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A Novel Approach of Safety Assessment at Uncontrolled Intersections using Proximal Safety Indicators

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Abstract

Historically PET is widely used to identify critical conflicts based on its predetermined threshold. Identification of critical conflicts only on a time-based threshold could be misleading because drivers of different vehicular categories do not always follow the posted speed limit. Moreover, PET alone can define only the probability of collision. In order to carry out safety assessment at uncontrolled intersections, four sites have been selected from the NCR India. This study is focused on proposing a new methodology over the existing one using two proximal safety indicators i) Post Encroachment Time (PET) and ii) conflicting speed of through moving vehicleson major roads. A parameter critical speed is introduced to determine critical conflicts as well as the severity of resulting collision. It is estimated based on the concept of braking distance. The result shows that PET values less than the threshold do not always create the critical situations when the speed of the corresponding conflicting vehicle is low and vice-versa. The key problem with the conventional method based on time-based PET threshold is found to be inconsistency associated with the identification of critical conflicts. It is suggested to verify the suitableness of the proposed methodology by using the crash data available for the study sites.

Keywords:Uncontrolled intersections; Proximal safety indicator;Post Encroachment Time; Critical speed; Critical conflicts

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1. Introduction

In any roadway system, intersections are the major bottlenecks affecting the traffic flows. Because of the presence of conflict points, they are crash prone areas as well. Ensuring traffic safety at intersection locations is a national, state and local priority. In the United States, where trafficsafety measures are being implementedin order to reduce the number of accidents and deaths on roadways, more than 20 percent of all traffic fatalities and about half of the traffic injuries were observed to take place at intersection

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locations. Most of the severe crashes and higher fatality rate are found to be associated with unsignalized intersections (Subramanian and Lombardo, 2007; FHWA, 2011). In India, several unsignalized intersections located both in rural and urban areasare mainly uncontrolled, i.e., no signs or pavement markings are available for traffic control. No precise priorities are assigned to a particular movement as stop and yieldsignsare not provided at these intersections. Even if any movement is prioritized with signs many drivers do not follow this, therefore, the priorities get established by the situations drivers perceive (Patil and Pawar, 2014). Such intersections have very less control over the traffic flow and these are potentially very unsafe. The crash rate at unsignalized intersections is also increasing at a high level. According to the latest Indian ministry report, 2,79,326 accidents occurred only at intersections in the year of 2014, out of which about 76.4% occurred at uncontrolled intersections (MoRTH, 2014). At the same time, traffic condition in India is highly heterogeneous in nature consisting of various non-motorized and motorized vehicles. Several vehicle categories with a wide range of static and dynamic characteristics are observed in any roadway system. All of these vehicles interact with each other on the same road space and create problems in traffic operations. Under such mixed traffic scenario, particularly at intersection locations, drivers usually take many unsafe actions such as the sudden application of brakes, abrupt lane changes or not following lane discipline, etc. The maneuver of left turning traffic (for the left-hand drive) is not a serious issue at intersection locations. At unsignalized intersections, through moving traffic on major roads have the right of way, and right turners have to look for suitable gaps in between through traffic to complete their crossing maneuvers. If high traffic volume exists at crossing situation, drivers turning right from the major/minor road onto the minor/major road have to wait long to complete their maneuver. Due to the long waiting time, drivers become impatience, and they have a tendency to accept smaller gaps which may be dangerous (Pirdavani et al., 2010). Consequently, critical conflict situations occur at frequent intervals between right turners and through traffic, which often lead to unsafe circumstances and result in probable collisions. While right turners reduce their speed in order to take a turn, higher speed is observed for through traffic on the major road which increases the chances of severe collisions. Therefore, it is important to conduct rigorous and reliable safety analyses to reduce the crash rate at uncontrolled intersection locations.

Traditionally, road safety analyses have been performed based on historical crash data and by using different types of statistical approaches. There are several drawbacks associated with these types of analysis such as random and rare nature, underreporting, improper documentationetc. The conventional methods of safety analyses are solely based on accident data, so these approaches are reactive in nature (deLeur and Sayed, 2003). To overcome these problems related to collision data, several researchers have proposed proactive methods using alternative indicators which are able to reflect the safety of a facility Among these surrogate safety measures, traffic conflict analysis using proximal safety indicators is found to be the most commonly used technique as it overcomes the major problems associated with the traditional methods (Cooper 1983; Hyden, 1987,1996; Sayed et al., 1994; FHWA, 2003; Archer, 2005; Songchitruksa and Tarko, 2006; Archer and Young, 2010; Pirdavani et al., 2010; Vedagiri et al., 2013,2014; Sacchi and Sayed, 2015). A traffic conflict is defined as an observable situation of two or more road users where one or both of them take evasive action to avoid an impending collision (Amundsen and Hyden, 1977). Conflicts occur more frequently than crashes, and characteristically both of them are similar, as conflicts represent a nearness to the collision. The key advantage of conflict based proximal safety indicators is that they represent the temporal and spatial proximity characteristics of unsafe interaction and near accident (Archer, 2005). Several proximal safety indicators such as Time to collision (TTC), Post Encroachment Time (PET), Deceleration rate (DR), Maximum speed (Max V), Delta speed (Delta V), Proportion of stopping distance (PSD), etc. have been proposed by various researchers to assess safety of a traffic facility using traffic conflicts. Among all of them, PET is the most commonly used indicator to identify the crossing conflicts between two road users. It refers to the time lapse between the moments when the first vehicle departs a conflict point and the second vehicle approaches that point. In fact, PET is a less resource-demanding measure as an estimation of vehicular speed, and distance from the common conflict point is not required as in the case of TTC (FHWA, 2003).

In the past, several studies have been carried out using PET as a proximal safety indicator for evaluating safety at intersection locations. Klunder et al., (2006) evaluated intersection safety using PET and critical gaps. PET values for crossing events at the intersections were observed, and the lowest PET value was recorded for each different set of critical gap values. Pirdavani et al. (2010) identified PET values under different traffic volume and varying speeds at the unsignalized intersection. Vedagiri et al. (2013) measured the PET at the unsignalized intersection by using square grids placed along the lane paths, and by assuming vehicles move in a single lane and a straight path. The mean value of PET was approximately 5 seconds, and maximum numbers of PET values were in the range of 0-3 seconds. Another study by Vedagiri et al. (2014) had identified PET at a unsignalized intersection using the grid of rhombus shape with the dimensions of 2.5m×2.5 m and internal angle of 60° and 120°. They found that 25-40% of PET values were in a negative range of less than 0 to -5 sec. They had also investigated the effect of changes in vehicle composition, traffic volume, and vehicular speed on the major as well as the minor road. In order to distinguish between the critical and non-critical conflict events, many researchers had carried out the conflict analyses using different PET threshold values with a range of less than 1 sec to 5 sec. (Archer,2005; Klunder et al., 2006; Archer and Young; 2010; Caliendo and Guida, 2012). The PET threshold depends on the type of road, type of vehicle as well as involved road users in a particular traffic conflict situation (Svensson 1988). In general, PET is used as a single indicator that can reflect the overall safety performance with respect to the probability of collision, but the severity point is still lacking. Therefore, in this study, a new methodology has been proposed which can be used to define the probability as well as the severity of resulting collision. To connect the conflict severity to the collision probability, the proposed method incorporates the conflicting speed of through vehicles along with PET to evaluate the safety level at uncontrolled intersections. Although other existing proximal indicators such as TTC, DR, etc. are usually calculatedwith respect to vehicular speed, but the problem lies in data extraction process. Apart from PET, other parameters are more resource-demanding as an estimation of these parameters by using videography technique is very tedious.

The primary objective of this study is to evaluate safety at uncontrolled intersections by observing the crossing conflicts between right-turning traffic on the major/minor road and through traffic on the major road. An attempt has been made to propose a new proximal safety indicator by integrating a speed component with PET to identify critical conflicts efficiently. Consequently, conflicts between the cross traffic at uncontrolled intersections are observed by using two relevant safety indicators, PET and corresponding speed of conflicting through vehicles. Initially, the risk of collision in terms ofnumber of critical conflicts is determined using PET values alone. Furthermore, the significance of consideration of the conflicting speed of through vehicles are investigated in quantifying the critical conflicts by taking into account the conflict severity. Finally, critical conflicts observed using these two indicators are compared and analysed.

2. Methodology

PET is a quantitative measure to identify the conflict situation. Thisis calculated as a time difference between the passages of two road users with a common spatial point or area of potential collision (Archer, 2005). For the present study, a threshold value of 2.5 sec is taken to determine the critical conflicts, which is the perception-reaction time of drivers for stopping sight distance as suggested by various international design standards (AASTHO, 2001; IRC, 1983)etc. Any conflict with PET value less than 2.5 sec is considered as a critical conflict. This measurement of PET at conflict point only includes the time events between two road users without measuring the speed of vehicles. At uncontrolled intersections, usually traffic signs such as stop and yield signs are not present and as a result of that drivers do not have any control on their approaching speed. The higher approaching speed of vehicles at intersections also contribute to the higher severity of conflict resulting in acollision. As PET alone cannot assess the conflict severity, the approaching speed of through vehicle i.e. conflicting vehicle is also an important factor to identify the conflict severities and evaluate the intersection safety. At any intersection, all the vehicles do not move with a reasonably similar speed. Different categories of vehicles move with a varying speed range instead of following the posted speed limit. Thus, it can incur error if the identification of critical conflicts is grounded only on a time-based PET threshold without considering the speed of conflicting vehicles. Moreover, it is a difficult task to identify an appropriate threshold to separate critical conflicts from other non-critical conflicts. Several studies have been carried out using predetermined threshold values which are mostly identifiedarbitrarily and no standard approach is established. It is also possible that threshold varies with types of conflict being observed. Researchers mentioned that an improper threshold can provide inconsistent findings for the relationship between conflicts and crashes (Peesapati et al. 2013; Zheng et al. 2014). Therefore, in this study, another parameter with respect to the vehicular speed, termed as critical speed, is utilized to identify the critical conflicts. If the conflicting speed of the vehicle is observed to be more than corresponding critical speed, the conflict is termed as a critical one. The critical speed of each PET value is calculated using stopping sight distance criteria. As the drivers of the conflicting vehicles already reached at the crossing situation, the distance travelled by the total reaction time is not considered. The distance available to a driver at crossing situation is calculated by multiplying PET with the critical speed (PET x critical speed). Thereafter, this distance is equated with the braking distance ($v^2/2gf$) and the critical speed is estimated as PET x 2gf for that particular PET value. The components of braking distance are i) 'v' which is the critical speed for a certain PET value (m/s), ii) 'g' is the gravitational acceleration (9.81 m/s^2), and iii) 'f' is the coefficient of friction, which is taken as 0.35. This value of the coefficient of friction is recommended by AASTHO (2001) as 90% of the drivers found to accommodate standard deceleration (3.4 m/s^2) with this value. Calculated critical speeds for different PET values are given in Table 1.

Table 1. Critical speeds for different PET values

PET in sec	Critical Speed in m/s	Critical Speed in Km/h	PET in sec	Critical Speed in m/s	Critical Speed in Km/h
-2	13.72	49.39	5	34.30	123.48
-1	6.66	24.70	6	41.16	148.18
0	0.00	0.00	7	48.02	172.87
1	6.86	24.70	8	54.88	197.57
2	13.72	49.39	9	61.74	222.26
3	20.58	74.09	10	68.60	246.96
4	27.44	98.78	11	75.46	271.66

As mentioned earlier, in the present study the critical conflicts are determined based on two methods: i) by taking a PET threshold value and finding the situation where PET is less than the threshold value and ii) by identifying the situations when conflicting speed for a particular PET value is greater than the respective critical speed. The first method identifies the probability of collision for a particular conflict situation whereas the second method determines the severity of resulting collision, as it includes a speed component.

2.1 Data Collection and Processing

To assess the safety performance at uncontrolled intersections, four sites located in NCR, India, have been selected which are not controlled by any priority rules. Out of these four sites, two are three-legged intersections having similar road geometry and traffic volume, and other two are of four-legged ones. All the selected intersections are at-grade intersections (on the same level).The locations are selected based on some criteria: i) traffic volume is enough to observe conflict situations within a short period of time, ii) motorists travel with their desired speed and iii) there are very less number of pedestrians and cyclists. The details of the intersection locations are provided in Table 2.

Table 2. Description of intersections used for the study

Name of Sites	Case	Lane width	Directional flow along major roadon the side of median	Type of intersection	Traffic Flow (Veh/hr)
Airport-NHAI-AIFF intersection at Dwarka	S-1	3.5 m	2-lane 1-way	Three-legged	1868
Faridabad-Gurgaon-Sikenderpur intersection at Gurgaon	S-2	3.5 m	2-lane 1-way	Three-legged	3778
Bahadurgarh intersection at Delhi	S-3	3.5 m	2-lane 1-way	Four-legged	1985
Dwarka-Kargil intersection	S-4	3.5m	2-lane 1-way	Four-legged	2451

Both traffic operational and conflict data are collected using videography technique. The video camera is set up at a vantage point, and the adequate view of a study area is obtained. It is ensured that a distance of 100 m along the major road is properly visible from the position of camera.Field survey has been conducted during daytime on weekdays under good weather conditions. A snapshot of video recording is shown in Figure 1. For all the sites, conflicts between right turning traffic of major/minor roads and through moving vehicles on major roadsare observed. At each site, the right turning traffic volume from the minor road is observed to be less. At the same time, the conflict situations between two right turners from the major and minor road are found to be quite less. Therefore, in the present study, conflicts between two right turning traffic are not considered.

Figure1. A snapshot of study site 1 (S-1)

Recorded videos are processed using a large monitor in the laboratory and necessary information i.e. PET, speed, and composition of conflicting vehicles, etc. are extracted. For extracting the conflict data, the conflict area of each intersection is equally divided into several grids. The dimension of grids is selected as 2.5 m x 2.5 m square as per standard dimension of vehicles. The grids have been drawn in Autodesk Maya 3D and then overlaid on the videos using software Corel Video Studio Pro X6. Recorded videos are played at a rate of 25 frames per second. Each videois played several times and two events t_1 and t_2 are noted down, where t_1 is the time when a right-turning vehicle exits a particular grid of conflict area, and t_2 represents the time when the front of through vehicle just enters the same grid. PET is calculated as the difference between these two-time events t_2 and t_1. For calculating the speed of conflicting vehicles, a trap of 20 m length is made at each study site and the time is taken by anindividual through vehicle to traverse this distance is recorded. The recorded speed of conflicting vehicles ranges from 8 km/h to 72 km/h. The composition of conflicting vehicles both at three-legged and four-legged intersections are shown in Figure. 2 and Fig. 3. It can be observed that conflicting vehicles are of six different categories, namely, two wheelers (2W), three wheelers (3W), car, big car, light commercial vehicles (LCV) and heavy vehicles (HV). LCV includes minibus, mini truck, van, whereas HV represents bus, truck and truck-trailer. The maximum number of conflicts are observedbetween car to car followed by car to 2W.

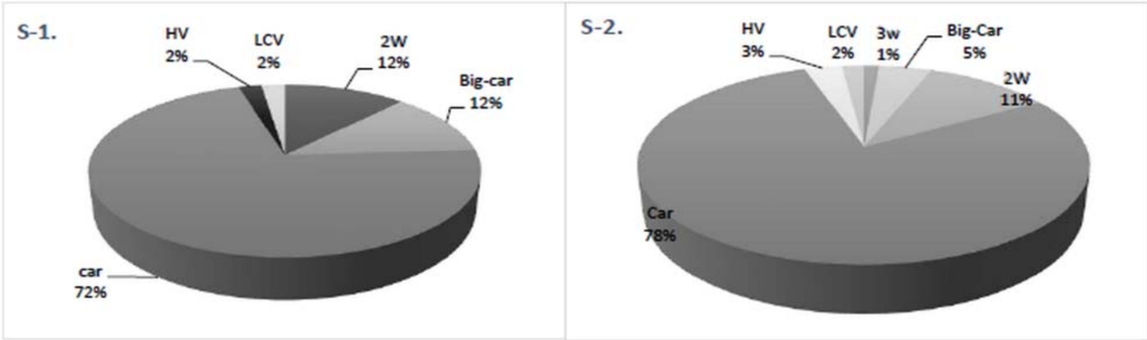

Figure 2. Composition of conflicting vehicles at three-legged intersections

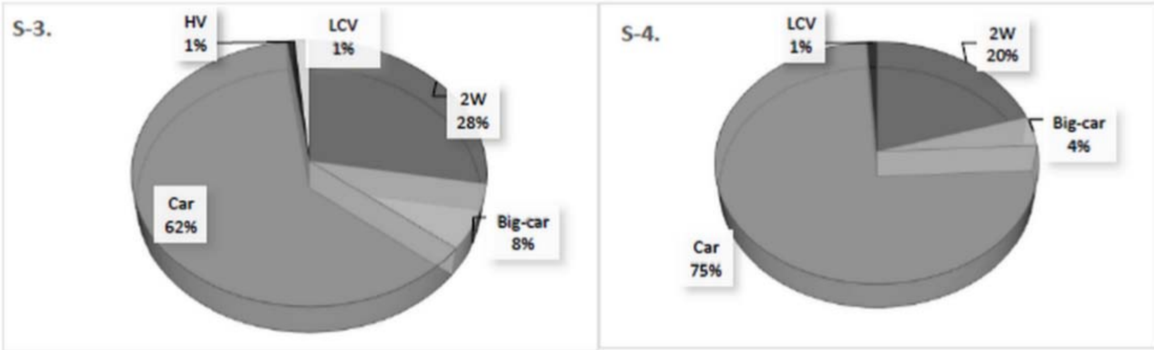

Figure 3. Composition of conflicting vehicles at four-legged intersections

Figure2 and Figure3 show that percentage of the car is more followed by the percentage of 2W at all the sites but at the first site (S-1) the big-car proportion is same as that of 2W. While comparing the total share of conflicting vehicles between three-legged and four legged-intersections, it is observed that at all the sites car constitutes a predominantshare of all conflicting vehicles. Another observation is that at four-legged intersections the percentage of 2W is more in comparison to three-legged ones.

3. Analysis and Results

Different traffic movements which are considered for the estimation of PET and subsequent analyses are shown in Figure 3 and Figure 4 for three and four-legged intersections respectively.

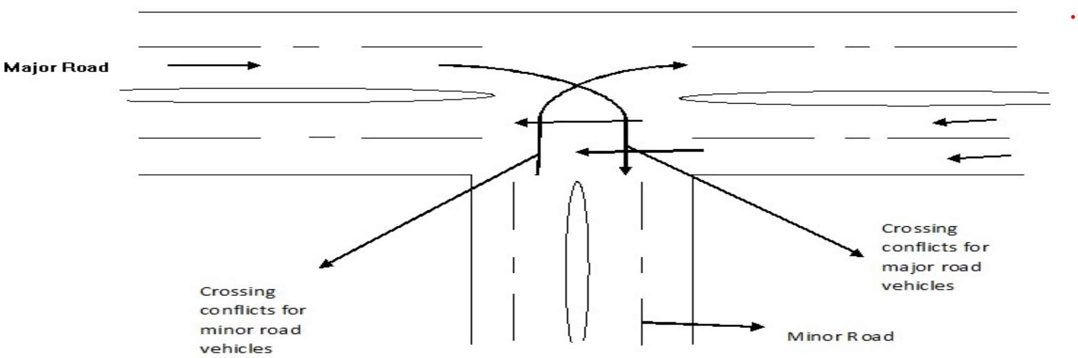

Figure 4. Crossing conflicts between right turners and through moving vehicles at three-legged intersection

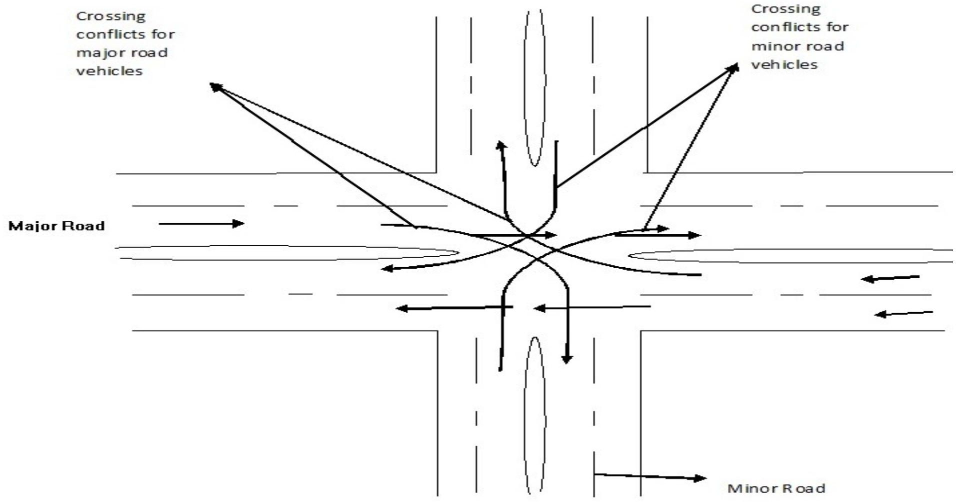

Figure 5. Crossing conflicts between right turners and through moving vehicles at four-legged intersection

From the video data, PET values are observed for all the sites between various right turning and through movements as illustrated in Figure4 and 5. Empirical analysis has been carried out with PET values between these movements. Accordingly, different parameters namely average, minimum and maximum values of PET and number of critical conflicts based on PET threshold value have been estimated. These are shown in Table 3.

Table 3. Characteristics of observed PET values

Study site	S-1	S-2	S-3	S-4
No of observed conflicts	175	157	137	182
Average PET	2.21	2.79	1.46	1.6
Minimum PET	-1	-1	-2	-2
Maximum PET	9	10	9	10
No of critical conflicts (i.e PET values less than 2.5 secs)	57 (32.57%)	91 (57.96%)	114 (83.21%)	145 (79.67%)

From all the sites, total 651 numbers of conflict are observed from the recorded data. The average value of PET for three study sites S-1, S-3 and S-4 are found to be 2.21 sec, 1.46 sec, and 1.6 sec respectively, which is less than PET threshold value. It implies that these three sites are unsafe with respect to PET threshold value. Unlike study site S-2, the drivers of other three sites have taken the crossing decisions before perceiving the situation properly. Interestingly, negative PET values are also observed between the right turning and through vehicles on major roads. This situation arises when right turning vehicles do not exit the grid and through vehicles of the major road enter into it.

3.1 Frequency distribution of PET values

The distribution of PET values has been looked into for all the sites, ranges from -2 to 10 sec. Figure6 and Figure7 show the distribution of PET values for three-legged (S-1 and S-2) and four-legged intersections (S-3 and S-4) respectively.

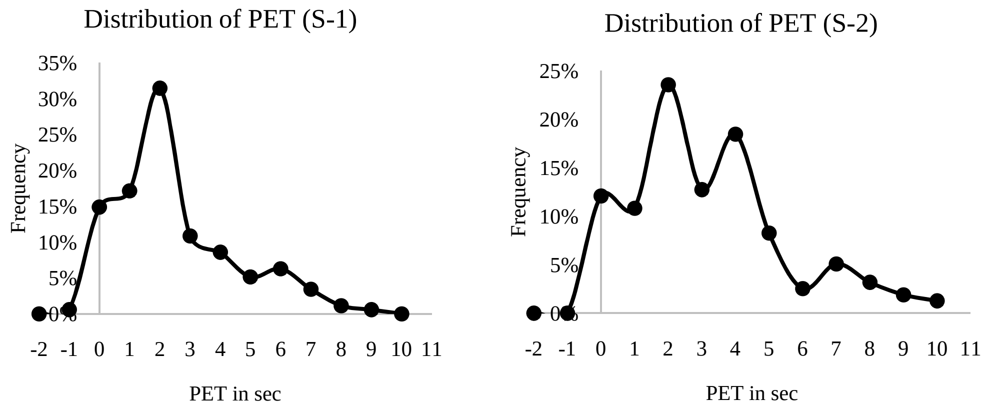

Figure 6. Distribution of PET at three-legged intersections

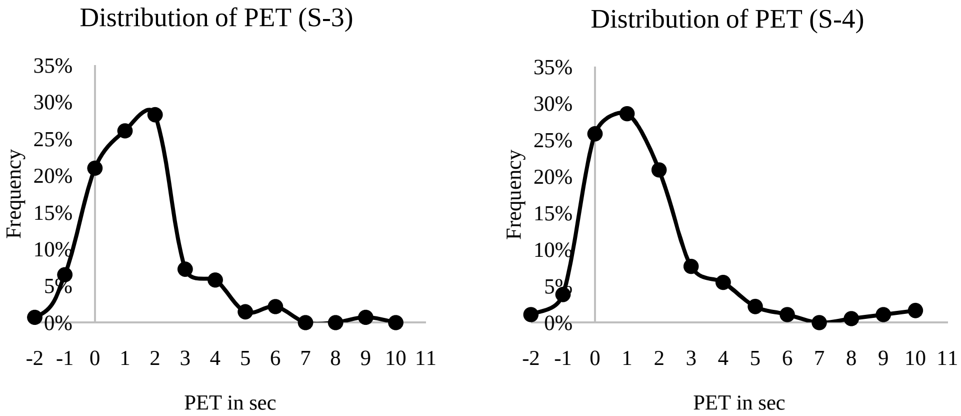

Figure 7. Distribution of PET at four-legged intersections

3.2 Distribution of conflicts based on conflicting speed and critical speed

In order to have a better insight of critical conflicts, observed PET values are distributed based on the critical speeds. PET values are found to be ranging from -2 sec to 10 sec as presented in Table 4 and 5. They are grouped with an increment of 1 sec, and corresponding critical speeds are separated for each PET values. For a certain PET value, the percentage of conflicts in which conflicting speed is found to be more than the critical speed are identified and separated as critical conflicts. Distribution of total conflicts and percentage of critical conflicts for each PET group observed at different study locations are also shown in Table 4 and 5.

Table 4. Distribution of critical conflicts for three-legged intersections.

PET in sec	Critical Speed in Km/h	S-1		S-2	
		% conflicts	% of critical conflicts	% conflicts	% of critical conflicts
-2 to-1	-49.39	0	0	0	0
-1 to 0	-24.70	1.14	0.51	1.27	1.2
0 to 1	0	14.29	12.02	10.83	8.24
1 to 2	24.7	29.14	25.36	19.75	18.48
2 to 3	49.39	25.14	17.53	24.84	24.24
3 to 4	74.09	9.71	0	14.65	13.44
4 to 5	98.78	4	0	10.19	0
5 to 6	123.48	6.86	0	5.73	0
6 to 7	148.18	6.29	0	3.82	0
7 to 8	172.87	2.29	0	5.1	0
8 to 9	197.57	0.57	0	0.64	0
9 to 10	222.26	0.57	0	0.64	0
10 to 11	246.96	0	0	2.55	0
Total		100	55.42	100	65.61

Table 5. Distribution of critical conflicts for four-legged intersections.

PET in sec	Critical Speed in Km/h	Site 3		Site 4	
		% conflicts	% of critical conflicts	% conflicts	% of critical conflicts
-2 to-1	-49.39	0.73	0.52	1.1	0.7
-1 to 0	-24.70	6.57	5.44	3.85	3.8
0 to 1	0	20.44	17.65	25.82	25.2
1 to 2	24.7	26.28	19.14	28.57	26.45
2 to 3	49.39	28.47	27.65	20.88	20.22
3 to 4	74.09	7.3	3.05	7.14	0
4 to 5	98.78	5.84	1	5.49	0
5 to 6	123.48	1.46	0	2.2	0
6 to 7	148.18	2.19	0	1.1	0
7 to 8	172.87	0	0	0	0
8 to 9	197.57	0	0	0.55	0
9 to 10	222.26	0.73	0	1.1	0
10 to 11	246.96	0	0	2.2	0
Total		100	74.45	100	76.37

From Table 4 and Table 5, it is seen that almost all the critical conflicts at three-legged (S-1 and S-2) as well as at four-legged intersections (S-3 and S-4) lie within PET values of -2 to 4 secs. Beyond a PET value of 4 sec, the conflicts are found to be non-critical for all the study sites. At S-1 and S-2, the maximum percentage of critical conflicts are observed for PET groups of (1-2) sec and (2-3) sec respectively. On the other hand, for the other two sites (S-3 and S-4), critical conflicts are observed for PET groups of (2-3) and (1-2) respectively.

Table 6. Comparison of critical conflicts based on PET threshold and critical speed.

Study Site	No of observed conflicts	No of critical conflicts based on PET threshold	No of critical conflicts based on critical speed
S-1	175	57 (32.57%)	97 (55.42%)
S-2	157	91 (57.96%)	103 (65.61%)
S-3	137	114 (83.21%)	102 (74.45%)
S-4	182	145 (79.67%)	139 (76.37%)

A comparison between the number of critical conflicts has been carried out for each site based on these two approaches, and they are presented in Table 6. At the first site S-1, the percentage of critical conflicts is obtained as 32.57% based on PET threshold and 55.42% based on critical speed. Hence, it is observed that thesecond approach exhibits a higher percentage of critical conflicts. A similar trend is observed for another three-legged intersection (S-2). It can be explained by the composition of the conflicting vehicles. From Figure 2, it is observed that at three-legged intersections, the percentage of cars is more followed by the percentage of 2W. Literature reveals that on multi-lane roads cars travel at higher speed in comparison to 2W and other vehicle categories (Rao et al. 2015). Due to the presence of alarger proportion of cars at the first two sites (S-1 and S-2), critical conflicts are observed to be more based on critical speed.

On the other hand, at four-legged intersections (S-3 and S-4), the percentage of 2W is observed to be higher than that of the remaining sites (as evident from Figure 2), which brings down the critical speeds of conflicting vehicles. It results intoa lower proportion of critical conflicts based on the second approach at S-3 and S-4. When critical conflicts are estimated based on PET threshold value, the percentage of critical conflicts is found to be more at these two sites S-3 and S-4 than S-1 and S-2 (three-legged ones). This is because S-3 and S-4 are uncontrolled four-legged intersections and therefore drivers of all four legs have equal opportunity to enter the intersection at the same time, either from the major as well as minor road. This makes the situations critical, and a higher proportion of low PET values are observed than PET threshold.

4. Conclusions

The present study utilizes traffic conflict technique to evaluate the safety performance at uncontrolled intersections. The assessment of safety level has been carried out using two proximal road safety indicators, PET and speed of corresponding conflicting through vehicles. Employing PET as an indicator provides a useful observation about the safety state of the selected study sites. A threshold value of PET has been widely used in many studies to distinguish the conflict as critical and non-critical ones. However, it is unreliable to rely only on a PET threshold in finding the safety level of an intersection where traffic is non-uniform and through vehicles on the major roads move with varying speed. Moreover, PET alone can only assess the probability of collision without assessing its severity. When the speed of the conflicting vehicles increases, the severity of conflict also generally increases. Therefore, along with PET values, the speed of conflicting vehicles is also determined in the present study to reflect the nature of conflicts. Traditional methodology as well as a new one, which is based on PET threshold and corresponding conflicting speed of through moving vehicles on the major road, are utilized to observe critical conflicts at four uncontrolled intersections. These two methods are adopted to represent the level of safety at uncontrolled intersections in terms of probability as well as the severity of resulting collision. For the first method, the threshold is taken as 2.5 sec i.e. reaction time of a driver based on the assumption that below this time driver could not perceive the situation properly, which may be unsafe and lead to a collision.

In the proposed method, another speed parameter termed as critical speed is calculated for a certain PET value based on the concept of braking distance for identifying the critical conflicts. Critical conflicts are observed in which conflicting speeds are found to be more than corresponding critical speeds. Based on PET threshold and critical speed, the percentage of critical conflicts are estimated for all the study sites, and a significant number of critical conflicts are observed. It indicates that drivers of right turning vehicles do accept smaller gaps in the major road while crossing the intersection, which is unsafe. A comparative analysis of critical conflicts shows that percentage of critical conflicts based on the critical speed of through vehicles are more at three-legged intersections. The percentage of cars is also found to be more at these two sites, so the overall conflicting speed of vehicles is found to be higher than other four-legged sites with lower car proportions. As the higher speed of the conflicting vehicles at conflict point reflects higher conflict severities, the severity of resulting collision is more at three-legged intersections. With respect to PET threshold, the percentage of critical conflicts are observed more at four-legged intersections. Hence, the probability of collision is found to be more at these sites. Overall, it is established from the present study that PET values less than the threshold do not always create the critical situations when the speed of conflicting vehicle is low. Similarly, conflict with PET values more than the threshold might be critical when high speed is observed for the conflicting vehicles. So, there is a priori reason to believe that critical conflicts based on PET threshold are misleading if the corresponding speed of conflicting vehicles is not considered. Several past studies have also mentioned that to identify the serious conflict scenario, selection of an appropriate threshold value is a challenging task. It is suggested to use different PET values as a threshold for traffic conflict counts and select the one that produces the best correlation between conflict and crashes (Peesapati et al. 2013; Zheng et al. 2014).

Although it is too early to talk about the efficiency of the new method based on two proximal safety indicators (PET and corresponding conflicting speed of through vehicles) for safety assessment at other traffic facilities, the critical conflicts identified on the basis of traditional PET threshold method do not always reflect the actual critical situations. At the same time, the intersections under study have multilane roads, and vehicles with diverse speed ranges are observed on these roads. It is also well known that speed difference among the different types of vehicles in the traffic stream is the potential cause of traffic crashes. Therefore, identification of critical conflicts based on the proposed methodology which is based on PET along with a speed parameter represents a valid approach to safety evaluation at an uncontrolled intersection. The appropriateness of the proposed methodology can be further verified by comparing critical conflicts observed between right turners and through moving traffic with the crash data of the study sites especially for the right-turn related crashes such as right turn right-angle and right-turn head-on collision. The new methodology will help traffic engineers and safety experts to assess safety at an uncontrolled intersection without any discrepancy and help to implement necessary countermeasures accordingly. The crossing maneuver of the vehicles depends on the static and dynamic characteristics of vehicles. Therefore, the influence of vehicle composition for both right turners and through moving vehicles on traffic conflicts can also be considered for the future research.

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