of the SPFs varies in the HSM, the predictive model to estimate the expected average crash frequency.

3. Data Collection and Analysis

The study was conducted firstly collecting the required data. The data was then analyzed and ranking of intersection was performed. On the basis of the results, priority for intersection safety countermeasures were recommended for top ranked intersection. For the collection of primary data, all the intersection were visited and the facilities available at each intersections were taken. Other primary data were taken through an interview with the traffic police officers for the purpose of nature of accident patterns, precise locations of accident, causes of accident and possible remedies for the intersections. After the collection of data it was analysed using Microsoft Excel and interpretation of data are done with the help of tabulated values and descriptive methods. Firstly the road accident data were analysed and ranking of the intersection according to the number of crashes. Then the crash frequency method was used for analysing the rank of intersection based on crash frequency with the help of traffic volume data. After that the prediction of crashes were done and intersections were ranked. For the secondary data the traffic accident records were taken from the Metropolitan Traffic Police Office (MTPO) at Singhadurbar as data for all the intersections were available centrally for the study period of 2013 to 2016.

3.1 Average Crash Frequency

The site with the most total crashes or the most crashes of a particular crash severity or type, in a given time period, is given the highest rank. Applying the Crash Frequency performance measure produces a simple ranking of sites according to total crashes or crashes by type and/or severity. This method can be used to select an initial group of sites with high crash frequency for further analysis.

3.2 Crash Rate

The crash rate performance measure normalizes the frequency of crashes with the exposure, measured by traffic volume. When calculating a crash rate traffic volumes are reported as million entering vehicles (MEV) per intersection for the study period. The exposure on roadway segments is often measured per million. Crash rate performance measure normalizes the number of crashes relative to exposure (traffic volume) by dividing the total number of crashes by the traffic volume.

3.3 Critical Crash Rate

The observed crash rate at each site is compared to a calculated critical crash rate that is unique to each site. The critical crash rate is a threshold value that allows for a relative comparison among sites with similar characteristics. Sites that exceed their respective critical rate are flagged for further review. Critical crash rate for each intersection can be calculated from following equation (Highway Safety Manual, 2009).

$$R_c = R_a + [P\ x \sqrt{\frac{R_a}{MEVi}} + \frac{1}{2(MEVi)}]$$

R_c= Critical Crash Rate

R_a = Average Crash Rate

P = constant related to level of statistical significance selected (1.96 used for this study) (AASTHO, 2009)

MEV_i= Million entering vehicle for the particular intersection.

Table 1: Input data Requirement for the Accident Prediction Model for Intersection

Input Data	Base Condition
Intersection type (3ST, 4ST, 4SG)	-
$AADT_{major}$ (veh/day)	-
$AADT_{minor}$ (veh/day)	-
Intersection Skew Angle (Degrees)	0
Number of signalized or uncontrolled approaches with a left turn lane (0,1,2,3,4)	0
Number of signalized or uncontrolled approaches with a right turn lane (0,1,2,3,4)	0
Intersection lighting (present/not present)	Not Present
Calibration Factor, C_i	1

3ST- Unsignalised three-legged intersection with minor road stop control

4ST- Unsignalised four-legged intersection with minor road stop control

4SG- Signalised four-legged intersection

$AADT_{major}$- Average Annual Daily Traffic of Major Leg

$AADT_{minor}$- Average Annual Daily Traffic of Minor Leg

The predictive method gives the estimate of total average crash frequency of the particular intersection. As per HSM (AASTHO, 2009) the model used for this study is:

$N_{predictedint} = N_{spfint} \times C_i \times (AMF\ 1i \times AMF\ 2i \times \ldots \times AMF\ 6i)$

Where,

$N_{predictedint}$= predicted average crash frequency for an individual intersection for the selected year;

N_{spfint}= predicted average crash frequency for an intersection with base conditions;

$AMF_{1i} \ldots AMF_{6i}$ = Accident Modification Factors for intersections;

C_i= calibration factor for intersections of a specific type developed for use for a particular jurisdiction or geographical area.

$N_{spfint} = N_{bimv} + N_{bisv}$

N_{bimv}= Predicted average number of multiple-vehicle collisions for base conditions

N_{bisv} = Predicted average number of single-vehicle collisions for base conditions

The effects of geometric design or traffic control features are incorporated through the Accident Modification Factor (AMF). The AMF for base condition of each geometric design or traffic control features has a value of 1.0 and features with higher crash frequency has AMF value greater than 1.0

whereas features with lower crash frequency has AMF value less than 1.0. AMFs considered for this study is enlisted as follows:

- AMF1i- Intersection Left Turn Lanes
- AMF2i- Intersection Right Turn Signal Phasing
- AMF3i- Intersection Right Turn Lanes
- AMF4i- Right Turn on Red
- AMF5i- Intersection Lighting
- AMF6i- Red Light Cameras

Appropriate countermeasure were selected on the basis of ranking prioritization and guidelines provided by National Cooperation Highway Research Program (NCHRP, 2003)shown in Table 2.

Table 2: Matrix for Countermeasures at Intersection

Traffic Control System	**Intersection Marking**	**Pedestrian Crossings**	**Geometry**	**Enforcement**	**Education**
Signalized Unsignalized Traffic Signs Condition of Traffic control devices Traffic Volume	Right Turn Lanes Left Turn Lanes Stop Marks Marking of Pedestrian Crossing	Type of crossing facility Availability of space for improving structures	Intersection Geometry Sight Distance	Traffic rule enforcements	Awareness among road users Drivers education

3. Findings

The crashes records according to (MTPO, 2016), has records of 34 locations out of which seventeen major intersections along Kathmandu valley are taken on the basis of their traffic volume. The intersections considered for the ranking purpose of the study are taken after the study was made on the accident record data and the ones with available data for all the study period are considered. However, according to (MTPO, 2016) the records of the crashes presented in the data are not of the intersections only but comprises of the locations along which the traffic police office is located, its surroundings and its duty areas. The actual number of crashes at the intersection itself ranges from 20-25% of the total accident as stated by traffic police during interview, and thus 20% of the total crashes are considered for the prediction of crashes in the intersection. The number of accident around the facility does not affect the ranking by average crash frequency and crash rate methods.

Average Crash Frequency

Applying the crash frequency performance measure produces a simple ranking of sites according to total crashes or crashes by type or severity. This method can be used to select an initial group of sites with high crash frequency for further analysis (Highway Safety Manual, 2009). For this analysis a crash data by location is essential. Firstly the name of intersections were arranged in alphabetical order and identification number (Intersection ID) was given. Figure 3 shows the total number of crashes at all the intersections for the three years showing that Koteshwor intersection has exceptional number of accident. Other intersection does however shows the similar number of crashes.

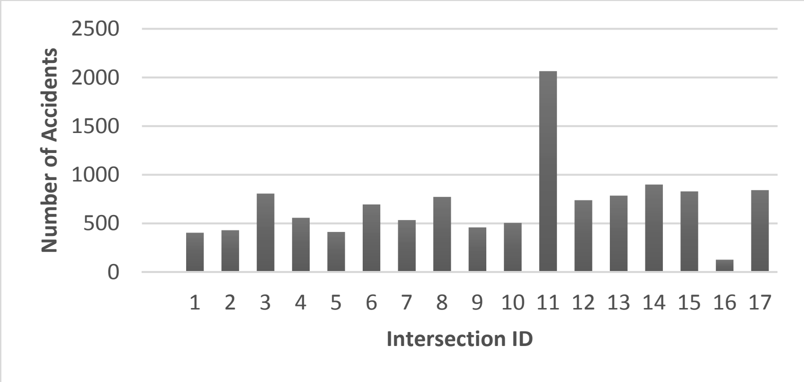

Fig 3: Total Number of Accident

With total accident records studied for the study year 2013/2014 to 2015/2016 the intersection were ranked according to the crash frequency at and around the location. Table 3shows the ranking of intersections for average crash frequency.

Table 3: Ranking of Intersection by Average Crash Freuency

Rank	**Intersection ID**	**Intersection Name**	**2013/ 2014**	**2014/ 2015**	**2015/ 2016**	**Total**	**Crashes at Intersections**
1	11	Koteshwor	597	674	795	2066	413
2	14	Singhadurbar	342	377	181	900	180
3	17	Thimi	280	227	335	842	168
4	15	Swyambhu	210	283	336	829	166
5	3	Buspark	284	327	196	807	161
6	13	Satdobato	319	214	253	786	157
7	8	Kalanki	194	243	336	773	155
8	12	Narayangopalchok	207	291	241	739	148
9	6	Gaushala	162	178	355	695	139
10	4	Chabahil	195	195	168	558	112
11	7	Jawalakhel	203	146	185	534	107
12	10	Kamalpokhari	122	194	189	505	101
13	9	Kalimati	125	147	187	459	92
14	2	Balkhu	138	133	159	430	86
15	5	Durbarmarg	67	128	217	412	82
16	1	Airport	145	133	126	404	81
17	16	Thapathali	31	25	71	127	25

Crash Rate

Crash rate of all the intersections were calculated as:

$$MEV = \left(\frac{TEV}{1{,}000{,}000}\right) X(n) X(365)$$

$$R = \frac{N_{observed\ (Total)}}{MEV}$$

R= Observed Crash rate at intersection

$N_{observed\ (Total)}$ = Total Observed crashes at intersection

MEV_i= Million entering vehicle at intersection

The crash rate of each intersections were calculated and the Table 4 shows the ranking of intersections on the basis of the crash rates at the intersection.

Table 4: Ranking of Intersection by Crash Rate

Ranking	Intersection ID	Intersection Name	Total Crashes	Accident at Intersection	Traffic Volume (AADT)	Exposure	Crash Rate
1	11	Koteshwor	2066	413	22,353	24.48	16.8733
2	14	Singhadurbar	900	180	13,673	14.97	12.0225
3	10	Kamalpokhari	505	101	7,762	8.50	11.8832
4	7	Jawalakhel	534	107	9,124	9.99	10.7099
5	2	Balkhu	430	86	8,678	9.50	9.05034
6	17	Thimi	842	168	18,250	19.98	8.40683
7	8	Kalanki	773	155	18,070	19.79	7.83356
8	3	Buspark	807	161	19,263	21.09	7.63287
9	15	Swyambhu	829	166	20,244	22.17	7.48855
10	13	Satdobato	786	157	19,557	21.41	7.33134
11	9	Kalimati	459	92	11,646	12.75	7.21435
12	4	Chabahil	558	112	17,346	18.99	5.89664
13	5	Durbarmarg	412	82	13,432	14.71	5.57518
14	12	Narayangopalchok	739	148	26,982	29.55	5.00926
15	6	Gaushala	695	139	25,619	28.05	4.95494
16	1	Airport	404	81	28,735	31.46	2.5743
17	16	Thapathali	127	25	12,142	13.30	1.88034

Critical Crash Rate

The observed crash rate at each site is compared to a calculated critical crash rate that is unique to each site. The critical crash rate is a threshold value that allows for a relative comparison among sites with similar characteristics. Sites that exceed their respective critical rate are flagged for further review. The critical crash rate depends on the average crash rate at similar sites, traffic volume, and a statistical constant that represents a desired level of significance.

$$R_c = R_a + [P\ x\ \sqrt{\frac{R_a}{MEVi} + \frac{1}{2(MEVi)}}]$$

R_c= Critical Crash Rate

R_a = Average Crash Rate

P = constant related to level of statistical significance selected (1.96 used for this study) (AASTHO, 2009)

MEV_i= Million entering vehicle for the intersection

Similarly the critical rate of all the intersection were calculated and presented in the Table 5 and highlighted intersections are the one flagged for further study.

Table 5: Ranking of Intersections by Critical Crash Rates

Ranking	Intersection ID	Intersection Name	Accident at Intersection	Traffic Volume (AADT)	MEV	Crash Rate	Average Crash (R_a)	Critical Crash Rate (R_c)
1	10	Kamalpokhari	101	7,762	8.50	11.883	7.785	8.801
2	2	Balkhu	86	8,678	9.50	9.050	7.785	8.743
3	7	Jawalakhel	107	9,124	9.99	10.710	7.785	8.718
4	9	Kalimati	92	11,646	12.75	7.214	7.785	8.606
5	16	Thapathali	25	12,142	13.30	1.880	7.785	8.588
6	5	Durbarmarg	82	13,432	14.71	5.575	7.785	8.547
7	14	Singhadurbar	180	13,673	14.97	12.022	7.785	8.539
8	4	Chabahil	112	17,346	18.99	5.897	7.785	8.452
9	8	Kalanki	155	18,070	19.79	7.834	7.785	8.438
10	17	Thimi	168	18,250	19.98	8.407	7.785	8.434
11	3	Buspark	161	19,263	21.09	7.633	7.785	8.416
12	13	Satdobato	157	19,557	21.41	7.331	7.785	8.411
13	15	Swyambhu	166	20,244	22.17	7.489	7.785	8.400
14	11	Koteshwor	413	22,353	24.48	16.873	7.785	8.369
15	6	Gaushala	139	25,619	28.05	4.955	7.785	8.330
16	12	Narayangopalchok	148	26,982	29.55	5.009	7.785	8.315
17	1	Airport	81	28,735	31.46	2.574	7.785	8.298

Crash Prediction for Intersections

For the prediction of crashes in intersections firstly the facility type of intersections are categorized. The intersections are categorized as three-leg unsignalized intersection (3ST) and four leg-unsignalized intersection (4ST). Separate calibration coefficient are calculated for each facility type. The SPFs for each of the four intersection types identified above predict total crash frequency per year for crashes that occur within the limits of the intersection. The SPFs and adjustment factors address the following four types of collisions.

- Multiple-vehicle collisions
- Single-vehicle crashes
- Vehicle-pedestrian collisions
- Vehicle-bicycle collisions

The regression coefficients for multiple vehicle collision for intersection are adopted from HSM.

Accident Modification Factors for Intersections

The effects of individual geometric design and traffic control features of intersections are represented in the predictive models by AMFs. AMF*1i* through AMF*4i* are applied to multiple-vehicle collisions and single-vehicle crashes at intersections, but not to vehicle-pedestrian and vehicle-bicycle collisions.

Predicted average crash frequency for Shinghadurbar Intersection

$N_{predictedint}$= 0.946 for calibration coefficient is considered 1 as per HSM (AASTHO, 2009).

For the crash prediction of the 3ST intersections for the study year 2015/2016 the calibration coefficient is calculated and calibrated as per the HSM (AASTHO, 2009).

For the calibration of 3ST intersection firstly the determination of calibration coefficient is carried out, which can be calculated as:

$$Ci = \frac{\sum Observed\ Crashes}{\sum Predicted\ Crashes} \qquad Ci = \frac{396}{9.572} = 41.371$$

The calculated calibration coefficient is greater than 1, thus the intersections used to calculate the coefficient has more crashes than the facility type used for development of SPF on an average.

After applying the calibration coefficient the prediction of crashes for the study year 2015/2016 is done and ranked in descending order as shown in Table 6 for 3ST intersection facilities.

Table 6: Ranking of Three Legged Unsignalized Intersection

Intersection ID	Intersection Name	Predicted Crash
1	Airport	94
11	Koteshwor	77
3	Buspark	62
4	Chabahil	54
14	Singhadurbar	39
5	Durbarmarg	38
9	Kalimati	32

Percentage Error(PE)= $\frac{|Observed\ Crash - Predicted\ Crash|}{Observed\ Crash}$ x 100%

Mean Absolute Deviation(MAD)= $\frac{\sum|Observed\ Crash - Predicted\ Crash|}{n}$

Mean Absolute Percentage Error(MAPE)= $(\frac{\sum|Observed\ Crash - Predicted\ Crash|}{Observed\ Crash})$/n x 100%

Table 7: Testing Parameters for Three Legged Unsignalized Intersections

Intersection ID	Intersection Name	Predicted Crash	Observed Crash	Predicted Crash-Observed Crash	Percentage Error	Mean Absolute Deviation (MAD)	Mean Absolute Percentage Error (MAPE)
1	Airport	94	88	6	6.818	20.571	29.952
11	Koteshwor	77	159	82	51.572		
3	Buspark	62	39	23	58.974		
4	Chabahil	54	34	20	58.824		
14	Singhadurbar	39	36	3	8.333		
5	Durbarmarg	38	43	5	11.628		
9	Kalimati	32	37	5	13.514		

The difference between predicted crash and observed crash here not only shows that crashes does not solely depend upon the driver's behaviour but may also depend upon other factors like vehicle numbers, presence of heavy vehicles and percentage of motor bikes in the AADT. From the results the countermeasures for the top three ranked intersections can be suggested from the site inspection and crash analysis.

For the calibration of the crash calibration factor a simple regression is carried out and R^2 value is calculated which is presented in figure 4 which gives the R^2 value of 0.7089 which is acceptable for the regression performed and hence can be concluded that the test of calibration factor has an acceptable value. For the regression analysis Koteshwor Intersection was not considered as the accident rates at this intersection showed alarming fluctuations and affected in the regression analysis. For better improvement of the results in the regression performed, number of intersection can be increased.

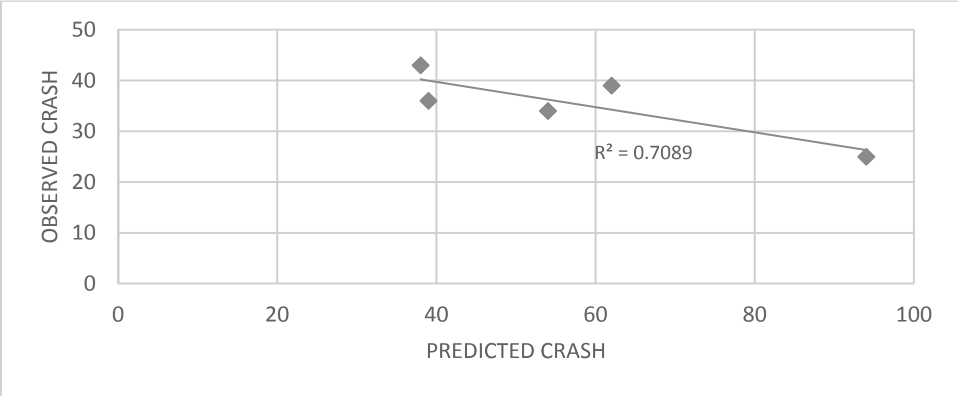

Fig 4: Regression Analysis for Three Legged Unsignalized Intersection

Predicted average crash frequency for NarayangopalChok Intersection

$N_{predictedint}$= 2.960 for calibration coefficient considered 1 as per HSM (AASTHO, 2009).

$$Ci = \frac{\sum Observed\ Crashes}{\sum Predicted\ Crashes}$$

$$Ci = \frac{388}{18.201} = 21.318$$

Table 8: Ranking of Four Legged Unsignalized Intersection

Intersection ID	Intersection Name	Predicted Crash
12	NarayangopalChok	63
6	Gaushala	60
15	Swyambhu	47
13	Satdobato	45
8	Kalanki	42
17	Thimi	42
7	Jawalakhel	21
2	Balkhu	20
10	Kamalpokhari	18
16	Thapathali	10

Table 9: Testing Parameters for Four Legged Unsignalized Intersections

Intersection ID	Intersection Name	Predicted Crash	Observed Crash	Predicted Crash-Observed Crash	Percentage Error	Mean Absolute Deviation (MAD)	Mean Absolute Percentage Error (MAPE)
12	Narayangopalchok	63	48	15	31.250	16.4	39.636
6	Gaushala	60	71	11	15.493		
15	Swyambhu	47	67	20	29.850		
13	Satdobato	45	51	6	11.764		
8	Kalanki	42	67	25	37.313		
17	Thimi	42	67	25	37.313		
16	Thapathali	10	14	4	28.570		
7	Jawalakhel	21	37	16	43.240		
2	Balkhu	20	32	12	37.500		
10	Kamalpokhari	18	38	20	52.631		

For the calibration of the crash calibration factor a simple regression is carried out and R^2 value is calculated which is presented in the following figure which gives the R^2 value of 0.6275 as shown in figure 5 which is acceptable for the regression performed and hence can be concluded that the test of calibration factor has an acceptable value. For better improvement of the results in the regression performed, number of intersection can be increased.

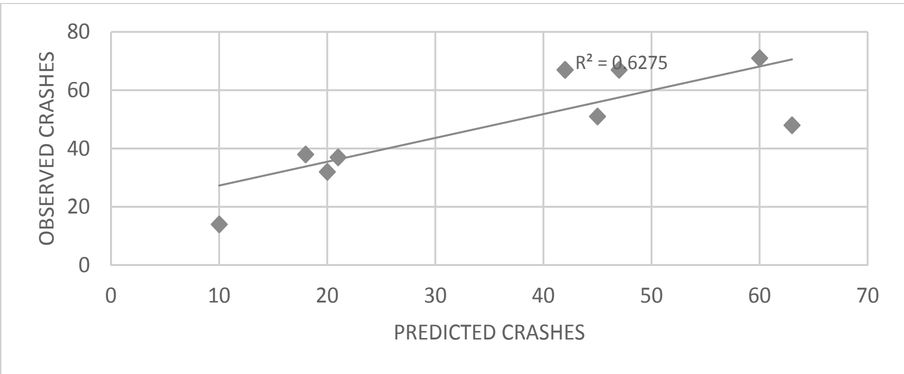

Fig 5: Regression Analysis for Four Legged Unsignalized Intersections

Countermeasures for the top three intersection of both 3ST type and 4ST type intersections are drawn on the basis of results, traffic police suggestions based on their experience and site inspections. Table 10 shows the countermeasures that can be adopted for reduction of crashes at the intersections which have more observed crash than predicted crash.

Table 10: Countermeasures for Intersections

S.N	Intersection Name	Facility Type	Countermeasures
1	Koteshwor	3ST	Installation of Traffic Signals, Overhead/Subway Pedestrian Crossings, Clear Road Markings
2	Durbarmarg	3ST	Installation of Traffic Signals
3	Kalimati	3ST	Installation of Traffic Signals, Enforcement of No U turn and No Right Turn at intersection
4	Kamalpokhari	4ST	Installation of Traffic Signals, Speed Limit
5	Thimi	4ST	Installation of Traffic Signals, Speed Limit
6	Kalanki	4ST	Installation of Traffic Signals, Overhead Pedestrian Crossings, Management of Heavy vehicles, Clear Road Markings

Education for awareness of all the road users is necessary. Implementation of laws and enforcements should be done effectively to reduce the crashes. Likewise knowledge of road markings to all the road users are necessary. The concerned authorities, DoR, DoTM and MoPIT should start the awareness program from the school level.

4. Conclusion and Recommendation

The study was focused on the pattern of accident in Kathmandu valley road network. The analysis of accident shows the trend of accident occurrence in different intersection locations and its surroundings. The minor injury rate is higher than that of seriously injured records. The number of motorbikes involved in the accident in the study locations are significantly high. The fatality of male road user is higher than female. Driver behaviour is the cause of most of the crashes. Technical difficulties in the vehicle, road geometry, road condition, overloading etc. are the other factors of crashes occurring in the location.

Crash occurrence method shows that Koteshwor Intersection is ranked at top among the seventeen intersection selected for the study. Crash rate frequency is another method defined in HSM for ranking of intersection and shows the same intersection (Koteshwor) as top ranked intersection. Critical crash rate value is another method mentioned in HSM for the ranking of intersections. With this method it is found that Kamalpokhari intersection is in the top of the rank. This intersection must be imposed with safety measures for decreasing the critical crash rate.

After the calibration coefficient is found, it was then calibrated using simple Linear Regression model and R^2 value was calculated and hence were found within the acceptable range. These intersections are predicted on the basis of HSM which gives the prediction of crashes only with the data available for the facility type describing the geometrics and traffic volume of the intersection only. The traffic control measures, pedestrian behaviour, effect of heavy vehicles are few of many parameters that may lead to crashes and needs to be considered for the prediction of the crashes.

5. Recommendations

The following recommendations can be made from the study performed and conclusions drawn:

- ❖ It is recommended to implement the countermeasures suggested to the respective intersections to increase its safety.
- ❖ Further research can be done with parameters other than traffic volume and accident frequency.
- ❖ It is also recommended to use more number of sites to calibrate the crash coefficient and use in predictive method.
- ❖ For the safety assurance of the intersections studied, safety audits can be performed on each intersection by prioritizing the intersection according to the rank to treat the sites as accordingly.

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