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Traffic Conflict Analysis of Unsignalised Intersections under Mixed Traffic Conditions

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Abstract

Traffic safety assessment by conflict analysis has been carried out by several researches in the past. Conflict study has its added benefits over the traditional methods of safety assessment which are based on past accident data. Post encroachment time is a popular proximal safety indicator for safety assessment of intersections where critical crossing conflicts are determined using certain threshold value of PET which ranges from 1s to 5s. But assessing conflicts only by PET alone is not appropriate, particularly for intersections under mixed traffic conditions. The speed of conflicting vehicle is also an important parameter for assessing the severity of conflicts. Therefore, in this study, conflicts were observed using two surrogate measures, PET and the corresponding speed of conflicting through vehicle. Considering both the surrogates, the required deceleration rate (RDR) for all the observed conflicts were obtained and critical conflicts were determined using threshold value of RDR as the maximum acceptable deceleration rate. A separate deceleration study was carried out using performance box to obtain the maximum acceptable deceleration rate. Using this proactive approach conflict analysis of three unsignalised intersections under mixed traffic conditions has been carried out. It is found that there are significant percentages of observed conflicts which are critical at all the intersections. Thus safety assessment of such unsignalised intersections may be carried out using the above concept.

Keywords: Conflict; Post Encroachment Time; Required Deceleration Rate; Maximum Acceptable Deceleration Rate; Critical Conflicts;

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1. Introduction

Today road traffic safety is a serious national concern in India, as large number of accidents occurs every year on Indian roads. The exponential growth in vehicular population, without adequate road infrastructure has been mainly responsible for increase in the number of road accidents. More than 50% of all urban road accidents occur at intersections. Increased urban development in many cities has created more intersections where arterial and highways intersect and meet with minor roads and cross streets. Many of these are unsignalised intersections, which are the major threat to the road users. The crossing manoeuvres of right turning vehicles at these intersections are highly complex and risky (traffic rule in India is keep left). Heterogeneous traffic conditions and ineffective traffic control devices have further aggravated the problem. The present study is focused on safety assessment of unsignalised three arm intersections by conflict analysis. Traditional methods of safety assessment based on past accident data has several shortcomings and require longer time period. Whereas safety assessment by conflict study is a proactive method which does not require any accident data and it requires less time as traffic conflicts occur more frequently than accidents. Further micro simulation can also be used for conflict study.

2. Literature Review

Conflict is defined as '*An observable situation in which two or more road users approach each other in time and space to such an extent that there is risk of collision if their movements remain unchanged'* (*Gettman and Head, 2008*). Traffic conflicts have proved to share approximate severity distribution with crashes (*Wang, C. 2012*). Conflict study may be carried out by quantitative measurements in terms of time and space proximity between vehicles using video technique (*Kassim et al.,2014; Hunter and Rodgers, 2012*). There are many proximal safety indicators which are defined as measures of crash proximity, based on temporal and spatial measures that reflect closeness of road-users, in relation to a projected point of collision. Previous research studies have shown that there is good correlation between accident rates and conflicts (*Hunter and Rodgers, 2012; Dikshara, et al., 2010; Ozbay et al., 2007; Caliendo and Guida, 2012*). Researchers have used different surrogate measures to carry traffic conflict study like Time to Collision (TTC), Post Encroachment Time (PET), Deceleration Rate (DR) etc and critical conflicts are determined using certain threshold value of these surrogate measures. Post-Encroachment Time (PET) is a time-based surrogate indicator which is defined as the time lapse from the moment the first vehicle departs a conflict point to the moment the second vehicle approaches that point (*Songchitruksa and Tarko, 2006*). PET has direct association with incident (*Hunter and Rodgers, 2012*) and is the most suitable proximal safety measure for determining crossing conflicts (*Klunder, et al., 2004; Archer, 2005*).

Traffic safety assessment of intersections using PET is carried out where critical conflicts are obtained taking certain threshold value of PET. Conflicts with PET less than 1 sec are generally unsafe (*Archer, 2000; Klunder, et al., 2004*). Many conflict studies have also been carried out using simulation and the simulated conflicts were compared with actual crash data where good correlation between conflicts and crashes have been obtained (*Archer, 2000, Klunder, et al., 2004; Caliendo and Guida, 2012*). The threshold values of PET used by researchers as 1s (*Archer, 2000)* and 5s *(Caliendo* *and Guida, 2012*), where critical conflicts are determined if PET values are less than the threshold value.

Determination of critical conflicts using specified threshold value of PET is appropriate for those highways where traffic is uniform and follows the posted speed but for mixed traffic with varied speeds this approach is not correct. It is observed that conflicts with PET less than threshold PET may not be unsafe if the conflicting speed is less. Similarly conflict with PET more than threshold value may be unsafe if conflicting speed is high. Therefore under mixed traffic conditions PET only is not sufficient to identify critical conflicts. The speed of conflicting vehicle is also necessary to assess the severity of the conflict. Earlier study shows that PET alone cannot assess the safety of angle collisions and the vehicle speed during a crash (crash speed) significantly contributes to the severity of that crash (Alhajyaseen, 2015). Therefore in the present study, conflicts are observed using two surrogate measures, PET and speed of corresponding conflicting through vehicle. Considering both the parameters, the required deceleration rate (RDR) for all the observed conflicts are obtained and critical conflicts are identified taking certain threshold value of RDR. The maximum acceptable deceleration rate is taken as the threshold value of RDR.

3. Study objective and Methodology

3.1 Study objective.

The unsignalised T-junctions along highways and arterials pose major threat to the road users due to complex crossing manoeuvres by the right turning traffic (keep left rule in India). The drivers of right turning vehicles both from major road and from the minor road have to wait at the intersection to find acceptable gaps in opposing through traffic of the major road. On a multilane carriageway, they have to judge and accept gaps in all the opposing through lanes which is a complex and risky task. It is observed that if gap on one lane is adequate but on the other lane it is not adequate, then the drivers of right turning vehicles would not cross the intersection and they continue waiting for next opportunity. They enter the intersection only when they get acceptable gaps in all the opposing through lanes. Further they have to wait longer if the major road traffic is heavy and due to long waiting the drivers may lose patience and then they may accept small gaps which are dangerous and hence unsafe. The objective of this study is to assess safety of crossing manoeuvre of right turning vehicles at unsignalised intersections. Figure 1 shows the crossing conflicts due to right turning vehicles from major road and from minor road with opposite through conflicting vehicles at a typical unsignalised T-junction on a multi lane major road.

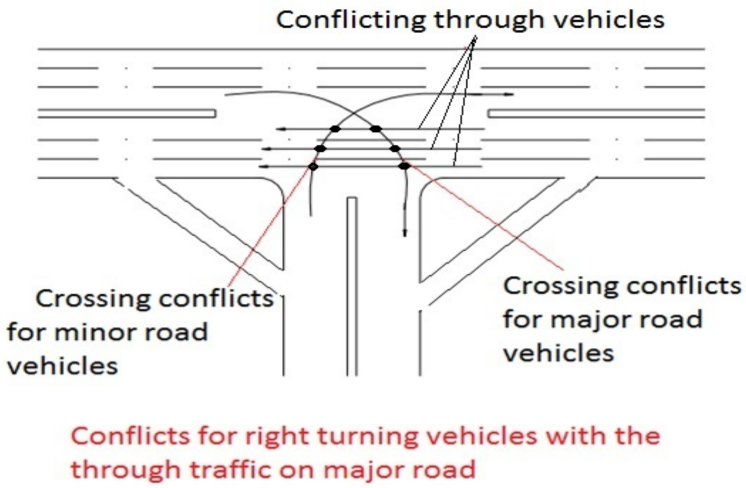

Figure 1: Sketch showing crossing conflicts at a typical unsignalised intersection

3.2 Methodology

The conflict area at the intersection is on the major road adjoining the minor road. Video camera is positioned at sufficient height such that the full view of the conflict area is clearly visible and traffic flow data at the intersection is recorded for about one hour during fair weather. Field measurements covering the conflict area are taken such that the reference points are also visible in the video. In order to track the movement of turning vehicles, the conflict area is divided in grids each measuring 3.5m x 3.5m square taking lane width as 3.5m. Grids are made on AutoCAD using the field measurements and converted into a transparent image and then it is overlaid on the video film using Corel video Studio Pro X6 software.

Conflict data of the intersection is extracted using AVS video editor software by playing the recorded video film at a speed of 25 frames per second which measures time with an accuracy of 0.04s. PET values are obtained by measuring the time difference of offending vehicle (turning vehicle) leaving the conflict grid and the conflicting vehicle (opposite through vehicle) entering the respective conflict grid. The speeds of conflicting vehicles are also determined by noting down the time to traverse the distance over the grids (three to four grids). All conflicts are determined by their PET values and the speeds of corresponding conflicting through vehicles.

On getting acceptable gaps in all the lanes of opposing through traffic, the drivers of right turning vehicles start crossing the intersection. The drivers of the approaching conflicting through vehicles also observe this movement and react accordingly. Few of them may reduce their speeds to facilitate turning vehicle to safely clear the conflict area. But some drivers may approach the conflict area without reducing speed in anticipation that the turning vehicle will clear the intersection before their arrival. This action may be dangerous as there are chances of collision if the turning vehicle does not clear the conflict area due to obvious reasons as the crossing manoeuvre depends on speed and length of turning vehicle. In that case, to avoid collision, the driver of the conflicting through vehicle has to stop the vehicle and if he/she manages to stop the vehicle before reaching the potential conflict grid by decelerating (applying brakes), then it is safe or else it will be a collision. It is observed that drivers prefer braking than to steer in hazardous situation. Moreover it is also dangerous to suddenly change lane on a multilane road.

Every conflict is observed by its PET and the speed of conflicting through vehicle ‘v'. For a conflict when the right turning vehicle just leaves the conflict grid, the conflicting through vehicle is positioned at a time- headway equal to PET or at a distance ‘s’ equal to PET times the conflicting speed (PET x v) from the conflict grid. If the driver of conflicting vehicle manages to stop his/her vehicle by applying brakes within this available distance, the conflict will be a normal conflict or else it will be a critical conflict. In order to stop the vehicle within shorter distance, high deceleration rate is required whereas for longer distance the required deceleration rate is less. Thus required deceleration rate (RDR) ‘d’ to stop the vehicle within the available distance ‘s’ may be calculated as d = v^2/2s where ‘v’ is the conflicting speed and‘s’ is the available distance. Substituting‘s’ by (v x PET), d may be obtained as v/ 2(PET). As the drivers of conflicting vehicles have already reacted to the turning vehicle manoeuvre, the perception distance is not considered.

$$Required\ Deceleration\ Rate \qquad d = \frac{v^2}{2\ s} \qquad \dots (1)$$

Substituting s = v x PET

$$Required\ Deceleration\ Rate \qquad d = \frac{v^2}{2v\ PET} \qquad \dots (2)$$

Thus

$$Required\ Deceleration\ Rate \qquad d = \frac{v}{2\ PET} \qquad \dots (3)$$

For all the observed conflicts the required deceleration rates are calculated and critical conflicts are obtained if the required deceleration rate is more than certain threshold value. The maximum acceptable deceleration which is adopted by most of the drivers is taken as the threshold value of RDR.

3.3 Maximum Acceptable Deceleration

The deceleration rate to stop the vehicle has been studied by several researchers for different types of vehicles in different traffic situations. AASHTO recommends maximum deceleration rate as 3.4 m/s^2 which is comfortable to most of the drivers for stopping vehicles when confronted with an unexpected object on the roadway. *Giuseppe Guido, et al.,* 2013 in their study has considered critical conflicts if Deceleration Rate to Avoid a Crash (*DRAC*) exceeds a threshold value of 3.35m/s^2. In Indian context (Kadiyali 1997), drivers normally prefer to stop vehicles with a deceleration rate 2.62m/s^2 which are comfortable to passengers. The deceleration rate up to 3.39m/s^2 is not alarming to passengers, but drivers normally not use. The deceleration rate of 4.26m/s^2, drivers classify as emergency stop which is severe and uncomfortable to passengers. *Maurya and Bokare (2012)* in their study have observed maximum deceleration rates of different vehicles like truck, car, motorized three-wheelers and motorized two-wheelers as 0.88, 1.71, 1.16, and 1.59 m/s^2 respectively. There is lot of variation in maximum deceleration rates used in various studies. Therefore in the present study, deceleration of vehicles has been studied separately to obtain maximum acceptable deceleration rate.

Deceleration of two types of vehicles, cars and auto rickshaws (Motorised three wheeler) have been obtained using performance box. Performance box (VBOX Mini) is an instrument with a display system and a self-contained GPS data logging facility, which is suitable for a large range of vehicle testing applications. Data such as position and velocity are recorded precisely with the help of a high performance GPS engine with an accuracy of 0.1 km/h. Figure 2 shows photographs of the performance box and performance box mounted in the test vehicle.

Figure 2: Showing Performance Box (Source: Racelogic Ltd, Performance Box Manual.)
And performance box mounted in the test vehicle.

The deceleration data is collected in a controlled manner to ensure that the deceleration behaviour of vehicles is not affected by any external factors other than the driver's desire to decelerate at the given conditions and the capability of the vehicle. A straight road stretch of length about 1.5 km on Eastern express highway near Bhandup East in Mumbai is selected for carrying out deceleration study. The selected road has five lanes with a width of 17m and is free from grade and side encroachment and pedestrian access. It is ensured that the vehicles travel under free flow traffic and there is no obstruction to decelerating vehicles. Before the start of each test run, drivers were explained that the data collected will be used for the research purpose to ensure possible bias in drivers' speed behaviour. The drivers were explained to speed up their vehicles to maximum comfortable speed which they feel safe for the given environment and roadway conditions. After achieving the max speed the drivers were asked to stop the vehicle within minimum possible time maintaining their lane without any danger of skidding. The test vehicles were selected randomly from the vehicles plying on the study stretch of Eastern express highway. GPS data logging performance box (VBOX Mini) was mounted in the test vehicles before the start of the test run to collect the position and speed data of the vehicle at an interval of 0.1 second.

A total of 42 motorized three wheelers (auto rickshaw) and 75 cars were tested for deceleration study and the speed profiles of these vehicles were analyzed. It is found that the deceleration of vehicles depend on the type of vehicle, its initial speed when brakes are applied and the driver characteristics. The speed profiles (speed-time trace) of vehicles have been obtained during deceleration from an initial maximum speed to stop position. Run (trip) reports are generated with the help of V-BOX analysis software. These run reports consist of distance travelled by vehicles (calculated from the position of the vehicle) and speed at 0.1 sec interval. This data is generated in the rep generator window of the analysis software, and this data is exported into excel for further calculations. The speed data is extracted for every 1 second interval and deceleration data is computed. The maximum acceptable deceleration for test vehicles is obtained by performance box as 3.58m/s^2.

In the present study the threshold value for RDR is taken as the maximum acceptable deceleration of 3.58 m/s^2 for identifying critical conflicts. Hence conflicts with RDR more than 3.58 m/s^2 are critical conflicts.

4. Data collection

In the present study conflict analysis of three unsignalised T-junctions namely Chanakya intersection in Vashi, Navi Mumbai, MIDC intersection in Pune, and Samarth intersection in Pune have been carried out.

4.1 Chanakya Intersection, Vashi

Chanakya intersection is a four arm unsignalised intersection on Palm Beach road connecting Belapur to Vashi in Navi Mumbai. The major road is a six lane divided carriageway. The intersection has straight approaches and free from the influence of bus stops, parking etc. The intersection has two minor roads. One minor road is a four lane divided carriageway whereas the other minor road is a single lane carriageway with negligible traffic. Therefore the intersection is practically a T-Junction. Figure 3 shows a snapshot of Chanakya intersection, Vashi. The traffic mainly consists of cars, auto rickshaws and two wheelers and few trucks and buses. The crossing conflicts at the intersection are due to right turning traffic volumes of 130veh/hour from major road and 50veh/hour from the minor road with the opposing through traffic volume of 1500veh/hour on major road. The intersection has crash history with one major crash in the year 2009 and two major crashes in 2010(*Source: Traffic Commissioner of Police, Navi Mumbai*).

Figure 3: Snapshot of Chanakya intersection, Palm Beach Road Vashi.

4.2 Samarth Intersection, Pune

This Intersection is a three arm unsignalised intersection on Pune -Nasik National Highway 50. The NH 50, the major road is a four lane divided carriageway whereas the minor road is a two lane single carriageway connecting Bhosari-Telco road, Pune. The intersection has straight approaches and is free from the influence of bus stops, parking etc. The traffic at the intersection mainly consists of cars, two wheelers, auto rickshaws, trucks and buses. The crossing conflicts at the intersection are due to right turning traffic volumes of 430veh/hour and 180veh/hour from major road and from the minor road respectively with the opposing through traffic volume of 2000veh/hour on major road. The intersection has crash history with one major and two minor crashes in the year 2013 and one major crash in 2014 (*Source: Bhosari Police Station Pune*). Figure 4 shows a snapshot of Samarth Intersection, Pune (*Shekhar Babu and Vedagiri, 2015*).

4.3 MIDC Intersection, Pune

This is a three arm unsignalised intersection on Pune -Nasik National Highway 50. The national highway, the major road is a four lane divided road whereas the minor road is a two lane single carriageway connecting MIDC area of Pimpri –Chinchwad. Traffic at the intersection mainly consists of trucks, buses, cars, two wheelers and auto rickshaws. The intersection has slight curved approach going towards Pune and straight approach towards Nasik. Both the approaches are free from the influence of bus stops, parking etc. The crossing conflicts at the intersection are due to right turning traffic volumes of 200veh/hour and 800veh/hour from major road and from the minor road respectively with the opposing through traffic volume of 2000veh/hour on major road. The intersection has crash history with one major accident in 2013 and one major and two minor accidents in 2012 (*Source: Bhosari Police Station Pune*). Figure 5 shows snapshot of MIDC Intersection, Nasik road Pune.

Figure 4: Snap shot showing Samarth Intersection Pune-Nasik Hwy, Pune

Figure 5: Snapshot showing MIDC Intersection Pune-Nasik Hwy, Pune

5. Results and Discussions

Conflicts are observed by recording PET values and the speeds of their corresponding conflicting through vehicles. The required deceleration rate for every conflict is determined as v/2PET. Conflicts with PET values less than 6s only are considered for the study. Conflicts with PET more than 6s are not considered as for such conflicts the driver of conflicting vehicle has sufficient time to control the vehicle and evasive action if needed can be taken by the driver (*Vogel, 2003*). The conflict data of all the three intersections are shown in table 1.

Table 1 Conflict data of the intersections

Name of Intersection	*No of conflicts observed*	*Range of observed conflicting speed (m/s)*	*Range of RDR obtained (m/s^2)*
Chanakya Int. Vashi	129	3.63 to 23.65	0.45 to 14.97
Samarth Int. Pune	327	3.42 to 20.83	0.47 to 16.37
MIDC Int. Pune	197	3.01 to 16.40	0.50 to 17.85

Table 1 shows that at Chanakya intersection, Vashi 129 conflicts were observed which have conflicting speeds ranging from 3.63m/s to 23.65m/s and RDR ranges from 0.45to 14.97 m/s^2. Similarly 327 conflicts were observed at Samarth Intersection Pune which has speeds ranging from 3.42m/s to 20.83m/s and RDR ranges from 0.475 to 16.37m/s^2. At MIDC intersection Pune, 197 conflicts were observed with conflicting speeds ranging from 3.01m/s to 16.4m/s and required deceleration rate (RDR) ranges from 0.50 to 17.85m/s^2. Threshold value of RDR is taken as 3.58 m/s^2. Conflicts with RDR more than 3.58 m/s^2 are critical conflicts and the conflicts with RDR less than or equal to 3.58 m/s^2 are the normal conflicts. The distribution of conflicts based on RDR for all three intersections are shown in Table 2.

Table 2 Distribution of conflicts based on Required deceleration rate(RDR)

Distribution of conflicts based on (RDR)				
Required Deceleration Rate (RDR)m/s²	*Percent conflicts at*			*Type of conflict*
	Chanakya Int. Vashi	*Samarth Int. Pune*	*MIDC Int. Pune*	
≤3.58	81	75	79	Normal conflicts
> 3.58	19	25	21	Critical conflicts

Table 2 shows that 81%, 75 % and 79% are normal conflicts whereas 19%, 25% and 21% are critical conflicts at Chanakya intersection Vashi, Samarth intersection Pune and MIDC intersection Pune respectively. The results show that at all the intersections the critical conflicts are more than 18% with required deceleration rate more than 3.58m/s^2 where drivers of right turning vehicles take risk in accepting small gaps in through traffic. Further about 25% conflicts are critical at Samarth intersection Pune which is the most risky intersection among the three intersections followed by MIDC intersection Pune which has 21% and Chanakya intersection with about 19% critical conflicts.

4. Summary and Conclusions

Safety assessment of unsignalised intersections using PET as surrogate measure may be useful for the intersections where traffic is uniform and follows posted speed of highways where critical conflicts are determined by certain threshold value of PET. For heterogeneous traffic with varied speeds, this method may not be appropriate. Therefore in the present study, safety assessment of three unsignalised T junctions were carried out by observing conflicts using two surrogate measures, PET and the speed of corresponding conflicting through vehicles. Using both the parameters the required deceleration rate (RDR) for all the observed conflicts are determined as the ratio of speed of conflicting vehicle to twice the PET. To obtain the threshold value of RDR, separate deceleration study was carried out and the acceptable maximum deceleration rate of 3.58m/s2 is achieved which is used as threshold value of RDR. Critical conflicts are obtained if RDR is more than 3.58m/s^2 .

It is found that there are significant percent of observed conflicts which are critical at all the three intersections. This shows that a significant percent of drivers of right turning vehicles accept small gaps in through traffic which are risky. Comparing the critical conflicts it is found that Samarth Intersection Pune is the most unsafe intersection followed by MIDC intersection Pune and Chanakya intersection Vashi. The past crash history also shows that the said intersections are not safe.

Thus this methodology with proactive approach may be useful to identify the unsafe unsignalised intersections on multilane highways and arterials under mixed traffic conditions and further remedial measures may be taken such as provision of rumble strips or raised table or installation of signal etc. Safety evaluation of various unsignalised intersections by observing conflicts using this concept may be carried out by simulation also. The influence of type of through vehicle may be considered for further research as the braking ability of vehicles depends on the type of vehicle.

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