Journal of Traffic and Transportation Engineering 5 (2017) 228-235
doi: 10.17265/2328-2142/2017.04.004

Traffic Conflict Technique Development for Traffic Safety Evaluation under Mixed Traffic Conditions of Developing Countries

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Abstract: In developing countries, the numbers of traffic accidents, injuries and fatalities are very high and tend to increase at signalized intersections. For example, in Ho Chi Minh City (HCMC) of Vietnam, the number of accidents at signalized intersections accounted for 45% of the total accidents at all the intersections. This fact leads to strong necessity for analyzing traffic safety at signalized intersections. Nevertheless, the historical accident data in HCMC is not available for deep analysis, this study uses video cameras to capture and analyze conflicts that potentially lead to accidents using TCT (traffic conflict technique). Conflict severity identification is one of the most significant steps to evaluate traffic safety at signalized intersections using TCT. Six zones (serious conflict, common conflict, non-conflict, highest potential serious conflict, potential serious conflict, and potential common conflict) are explored in this study to clarify conflict severity. This result is based on being the cut off value between serious conflicts and common conflicts, according to 85% cumulative frequency of TTC (time to collision) and CS (conflict speed) under 3,050 samples size which were observed at 10 signalized intersections during August-November, 2014. Such a deep understanding is a scientific basis to study how to apply TCT to evaluate traffic safety at signalized intersections under mixed traffic conditions.

Key words: Traffic conflict technique, traffic safety, signalized intersections, traffic conflict severity, mixed traffic condition.

1. Introduction

According to Antonucci et al. [1], nearly 25% of the total fatal crashes occur at all the intersections, and about 30% of those are at signalized intersections. In 2003, ADB (Asian Development Bank) has carried out the study regarding accident cost for developing countries in Asia; in this report, the cost of accident in Vietnam accounted for 2.45% GDP (gross domestic product)/year. Hence, traffic accidents have been not only affecting on individual but also influencing on society. In Vietnam in 2014, the number of fatalities, injuries have been slightly decreased accounted for 9,000 (fatalities); and 25,000 (injuries), while in HCMC, these rates were 725, and 4,074, respectively. Although, this showed that in comparison with 2013, the numbers of fatalities, and injuries in HCMC in 2014 have slightly decreased (8.1%, 16.3%), respectively, these are still really high at signalized intersections in HCMC accounted for 45% (56 accidents) of the total accident occurrence at all the intersections (125 accidents). This fact leads to strong necessity for analyzing traffic safety at signalized intersections. Hence, there have been a lot of previous researches on traffic safety at signalized intersections. Unfortunately, most of them have just focused on traffic safety at signalized intersections with main-stream vehicles. Until now, there is lack of empirical research about traffic safety at signalized intersections under mix traffic in MDCs (motorcycle-dependent cities), like Ho Chi Minh City (Vietnam), where more than 90% people use motorcycle as major mean of transport.

The objective of this study is to develop traffic conflict technique for traffic safety analysis at signalized intersections. Especially, how to determine

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traffic conflict severity, which is the most important step of traffic conflict technique based on time to collision and conflict speed value.

The objective is addressed through several steps, including literature review, examining the current traffic situation, field survey and analysis, determining TTC (time to collision) and CS (conflict speed) value for all conflicts at signalized intersections under mixed traffic conditions, and proposing six conflict severity zones. HCMC, Vietnam is selected for an empirical study. Because historical accident data in the city is not available for deep analysis; this study uses video cameras to capture and analyze conflicts that potentially lead to accidents. TCT is developed for the context of mixed traffics with motorcycle dominance to help the analysis. The results of this study are based on being the cut off value between serious conflicts and common conflicts, according to 85% cumulative frequency of TTC and CS under 3,050 samples size, which were observed at 10 signalized intersections during August-November, 2014 to distinguish traffic conflict severity zones under mixed traffic conditions. Such a deep understanding is a scientific basis to study how to apply TCT to evaluate traffic safety at signalized intersections under mixed traffic conditions.

This paper is divided into five parts; following the introduction is the literature review. Data collection and analysis, results are the third and fourth parts, respectively, and the last part is discussions.

2. Literature Review

Many road traffic accidents occur at intersections because there are huge traffic conflicts between vehicles. Especially, at signalized intersections where there have been a lot of crashes occurrence and accounted for high rate of the total traffic accident at intersections, even though these nodes are considerably safer compared with the others in terms of theory. Thus, many researchers have focused on this approach aiming at improving this situation both for developed and developing cities. It is obvious that traffic safety analysis and evaluation at signalized intersections are quite necessary at the moment. Until recently, to analyze and evaluate traffic safety at intersections has been classified into two categories as follows:

(1) Direct analysis and evaluation, which use historical accident data. It is infeasible to apply this method for analyzing traffic safety where the historical accident data is unavailable like HCMC;

(2) Indirect analysis and evaluation, which is mainly focused on using the traffic conflict technique. This technique can be used as good surrogate method when the historical accident data is not available to analyze and evaluate traffic safety as well. Since, lack of the historical traffic accident data, traffic conflict technique can be applicable in HCMC to assess traffic safety performance at signalized intersections.

Traffic conflict technique was initially developed by Christer Hydén at the Lund University, Sweden in terms of definitions and procedures for observing traffic conflicts at intersections. The patterns of traffic conflict corresponding with accident types were explored by Perkins and Harris (1968). Spicer (1971) stated that serious conflict are defined by road-users' action to resolve a conflict situation and involves making a sudden rapid deceleration, and/or lane change. Further study by Spicer (1972, 1973) has also determined the strong positive correlation between serious conflict and frequency of accident at difference junctions using traffic conflict technique. Based on speed from comparing the report of accident involving injury with observed serious conflicts at 50 intersections, Hydén (1975) examined a correlation between conflicts and these accidents.

One of the most important issue in traffic conflict technique is to observe and assess traffic conflict severity. Hence, there are a lot of researchers who have carried out many studies in different approaches, in various countries. Glauz (1980) carried out research in terms of conflicts concerning providing standards definitions, data collection procedures, and the application of this technique to estimate the number of accident at an intersection. In 1985, Migletz indicated that traffic conflict technique can be used to predict traffic accident based on traffic conflicts. Archer [2] demonstrated to apply this technique for assessment and prediction of traffic safety indicators. In 2008, Wu et al. [3] indicated that conflict severity concept can be used to evaluate traffic safety of highway intersection.

Traffic conflict is "an observable situation in which two or more road users approach each other in space and time for such an extent that there is a risk of collision if their movement remain unchanged" (Amundson and Hyden, 1977).

In summary, most of the previous studies show that traffic conflict data can be determined by using TCT and predicting traffic accident. It is obvious that TCT is one of the techniques, which were used in many earlier study to evaluate traffic safety with car dominance. Nevertheless, there was few researches focused on whether TCT can be applied in mixed traffic conditions or not in spite of many difference in terms of the patterns of traffic accident, characteristic of traffic flow, and behavior of road-user in comparison with car dominance. Hence, in this study, traffic conflict techniques are developed to analyze traffic safety at signalized intersections under mixed traffic conditions. Especially, how to determine traffic conflict severity under mixed traffic conditions, which is a significant issue of traffic conflict technique.

3. Method

3.1 Overview of HCMC

HCMC is one of the biggest economic center of Vietnam which contributes one third of the total GDP, and holds 25% production capacity of the country with land use accounted for 2,093.7 km^2, in particular, the urban area occupies 10% of total land, being divided into three zones. City centre (Zone 1) includes 13 urban districts—1, 3, 4, 5, 6, 8, 10, 11, Go Vap, Tan Binh, Tan Phu, Binh Thanh, and PhuNhuan. Being the centre area of the whole city, there are many high rise buildings, shopping malls, big schools, major hospitals, etc., concentrated in this area. Newly developed areas (Zone 2) include 6 newly developed districts—2, 7, 9, 12, Binh Tan, and Thu Duc. Those districts were mostly established from rural districts in 1997. Urbanization rate in those districts is quite high as compared to the others. Located in places nearby the city centre, these districts have received huge investment in recent years to develop new residential areas. Besides, investments in infrastructure system have also been provided to support urban development. Rural areas (Zone 3) include 5 rural districts—Hoc Mon, Nha Be, Can Gio, Cu Chi and Binh Chanh. They are remote districts with low population density. Infrastructure systems in this area are still poor due to limited investment (Fig. 1).

Table 1 showed clearly that there have been distinguish between three zones in term of demographic conditions, social-economic conditions, and infrastructure conditions.

3.2 Data collection and Analysis

Since the historical accident data in HCMC is not available for analysis in detail, this research has been carried out based on traffic conflict data, which has been observed at 10 signalized intersections using video camera during August-November, 2014. According to Vuong [4], most of the traffic accidents occur at signalized intersections at off-peak hour, accounted for 63% (Zone 1), 54% (Zone 2), and 38% (Zone 3). Thus, this study just focuses on surveying of three period times in a day (9:00-10:30; 14:00-15:30; 21:30-23:00).

Hero 3+ black and Sony HD cameras with features video resolutions up to 4K (1080), 12MP (12MP) photos up to 30 (25) frames per second, respectively, are the main equipments which are used to survey.

The difficulties in the traffic conflict technique are how to determine traffic conflict severity. Based on many researches, which are carried out in different countries, time to collision is the most appropriate to

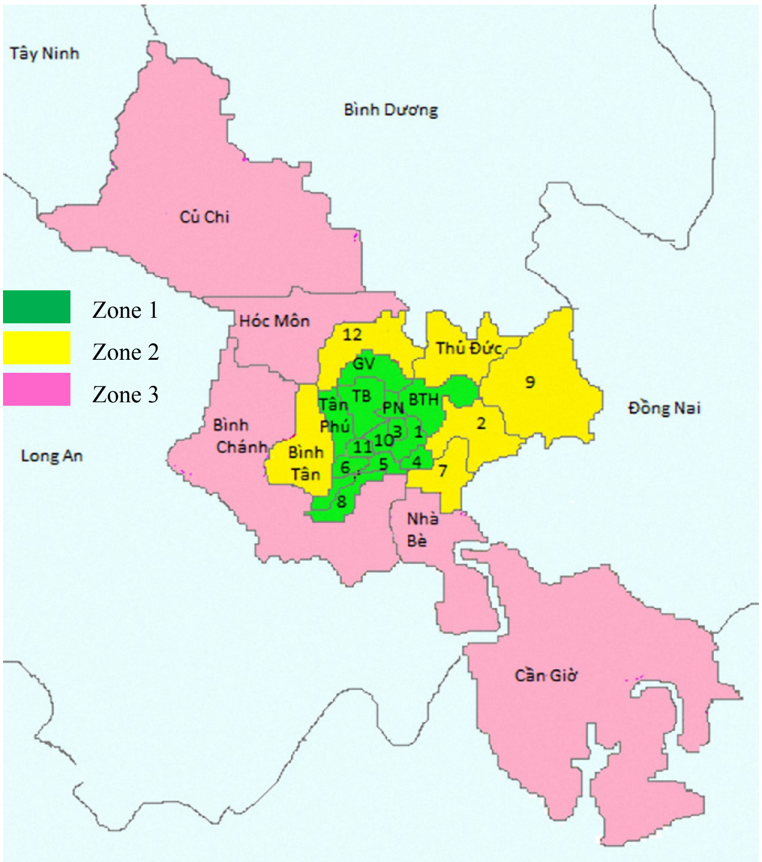

Fig. 1 Classification zone in HCMC.

Table 1 Classification criteria for three zones.

No.	Items	Zone 1	Zone 2	Zone 3
1	***Population (million)***	3.90	2.16	1.34
2	***Area (km2)***	142.00	352.00	1602.00
3	***Road area (km2)***	8.18	8.48	14.83
4	***Road length (km)***	853.47	1017.47	2589.24
5	***Main road length (B≥7m)(km)***	592.42	542.71	300.60
6	***Main road area (B≥7m)(Km2)***	6.70	6.12	3.31
7	***Road area/ area (%)***	6%	2%	1%
8	***Road width (B)***			
8.1	*- B < 7m (%)*	16.65	23.28	60.06
8.2	*- 7m ≤ B < 10m (%)*	54.70	34.49	10.81
8.3	*- 10m ≤ B < 12m (%)*	61.50	22.07	16.43
8.4	*- B ≥ 12m (%)*	56.89	29.68	13.43
9	***Type of road***			
9.1	*- Urban road (%)*	49.92%	44.52%	5.56%
9.2	*- National highway (%)*	0.00%	26.12%	73.88%
9.3	*- Provincal road (%)*	0.00%	0.00%	100%
9.4	*- District road (%)*	0.00%	0.00%	100%
9.5	*- Ward road (%)*	0.00%	0.00%	100%
9.6	*- Other(%)*	0.00%	96.96%	3.04%
10	***Signalized intersection***	479	159	104

Source: DOT (Departmenf ot Transportation) in HCMC, 2014.

clarify traffic conflict severity. Moreover, in this study, conflict speed is a also significant indicator to clarify conflict severity. The conflicts were determined conflict severity (common, serious) by observer's subjective judgments using signal to clarify conflict severity in Table 2 and post-production video as well. TTC and CS of each type of conflict class (common, serious) are processed to determine the cut off value between them for each indicator (TTC and CS) using method based on mathematical and statistical theory. The cut off value of each indicator is the significant value to distinguish conflicts severity.

TTC and CS values were determined for each conflict severity (common, serious) based on the processing framework for determination of TTC and CS values (Fig. 2), processing conflict simulation (Fig. 3), and speed estimation by Video Data (SEV) tool (Fig. 4), which was developed by Dr. Chu.

TTC equals the ratio of conflict distance and conflict speed (Eqs. (1) and (2)).

Conflict distance is the distance between potential collision location and the vehicle taking prior evasive actions denoting braking, weaving or deceleration. While conflict speed denotes the original speed of vehicle taking prior evasive actions:

$$TTC = S/CS \quad (1)$$

$$S = \sqrt{(x_3 - x_2)^2 + (y_3 - y_2)^2} \quad (2)$$

where, x_2, y_2, x_3, and y_3 are the location of Points D2 and D3 in Fig. 3, respectively.

Table 2 Signal to clarify conflict severity.

Conflict severity	Level	Description
Common (Slight)	1	Applied the brake or direction change to avoid collision but with ample time for manoeuvre or steady deceleration
Serious	2	Applied the brake or direction change to avoid collision with less time for manoeuvre than level 1 or requiring more complex actions
	3	Rapid deceleration or rapid acceleration, direction change or stopping to avoid collision resulting in a near-miss situation
	4	Emergency braking or violent swerve to avoid collision resulting in a very near-miss situation

Source: Baguley, et al., 1982.

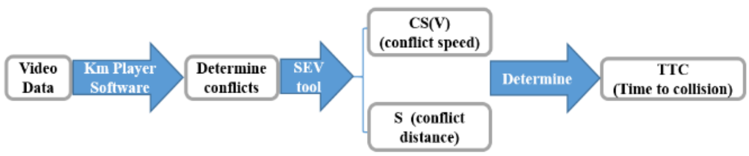

Fig. 2 Processing for determination of TTC and CS values.

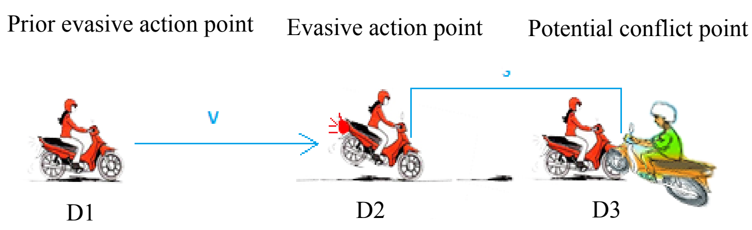

Fig. 3 Conflict processing simulation.

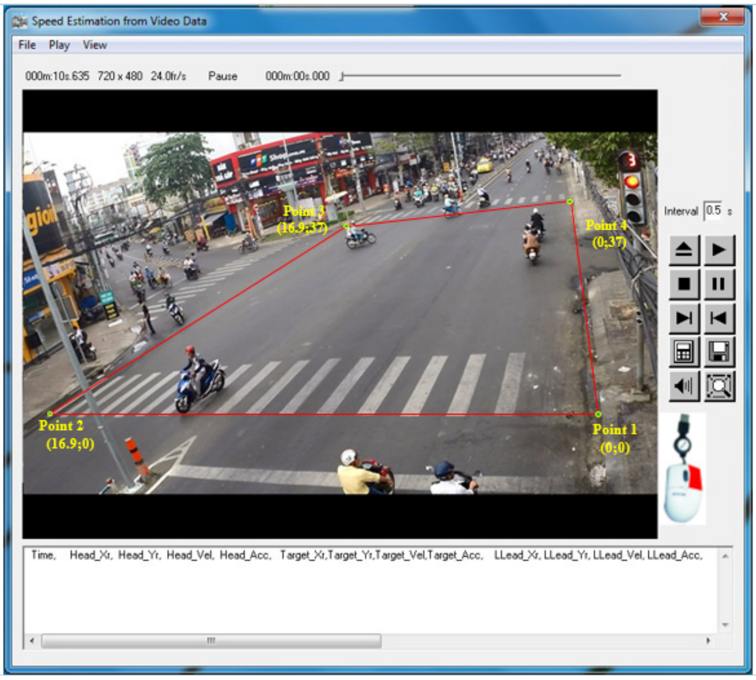

Fig. 4 SEV tool and video post-production.

Using this method, CS and TTC values of each conflict severity (common, serious) can be calculated based on video observation. TTC and CS values are divided into groups, respectively, to determine frequency and cumulative frequency. TTC and CS values for 85% cumulative frequency are selected as the maximum value of common and serious conflicts.

4. Results

The results analysis showed that there are 2,040 common conflicts and 1,010 serious conflicts of the total 3,050 traffic conflicts. TTC and CS value for 85% cumulative frequency corresponding to conflict severity (common, serious) as follows:

TTC and CS values of common conflicts are determined lying in the range of 0.1-1.9 s; 2.0-16 m/s in which the maximum values of TTC and CS for 85% cumulative frequency are 1.108 s; 9.086 m/s, respectively (Figs. 5 and 6).

While TTC and CS values of serious conflicts are determined lying in the range of 0-1.5 s; 11.82 m/s, respectively, in which the maximum values of TTC and CS for 85% cumulative frequency are 0.822 s; 11.82 m/s, respectively (Figs. 7 and 8).

Then, all of the conflicts were distributed on graph to clarify conflict severity (non-serious, serious) which are developed by Hyden (Fig. 9).

It is easy to recognize that most of conflicts (common, serious) are located on the left hand side of the curve on the graph. This illustrated that the results do not reflect real situation in the right way. It is obvious that this graph can not be applied to distinguish conflict severity (common, serious) under mixed traffic. Hence, TTC and CS values are used to determine conflict severity under mixed traffic (Fig. 10).

Based on the graph above, traffic conflict severity is categorized into six levels as follows:

(1) Zone 1: serious conflict ($CS \geq 11.82$ m/s; $TTC \leq 0.882$ s);

(2) Zone 2: common conflict (9.086 m/s $\leq CS <$ 11.82 m/s; 0.822 s $< TTC \leq$ 1.108 s);

(3) Zone 3: Non-conflict ($CS <$ 0.086 m/s; $TTC >$ 1.108 s);

(4) Zones 4 and 7: highest potential serious conflict (9.086 $< CS <$ 11.82 m/s; $TTC <$ 0.882 s);

(5) Zones 5 and 8: potential serious conflict ($CS <$ 9.086 m/s, $TTC <$ 0.882 s and $CS >$ 11.82 m/s, $TTC >$ 1.108 s);

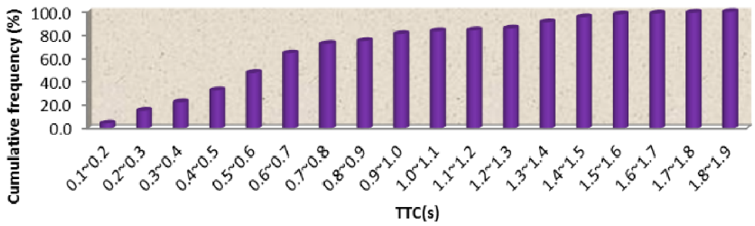

Fig. 5 **Cumulative frequency of *TTC* for common conflict.**

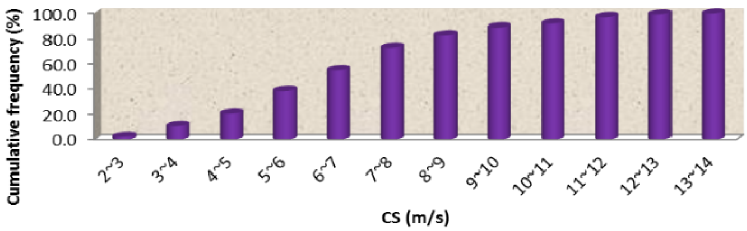

Fig. 6 **Cumulative frequency of *CS* for common conflict.**

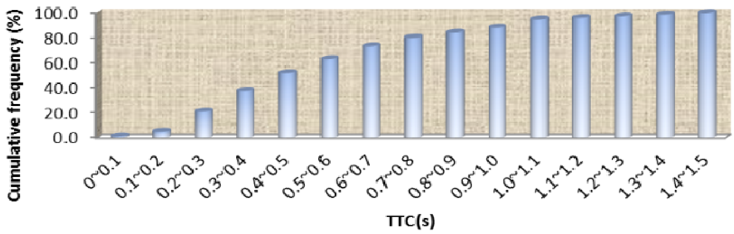

Fig. 7 **Cumulative frequency of *TTC* for serious conflict.**

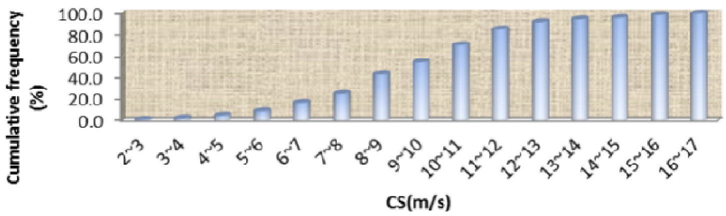

Fig. 8 **Cumulative frequency of *CS* for serious conflict.**

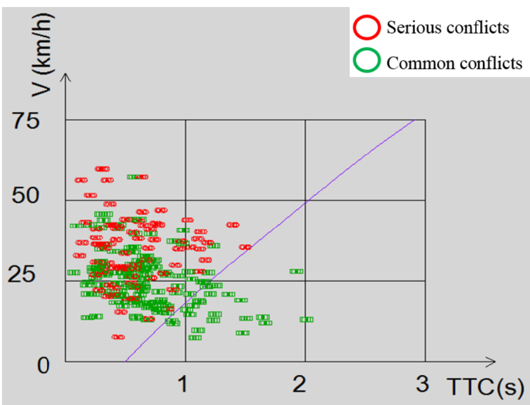

Fig. 9 **Conflict distribution by conflict severity.**

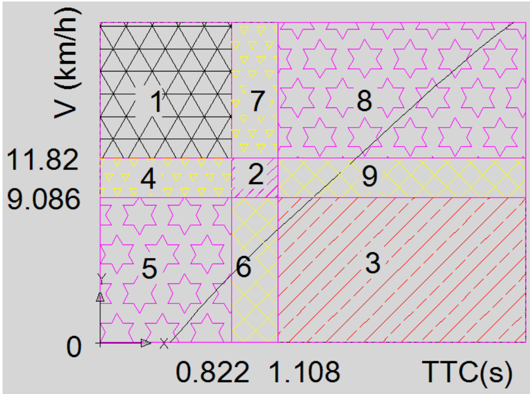

Fig. 10 Clarification conflict severity.

(6) Zones 6 and 9: potential common conflict (0.822 s < *TTC* < 1.108 s, *CS* < 9.086 m/s; 9.086 s < *TTC* < 11.82 s, *CS* > 1.108 m/s).

5. Conclusions

This study indicates that we cannot apply the clarification conflict severity graph under mixed traffic conditions.

This study also points that TTC and CS are two significant indicators to determine traffic conflict severity. Serious conflict, common conflict, non-conflict, highest poteintial serious conflict, poteintial serious conflict, and poteintial common conflict are six zones to distinguish traffic conflict severity under mixed traffic conditions.

The result of this research is also initial meaningful science basic for the next study regarding whether TCT can be applied to analyze traffic safety performance at signalized intersections under mixed traffic conditions.

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