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Conflict Severity Estimation of Uncontrolled Intersections using Surrogate Safety Measures

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Abstract

Accident prediction models are used to analyze accident data and predict the accidents. However, a paradoxical situation arises as accidents are infrequent whereas large accident data is required to construct better models. Therefore, surrogate safety measures (SSMs) are used to explain and predict accidents. As vehicular conflict data is easily available from video-data, the SSMs can be extracted, and conflict severities can be explained. Post encroachment time (PET) is one such SSM preferred by the researchers because of the ease in its extraction. However, PET has a limitation, i.e., same value of PET can be obtained in different situations, thereby different situations are rated as of same severity. Therefore, the first objective is to use stopping distance (SD) to enhance PET to obtain threshold conflicting speeds thereby explaining the severity of conflicts. The second objective is to model an interaction, i.e., given the initial and intermediate stages of an interaction, final stage/result of an interaction should be explained. To achieve this, a multiple linear regression model is developed using surrogates for various stages. The initial stage is the circumstances leading to a conflict represented by Gap Time, whereas the intermediate stage represents the response of the driver represented by Initially Attempted Post-encroachment Time. The final stage/result of interaction is represented by the journey speed during post encroachment phase and PET. Model results supported the hypothesis that the surrogates for the two stages can be used to explain the final stage of interaction as the variables were found to be significant.

Keywords: Surrogate safety measures; Post-encroachment time; Stopping sight distance; Journey Speed; Gap time; Multiple linear regression

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1. Background

Accidents are unfortunate outcomes of coincidence of less probable events. Therefore, their usage to ascertain the accident potential of an intersection or a mid-block is paradoxical, as it requires more accident data to model with higher accuracy. Therefore, researchers are exploring a proactive method using different surrogate safety measures (SSMs) to model the level of safety at the intersections and other critical locations on the road network. The SSMs are obtained by the microscopic observation of interactions between vehicles at the intersection and/or at the midblock section. The initial usage of SSMs can be dated back to the year 1967 by General Motors. Several researchers have been developing new SSMs to indicate the severity of interactions with higher reliability. As numerous SSMs are developed, FHWA according to Gettman et al. (2003) has ranked the SSMs on overall desirability as follows: Gap time (GT), Post Encroachment Time (PET), Deceleration Rate (DR), Initially Attempted Post Encroachment Time (IAPE), and Proportion of Stopping Distance (PSD).

Allen et al. (1978) defined GT as the time difference between the projected arrival of the conflicting vehicle (CV) at the conflict point (CP) and the exit of the crossing vehicle from the CP assuming the CV maintains the approach speed. The GT is defined only for crossing conflicts, whereas time to collision (TTC) is useful for rear-end and lane-changing conflicts along with crossing conflicts. Hayward (1972) defined time measured to collision (TMTC) or TTC as the time remaining for a collision to occur if both the vehicles involved in the conflict move with the same speed and on the same path without any evasive action. Though TTC is the most prominent SSM, its extraction from video data is quite challenging as it is a continuous parameter and involves prediction of the position of vehicles along with the location of the conflict point in the future time-steps. Whereas, the Time to Accident (TA) is a measure like TTC; the difference being that it is a single value parameter measured at the onset of evasive action of one of the vehicles involved in the conflict according to Mahmud et al. (2017). Since the rural roads have higher approach speeds (60 to100 kmph) and the drivers start braking as far-ahead of the intersection as 50 to 110 m, it becomes difficult to capture the braking instance in video graphic surveys and therefore TA and TTC are widely used in simulation studies. GT also has a similar drawback. The approach speed of the conflicting vehicle at the beginning of the encroachment is required to calculate GT, but due to the limitation on capturing the details of vehicles far away from the intersection, it becomes difficult to ascertain the accurate approach speed values. Therefore, PET is the preferred indicator based on the ease of measurement from video graphic surveys according to Peesapati et al. (2013).

PET is defined as the time from the end of the encroachment of crossing vehicle to the time that the conflicting vehicle arrives at the conflict point. The PET values can be easily extracted from video data of an unsignalized intersection compared to other SSMs. Svensson (1998) observed that for a PET value there is no necessity for collision course or evasive action. The author also stated that lower PET values indicate interactions with high severity. Therefore, Thresholds for PET values are utilized to classify the conflicts as severe and non-severe. Peesapati et al. (2013) developed models to correlate the severe conflicts with crashes using different thresholds of PET. Authors observed that the absolute number of PETs of less than 1 second yielded a higher correlation with crashes. Similarly, cumulative distribution function (CDF) plots for conflicts within a threshold of 1 second also showed a higher correlation with crashes. However, there are two major limitations of PET.

(1) The same value of PET can be observed in different situations (Laureshyn et al. (2010) and
(2) Empirical validity of the PET's dependence on the parameters related to the initial and intermediate stages of an interaction.

Laureshyn et al. (2010) identified the first limitation which is common for any time-based indicator in explaining the severity of conflict. Research suggested that the time-based indicators such as TTC and PET be complemented using a speed-related indicator. Proportion of stopping distance (PSD) is a speed related SSM proposed by Allen et al. (1978). PSD is the ratio of the remaining distance (RD) from the potential point of collision to the acceptable minimum stopping distance (MSD). It is calculated at the beginning of encroachment. It does not convey the efficiency of the evasive action taken during the encroachment stage, thereby explaining only the initial stage severity. Therefore, Paul et al. (2018), Babu et al. (2018), used stopping sight distance (SSD) with PET to explain the severity of conflict at the end of encroachment phase. Authors analyzed threshold conflicting speeds based on PETs and SSDs. However, the thresholds calculated from the PET and SSD were either overestimating or underestimating the severities of conflicts. So, the first objective of the paper is to represent the severity of a conflict using threshold speeds.

The second limitation of PET was based on another observation made by Allen et al., (1978) and reiterated by Peesapati et al., (2013) that the PET explains the resulting events in the final stage of a traffic conflict without giving any information of the initial stage or the evasive action taken by the drivers in the intermediate stage. The initial stage is represented by GT and a positive value of GT indicates that the CV is projected to reach after the crossing vehicle left the CP and a negative value indicates that the CV is projected to reach before the crossing vehicle leaves the CP. Absolute values of GT if higher, indicate higher safety and vice-versa. IAPE represents the intermediate stage or the encroachment stage. IAPE is based on the projected arrival of the CV at CP if it follows the initial deceleration rate maintained during the encroachment stage. ET is inversely related to the severity of a conflict. However, a relationship between the representatives of different stages needs to be established and the hypothesis that the PET is dependent on GT, IAPE, ET needs to be proved empirically. The study developed a multiple linear regression equation to explain the dependency of PET on GT, IAPE, ET and post-encroachment journey speed.

2. Methodology

Paul et al. (2018) and Babu et al. (2018), utilized stopping sight distance to complement PET in explaining the severity of a conflict by obtaining threshold conflicting speeds. The threshold speeds obtained were compared with the observed conflicting speeds and conflicts were classified as severe or non-severe. To avoid a collision with the crossing vehicle, the authors stated that the conflicting vehicle needs to stop within the available distance. Therefore, the available distance was considered as SSD and the threshold conflicting speed was found out. However, the authors stated that the lag distance was taken as zero to indicate critical conflicts. Eventually, the available distance was equated to required braking distance rather than SSD. The available distance was calculated as the product of the conflicting speed and PET. Thereby, the equations (1) and (2) provide the formulation for threshold conflicting speeds according to literature.

$$v \times PET = \frac{v^2}{2gf} \tag{1}$$

$$v = PET * 2gf \tag{2}$$

Where 'v' is the conflicting speed in mps,
'PET' is the post-encroachment time in seconds,
'g' is acceleration due to gravity taken as 9.81 m/s^2 and
'f' is the coefficient of friction taken as 0.35.

However, using the product of PET and conflicting velocity, the available distance is overestimated or underestimated as during the course of interaction in the post-encroachment phase, the driver of CV might have decelerated or accelerated yielding the observed PET. That is, for a particular distance, if the driver decelerates heavily and maintains a lower journey speed than the conflicting speed, the PET value increases and therefore the threshold conflicting speed will also increase. Therefore, it can be observed that the effect of the available distance is not fully considered in the model. In the present study, this limitation is addressed by calculating the available distance as the product of the journey speed of the conflicting vehicle in the post-encroachment phase and the PET (equation 3).

$$Available\ distance = Journey\ speed\ of\ CV\ after\ encroachment\ \times PET \tag{3}$$

Further the available distance is equated to the SSD and perception-brake reaction time is considered zero as the conflicting vehicle driver is aware of the crossing vehicle right from the beginning of the encroachment *(9)* (see equation 4). Hence, the conflicting threshold speed can be obtained by equating (3) and (4) and rearraging as in equation (5).

$$Stopping\ Sight\ Distance = \frac{(Conflicting\ Threshold\ veolcity)^2}{2gf} \tag{4}$$

$$Conflicting\ Threshold\ speed = \sqrt{Journey\ speed\ \times PET\ \times 2gf} \tag{5}$$

Where 'PET' is the post-encroachment time, 'g' is acceleration due to gravity and 'f' is the coefficient of friction.

As the driver behaviour varies widely, the journey speeds maintained in the post-encroachment phase differ from driver to driver, thereby achieving different PET values for the same distances. But, the threshold conflicting speeds according to the equation (5) will solely depend upon the distance available. Therefore, the curves indicated in the figure 1, show the threshold speeds for various possible journey speeds and PETs. For convenience in comparison of the existing and current methodologies are addressed as Method 1 and Method 2. To illustrate the variation in methods 1 and 2, a comparative analysis is demonstrated in table 1.

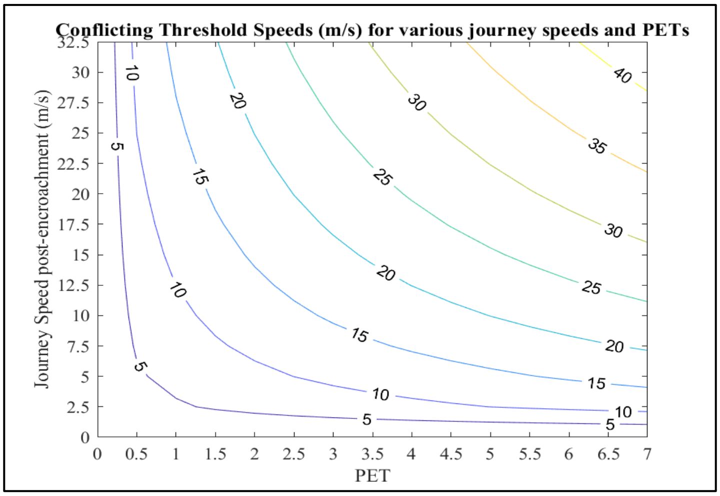


Fig. 1. Conflictng threshold speeds for various journey speeds and PETs

Table 1 Comparative methodology illustration

Intersection	Observed Conflicting speed (m/s)	Distance from CP (m)	Journey speed (m/s)	PET (s)	Threshold speed (m/s)		Severity	
					Method 1	Method 2	Method 1	Method 2
Illustration 1	14	21	9	2.33	16	12	Non-Severe	Severe
Illustration 2	14	21	16	1.31	9	12	Severe	Severe
Illustration 3	20	65	27.89	2.33	16	21	Severe	Non-Severe

Overcoming the limitation of the method 1, method 2 will yield higher thresholds for vehicles located farther from the intersection as required deceleration is attainable over longer distances to safely stop at the intersection.

To achieve the second objective of the paper, statistical methods are used to develop an empirical relationship between the parameters representing various stages of conflict. Multiple linear regression performed better compared to other functional forms. The R^2 and adjusted R^2 values indicates the goodness of fit of the regression and the values obtained for the regression are presented in a further section.

3. Study Area

Four unsignalized intersections are selected on the National Highway – 65 (NH-65) in the state of Telangana, India. The first three intersections selected are near a village 'Sadashivpet' in the state of Telangana. The fourth intersection is near 'Ganesh gadda', 25 km away from Sadashivpet (Figure 2). The intersections were selected such that they serve medium to low traffic, as in such traffic scenarios, PET values can be attributed to the conflicts between two vehicles.

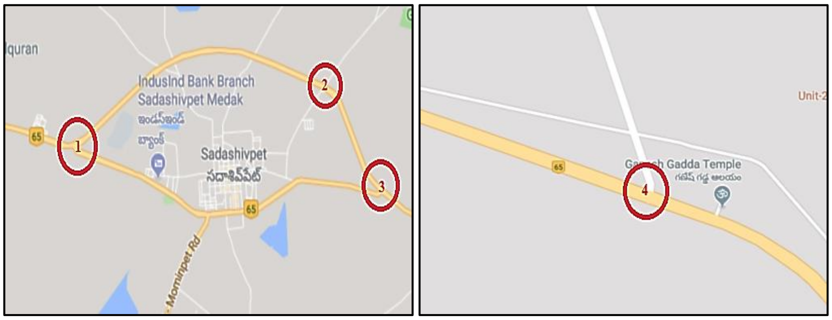


Fig. 2. Locations of intersections on google maps

4. Data Collection

Videographic method of data collection was chosen as it allowed for a re-examination of data. Literature indicates that many researchers preferred videographic data collection. The traffic videos for the current study were obtained by placing the cameras at 16 feet height from the ground level with the aid of tripods. The video data was collected at high definition as manual data extraction was planned (see Figure 3). The video recording period was for 1 hour long or each site. The data was collected on weekdays at peak hours. Apart from the video data, site geometric data such as lane widths, median widths, lengths of road markings, landmark locations were collected. Measuring wheel and tapes were used to collect geometry data.

Fig. 2. Selected Study sites for surrogate safety analysis

5. Data Extraction

Manual data extraction of SSMs from the videos was performed. The data extraction process consisted of noting down the time-stamps at which the crossing and conflicting vehicles reached predefined points. AVS video editor software was used to extract the data. The software supported playing the videos frame-by-frame. The videos were played at 25 frames per second speed yielding each frame at a time-step of 40 milliseconds. To facilitate data extraction, markings were made on the videos (see Figure 4). Apart from SSM data, turning and through traffic volume counts were also extracted from the videos.

Fig. 4. Speed trap markings to facilitate data extraction

6. Data Analysis

Out of 520 interaction data, 308 conflicts were observed from the four intersections having PET values less than 5 seconds according to the definition by Alhajyaseen (2015). The threshold of 5 seconds was chosen based on the approach speeds of the vehicles that varied between 25-90 kmph (see Figure 5). Vehicles travelling with 90 kmph (maximum observed approach speed) will traverse a distance of 125 meters in 5 seconds. As the threshold of 5 seconds will encompass all the interactions affected by the crossing vehicles, it has been chosen to classify conflicting situations from interactions. Normal probability plots for the conflicts were plotted and observed to follow a normal distribution. A sample of intersection-4 normal probability plot is shown in Figure 6.

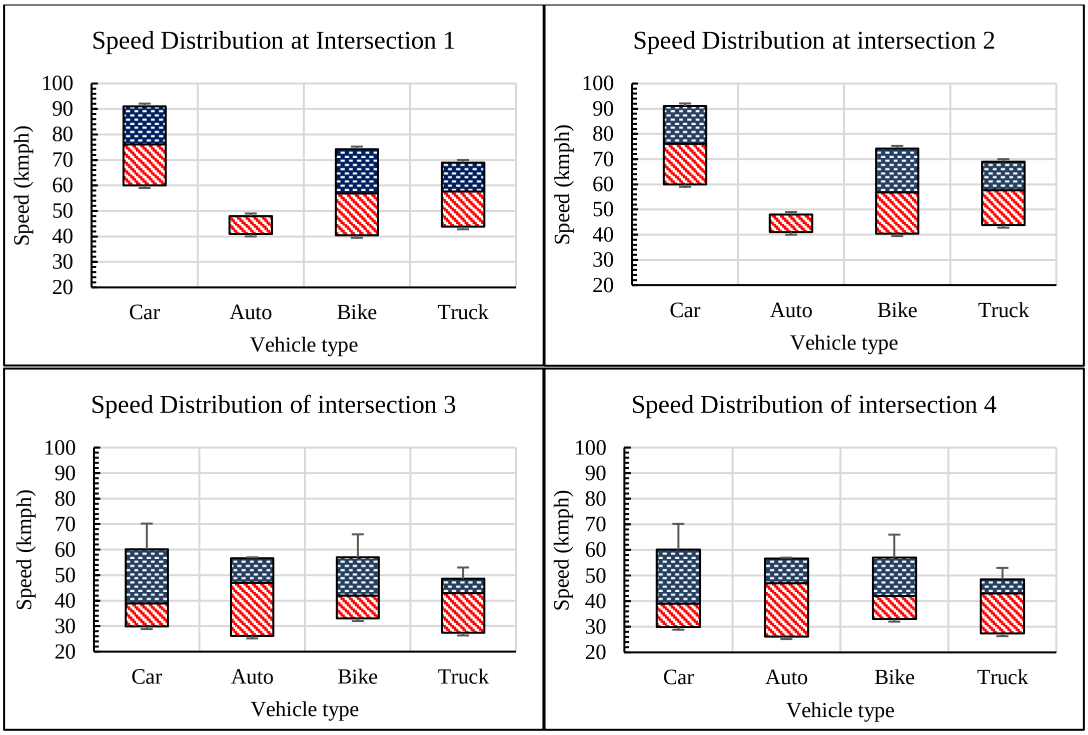


Fig. 5. Speed Distribution of intersections

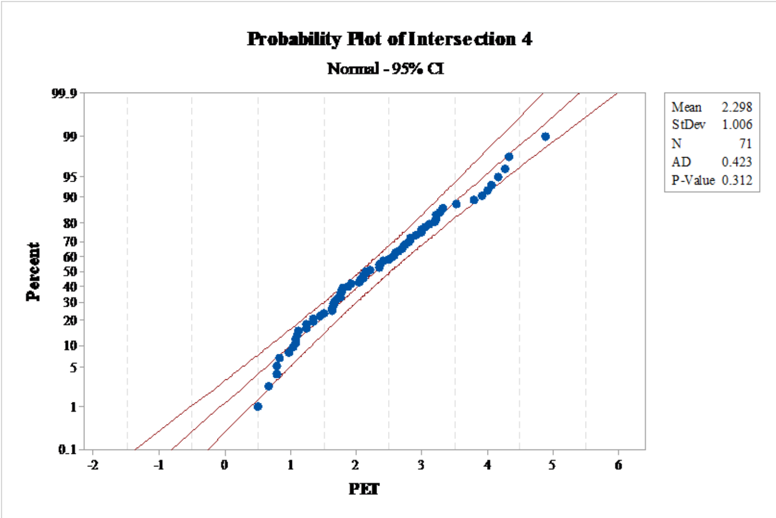
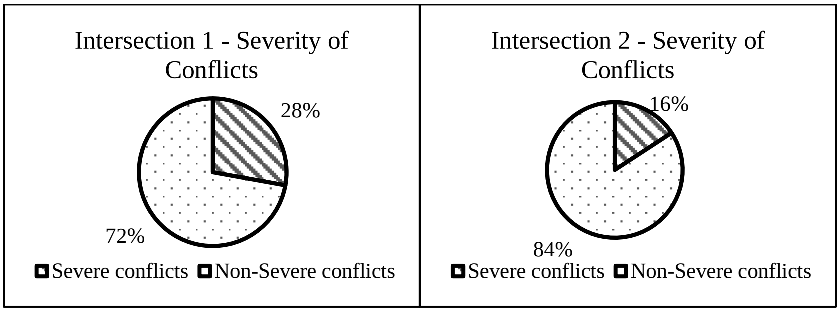


Fig. 6. Normal probability plot of intersection 4 showing normal distribution fit

As the current methodology for grading the conflicts as severe/non-severe cannot be validated with the accident data because of its unavailability, the severe conflicts based on a threshold of 1.5 seconds was used. The threshold of 1.5 seconds was chosen as it was correlating to accident rate in previous studies (Zangenehpour (2016)), and therefore was adapted. Figure 7 shows the severe conflict percentage for all the intersections. Higher percentage of severe conflicts (72%) were observed for intersection 4 using a threshold of 1.5 seconds. It can be attributed to the geometry of the intersection. The first three intersections near Sadashivpet had deceleration lanes for taking right turns on the major road. The fourth intersection, however lying on the same highway (NH-65), does not possess deceleration lanes for the right turning vehicles. Therefore, the major-road right-turning vehicles (left hand traffic rule) were accepting smaller gaps in the opposing through traffic, to prevent queuing up of the through traffic behind them putting themselves at risk of accidents which is reflected in the higher percentage of PET values being less than 1.5 seconds. For the four intersections, mode-wise percentage severe conflicts are given in table 2. It can be observed from the table that the percentage of motorcycles (motorized two wheelers) is the highest compared to other modes as of any other developing country. And it can be observed that motorcycle's share in percentage severe conflicts is the highest in all the four intersections owing to the risk taking behavior of motorcycle riders and easy manuverability compared to cars, HGVs and Autorikshaws (motorized 3 wheelers). The motorcycles (motorized two wheelers) are classified as vulnerable category because of their smaller size and less protection offered by the vehicle during accidents. It can be observed from figure 5 presented earlier that the highest speeds were observed for cars at all the intersections. Therefore, the most dangerous type of interaction of vehicles is when a crossing vehicle is a motorcycle and conflicting vehicle is a car with high conflicting speeds. For the purpose of comparative analysis, the method of obtaining critical/severe conflicts based on 1.5 seconds threshold be called as method 3.



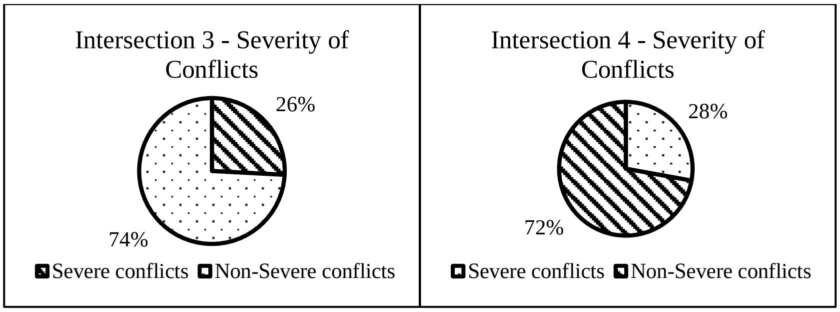


Fig. 7. Percentage of Severe conflicts observed at study intersections

Table 2 Mode-wise conflict statistics

	Intersection 1			Intersection 2			Intersection 3			Intersection 4		
Vehicle type	**<5s**	**<1.5s**	**%**	**<5s**	**<1.5s**	**%**	**<5s**	**<1.5s**	**%**	**<5s**	**<1.5s**	**%**
Autorikshaw (motroized 3 wheeler)	17	5	0.21	6	0	0.00	8	1	0.03	6	1	0.02
Bike	41	13	0.54	29	5	0.83	60	15	0.48	36	29	0.57
HGV	10	4	0.17	1	0	0.00	15	5	0.16	24	19	0.37
Car	11	2	0.08	2	1	0.17	37	10	0.32	5	2	0.04
Total	79	24		38	6		120	31		71	51	

To facilitate comparison of the methods 1 and 2, threshold speeds were calculated based on equations (1) and (2) and the percentage severe conflicts for the four intersections were determined. Table 3 shows the percentage severity calculations of first intersection for reference.

Table 3 Percentage critical conflicts observed for first intersection by method 1

		Conflicting vehicle speed (kmph)							
PET range	**Threshold (kmph)**	**0.0-12.4**	**12.4-24.7**	**24.7-37.1**	**37.1-49.4**	**49.4-61.8**	**61.8-74.2**	**74.2-86.5**	**Critical conflicts (%)**
0.0-0.5	0	0.0	2.5	3.8	1.3	0.0	0.0	0.0	7.6
0.5-1.0	12.4	0.0	2.5	0.0	1.3	1.3	0.0	0.0	5.1
1.0-1.5	24.7	1.3	2.5	2.5	5.1	2.5	1.3	0.0	11.4
1.5-2.0	37.1	0.0	3.8	2.5	2.5	1.3	0	2.5	6.3
2.0-2.5	49.4	0.0	2.5	1.3	3.8	2.5	3.8	0.0	6.3
2.5-3.0	61.8	0.0	0.0	0.0	5.1	5.1	0.0	0.0	0
3.0-3.5	74.2	0.0	1.3	5.1	12.7	0.0	0.0	0.0	0
3.5-4.0	86.5	0.0	0.0	2.5	2.5	1.3	1.3	0.0	0
4.0-4.5	98.9	0.0	0.0	1.3	1.3	1.3	0.0	0.0	0
4.5-5.0	111.2	0.0	1.3	2.5	0.0	1.3	0.0	0.0	0
Total									**36.7**

Using the method 2, the observed conflicting speeds were compared with the threshold speeds, and the conflicts are categorized as severe or non-severe. Some of the conflicts which were under severe category due to overestimation of method 2 were observed as non-severe and vice-versa. Table 4 summarizes the outcomes of methods 1 and 2 along method 3. It can be observed that the methods 1 and 2 yield the percentage-severity closer to that obtained through method 3, the better performed method being method 2. The effective variation along with absolute variation between methods 1 and 2 is given (refer to illustration in table 1 for explanation). The absolute variation shows the error in classifying the conflicts as severe or non-severe in method 1. Therefore, the effective variation should not be taken for identifying the better method. The method 2, however, needs to be validated by correlating it with actual accident data which could be the further scope of this work.

Table 4 Comparison of Existing and Proposed Methodology

Description	Intersection 1	Intersection 2	Intersection 3	Intersection 4
Method 1	36.70	16.84	21.70	63.16
Method 2	34.90	15.12	25.60	68.16
Method 3	27.85	15.78	25.83	71.83
Severe – based on method 2 Non-severe – based on method 1	5	4.2	6.5	7.8
Non-severe – based on method 2 Severe – based on method 1	3.2	2.5	2.6	2.8
Effective variation (%) between methods 1 and 2	1.8	1.7	3.9	5
Absolute variation (%) between methods 1 and 2	8.2	6.7	9.1	10.6

The second objective is to find a relationship between the parameters representative of the stages of conflict. PET, indicative of the resulting severity of conflict was taken as the dependent variable and GT, IAPE, journey speed in the post-encroachment stage were considered as independent variables. Multiple linear regression models various functional forms were developed and compared with the R^2 values and Adjusted R^2 values. Twenty models with various functional forms with an additional variable called encroachment time were tested. However, encroachment time was not significant and hence removed. The linear form performed well as compared to other forms, the results of which are given in table 5.

Table 5 Multiple Linear Regression model output

Variable	Model Output		
	Coefficient	t-stat	p-value
Constant	3.40	5.51	0.00
Gap Time	0.19	4.52	0.00
IAPET	0.41	4.93	0.00
Post-Encroachment Journey Speed	-0.20	-5.35	0.00
R^2	0.77		
R^2_{adj}	0.76		

The positive coefficient of variable "GT" indicates that, as gap time (time difference between the projected arrival of the conflicting vehicle at the conflict point and the actual arrival of the crossing vehicle) increases, PET also increases and vice-versa, implying that the reduction in speed in the post encroachment phase is proportional to the gap time predicted by the driver. The IAPET is positively correlated to the PET with a correlation coefficient of 0.68. That is, in 32 % cases, the drivers either predicted that the IAPE was more, thereby increasing the speed obtained lesser PET or predicted that IAPET was less thereby reducing the speed achieved higher PET values. The PET is inversely proportional to the post encroachment journey speed which was as expected. That is higher the encroachment time, the drivers have accelerated in the post-encroachment phase yielding lesser PET values.

Conclusions

Road safety researchers have been utilizing accident data for ascertaining the probabilities of accidents at intersections and midblock sections. However, relying on accident data is paradoxical because to build better predictive models, large accident data would be necessary. Therefore, surrogate safety measures can be utilized to identify severe conflicts that may lead to accidents. Post encroachment time is one such measure utilized to explain the severity of conflicts. The magnitude of Post encroachment time alone cannot fully explain the severity of conflict so it had to be complemented with another parameter. Stopping distance was used as a speed parameter along with PET to ascertain the severity of conflicts by developing thresholds for conflicting speeds. The governing equation for the determination of threshold speeds is developed by equating the available distance to the stopping distance. The available distance is found out as the product of journey speed in the post-encroachment phase and PET instead of the product of PET and conflicting velocity as in the literature. Thereby, the overestimation or underestimation of the available distance is avoided. The variation in the percentage severe conflicts based on existing literature and current methodology is presented. The second objective was to develop a relationship between SSMs representing the final stage/result of an interaction and the initial and the intermediate leading to the result. Multiple linear regression was used to model the relationship. Variables considered viz, gap time, initially attempted post-encroachment time, and journey speed in the post encroachment phase were found to be statistically significant i.e., the theoretical dependence of PET on the initial stage parameters is empirically validated.

References

Alhajyaseen, W. K. The integration of conflict probability and severity for the safety assessment of intersections. Arabian Journal for Science and Engineering, 40(2), 2015, 421-430.

Allen, B. L., Shin, B. T., & Cooper, P. J. Analysis of traffic conflicts and collisions (No. HS-025 846), 1978.

Bagdadi, O. Estimation of the severity of safety critical events. Accident Analysis & Prevention, 50, 2013, 167-174.

Chandrappa, A. K., Bhattacharyya, K., & Maitra, B. Estimation of post-encroachment time and threshold wait time for pedestrians on a busy urban corridor in a heterogeneous traffic environment: an experience in Kolkata. Asian transport studies, 4(2), 2016, 421-429.

Gettman, D., & Head, L. Surrogate safety measures from traffic simulation models. Transportation Research Record: Journal of the Transportation Research Board, (1840), 2003, 104-115.

Fambro, D., Koppa, R., Picha, D., & Fitzpatrick, K. Driver perception-brake response in stopping sight distance situations. Transportation Research Record: Journal of the Transportation Research Board, (1628), 1998, 1-7.

Hayward, J. C. Near miss determination through use of a scale of danger, 1972.

Laureshyn, A., Svensson, Å., & Hydén, C. Evaluation of traffic safety, based on micro-level behavioural data: Theoretical framework and first implementation. Accident Analysis & Prevention, 42(6), 2010. 1637-1646.

Mahmud, S. S., Ferreira, L., Hoque, M. S., & Tavassoli, A. Application of proximal surrogate indicators for safety evaluation: A review of recent developments and research needs. IATSS research, 2017.

Paul, M., & Ghosh, I. Speed-Based Proximal Indicator for Right-Turn Crashes at Unsignalized Intersections in India. Journal of Transportation Engineering, Part A: Systems, 144(6), 2018, 04018024.

Peesapati, L. N., Hunter, M. P., & Rodgers, M. O. Evaluation of post-encroachment time as surrogate for opposing left-turn crashes. Transportation research record, 2386(1), 2013, 42-51.

Shekhar Babu, S., & Vedagiri, P. Proactive safety evaluation of a multilane unsignalized intersection using surrogate measures. Transportation letters, 10(2), 2018. 104-112.

Svensson, A. A method for analysing the traffic process in a safety perspective. Lund Institute of Technology, 1998.

St-Aubin, P., Miranda-Moreno, L., & Saunier, N. An automated surrogate safety analysis at protected highway ramps using cross-sectional and before–after video data. Transportation Research Part C: Emerging Technologies, 36, 2013, 284-295.

Zangenehpour, S., Strauss, J., Miranda-Moreno, L. F., & Saunier, N. Are signalized intersections with cycle tracks safer? A case–control study based on automated surrogate safety analysis using video data. Accident Analysis & Prevention, 86, 2016, 161-172.