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TRAFFIC CONFLICT ANALYSIS AS A ROAD SAFETY DIAGNOSTIC TOOL FOR URBAN ROAD FACILITIES

Greece Maria Lawalata[1*], Heddy R. Agah[2]

[1]Road and Bridge Development Research Center, Bandung, Indonesia
[2]Faculty of Engineering, Universitas Indonesia, Indonesia

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ABSTRACT
Urban road improvement programs, such as geometric intersection improvement or recalculation of cycle time for traffic lights, should include road safety and accessibility considerations. These components could be evaluated in a short time without waiting for accident data from police departments or accident events by using a tool known as a traffic conflict study. With a traffic conflict analysis, the effectiveness of any road improvement could be evaluated, and any traffic event involving two or more vehicles, or single vehicles taking evasive action to avoid crashes, could be investigated. Traffic conflict studies have been used in many countries, but less extensively for analyzing road improvement projects. This paper describes traffic conflict studies which have been applied at intersections in Bandung, resulting in a new Special Stopping Space (SSS) for motorcycles at a major intersection, intersection design improvements, and traffic management improvements at intersections. This research shows the applicability of the traffic conflict study technique to road facility improvement projects in Indonesia.

Keywords: Intersection; Road facility; Road safety; Traffic conflict; Vehicle maneuver

1. INTRODUCTION
Improvement of road networks in urban areas has become routine to provide better and safer roads. Projects include link or road segment surface maintenance, recalculation of traffic light cycle times as part of traffic management, or even realignment. In order to develop comprehensive traffic safety strategy measures including the application of those projects, it is important to evaluate objectively the risk of traffic accidents. However, it is difficult to statistically evaluate the effects of road network improvement programs on traffic safety measures in terms of the variation in number of traffic accidents in a studied section, because the traffic accident itself is an infrequent type of event.

This study applies a kind of traffic conflict analysis as a tool to achieve the objective of evaluating the effect of road improvements on traffic safety; the technique identifies near-accidents or potential conflicts. This tool can be used as a method for identifying, observing, studying and evaluating potential accident locations without necessarily waiting for an accident history to evolve. Evaluation is undertaken without waiting for accidents to occur or for traffic accident data to be collected from the police.

[*] Corresponding author's email: grey_ml@yahoo.com, Tel: +62-22-7802251, Fax: +62-22-7802726

Traffic conflict studies are carried out by manual observation and recording techniques in the field. It originates with manual observation onsite, and includes the additional component of automatic observation in laboratory. An observer is assigned to subjectively judge the potential movement of traffic leading to an accident occurrence; costs to evaluate and collect information from other related surveys are relatively high. With the help of automatic observation using a video camera, the work is much easier. This study has been used extensively in many countries and is effective n reducing traffic accidents (Wakabayashi & Renge, 2003; Uno et al., 2002; Gettman & Head, 2003).

Considering the total length of both provincial and national roads in Indonesia, it is important to guarantee safer roads by indentifying potential accidents.. Traffic conflict analysis is one of the tools for the evaluation of traffic movement leading to vehicle crashes and traffic accidents. However, some requirements of the technique need to be assessed in order to make certain that traffic conflict analysis works properly. This paper discusses some experiences in the implementation of the model on certain streets and reviews the use of it in Bandung and Denpasar, Indonesia.

2. METHODOLOGY

A review of traffic conflict methodology, analysis, and results follows, with descriptions of experiences using conflict analysis in Bandung and Denpasar, Indonesia.

2.1. Literature review

Research on traffic conflict analysis has been developed and used in many countries in order to prevent accidents. Some related procedures are currently in practice by UK's Transport and Road Research Laboratory (TRRL) and General Motors, and by use of Space-time Trajectories. (Gettman & Head, 2002). Brief descriptions for each of these traffic conflict studies follows.

- **TRRL Version**: TRRL defines a traffic conflict 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 (Glennon et al., 1977; Idris, 2009). Conflict is described based on severity, which is influenced by four factors: starting time of evasive action before commencing possible collision, seriousness of evasive action to avoid collision; type of evasive action which may require further action; and proximity or distance between vehicles involved/instant evasive action terminated (Wakabayashi & Renge, 2003). See Table 1.

Table 1 Conflict severity assessment

Time to Collision		Long		Moderate				Short			
Severity of Evasive Action		L	M	L	M		H	M		H	E
Complexity of Evasive Action		S/C	S/C	S	C	S/C	S/C	S	C	S/C	S/C
Proximity of Conflicting Vehicles	>2 car lengths	1	1	1	1	1	2	1	1	2	3
	1 to 2 car lengths	1	2	1	2	2	3	2	3	3	3
	<1 car lengths	2	3	2	3	3	3	3	3	4	4
	Light collision	3	4	3	3	4	4	4	4	4	4
	Heavy collision	5	5	5	5	5	5	5	5	5	5

Source: Baguley (1984); L=low, M=medium, H=high, E=emergency, S=simple, C=complex

- **Time Classification**: Estimated timebegins with the ction to avoid collision, as indicated by the first observer during the field observation. A short period is 1 second from the beginning to the last action to avoid collision; a medium period is 1.0-2.5 seconds from the beginning of action until the evasive action is complete; and a long period is 2.5 seconds from the first evasive action until its conclusion. ***Seriousness of evasive action*** includes: light breakage on red light or evasive (R) speed deccelaration; medium breakage or evasive (M) sudden deccelaration so that a lamp or sign is overtaken and front vehicle side *moves down*; heavy breakage and/or evasive (B) uncontrolled action, characterized by front vehicle *slide down* with sudden stop and sound from breaking action; and finally, emergency braking and/or evasive braking, which wheel locked but vehicle keep moving. **Evasive action** can be simple (S) as avoidance with either breaking or turning movement; or complex (K) action to escape with two or more actions that include breaking action and a twisted vehicle (Baguley, 1984). ***Proximity distance*** is described by: (a) gap between vehicles of more than two vehicles (>2); (b) gap between two vehicles measures one to two vehicle lengths (2); (c) gap between vehicles is one vehicle length or less; (d) light collision with minor damaged vehicle parts; and (e) heavy collision indicated by major damaged vehicle parts. The first three definitions are attributed to C. J. Baguley (1984), while the last two are proposed in this research.
- **General Motors Version**: General Motors defines “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.” Classification of conflict based on severity and time to collision is used, and reference time is less than 1.5 minutes or more than 1.5 minutes (Legowo, 1990). The observer should be well trained and observed subjectively.
- **Space-Time Trajectories Version**: Procedures of analysis are development of vehicle space-time trajectories collected from video recordings, and assessment of trajectories to identify conflict and rate of seriousness. Proposed measures to use are (Legowo, 1990): (a) time measured to collision; (b) time to accident; (c) the proportion of stopping sight distance; (d) gap time; (e) post-encroachment time (PET); and (f) deceleration rate.

2.2. Implementation of conflict analysis

Traffic conflict studies have been performed since 1963 to evaluate a number of intersections observed manually by 2-3 persons. In Japan, a computerized tool has been developed (Uno et al., 2002) to evaluate the number and severity of traffic conflictsdue to the difficulty in observing each traffic accident. This study uses two indices to evaluate the conflicts: TTC (Time to Collision) and PICUD (Potential Index for Collision with Urgent Deceleration). M. Idris (2009) proposed conflict indicators for traffic analysis in developing an ITS-assisted traffic safety system under a congested and high speed traffic environment. Data acquisition was carried out using a Vehicle Tracking System with a digital video camera recorder. Hazard and risk concepts associated with traffic are significant factors in data analysis indicated by TTC, approximate TTC and PET (Post Encroachment Time).

Potential for deriving surrogate safety measures was investigated (Gettman et al., 2003) from existing microscopic simulation models for intersection. Conflict severity was used in the model for surrogate measures derived from the theory of Space-time Trajectories, which can be used to support traffic engineering alternatives with respect to safety for both signalized and unsignalized intersections.

2.3. Implementation of conflict analysis in Indonesia

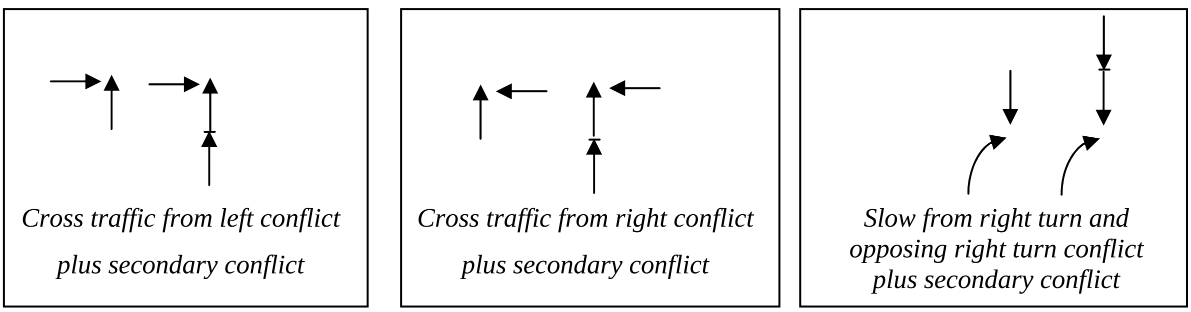
2.3.1. Intersection conflicts

Traffic conflict analysis has been implemented in some locations in Indonesia to minimize potential vehicle crashes. In this paper a number of experiences are presented in brief to illustrate how the model can be used to minimize conflict in the intersection areas. The TRRL conflict model was used in most of the research undertaken in Indonesia to observe traffic movement and determine sources of potential conflict. Two signalized intersections and two non-signalized intersections in Bandung, Indonesia were observed (Legowo, 1990). Four surveyors were assigned to record all types of conflict per 15 minute intervals. Surveyors collected and recorded data for every consecutive leg of intersection. Observations were recorded by video camera to compare with manual observation. Proper installment and placement of the video camera affected the accuracy of data gathered. Depending on the situation and condition for a particular site, we determined that the minimum height of the video camera should be at least three meters above pavement. Thirtyfive conflicts, primary and secondary, were recorded 20 in the category of single and 15 for a combination of occurrences. Observation took place for 5 hours in one day for each intersection and not during busy traffic periods.

Table 2 Total conflict per observer and per intersection

No	Intersection	Most Common Type of Conflict per Intersection	Total Traffic Conflict			
			Observer 1	Observer 2	Observer 3	Observer 4
1	Unsignalized, Jl Pasirkaliki-Jl. Dursasana	*All cross traffic from left conflict plus secondary conflict*	161	212	160	159
2	Unsignalized, Jl Bima-Jl Arjuna	*All cross traffic from right conflict plus secondary conflict*	81	101	89	111
3	Signalized, Jl Pajajaran-Jl Cicendo	*Slow from right turn and opposing right turn conflict plus secondary conflict*	205	220	218	196
4	Signalized, Jl Ir.Djuanda-Jl Dipatiukur	*Slow from right turn and opposing right turn conflict plus secondary conflict*	159	150	177	169

Source: Legowo, 1990



Source: Legowo, 1990

Figure 1 Common conflicts for intersections in Bandung, Indonesia

Type of conflict which happened the most in each intersection is shown in Table 2 and Figure 1. Overall results from four observers were relatively the same. For unsignalized intersections, a yield sign or a stop sign at minor leg intersections should be installed, considering that drivers' sight distance of both intersections is available. Most common type of conflict for both signalized intersections was a right turn and opposing right turn conflict (see Table 2); this conflict might be reduced by resetting the cycle time of the traffic signal. The results confirmed that conflict surveys could be administered by four well trained observers.

2.3.2. Traffic management at T-intersection

Traffic management at the non-signalized T-intersection located in Bandung, Indonesia was observed (Lawalata, 2006, 2007) to analyze the function of illegal officers (IO) in maintaining smoothness of flow. An IO attempts to manage traffic flow at intersections or U-turns, and seeks to give opportunities to right turn vehicles, since there is no appropriate sign or marking in the intersection area. The effect of right turning vehicle flow across major roads from minor roads and the effectiveness of private police in preventing collisions were evaluated. There was an indication that sudden stops may attributable to an illegal officer's traffic flow arrangement, since IOs are not equipped with appropriate tools or knowledge. In these intersections, traffic flow in the major road was significantly higher compared to the minor road.

By using the TRRL method, data for right turn movement conflict and other types of movement as causes of conflict were recorded; total conflict recorded was 14 (see Figures 2 and 3), and 8 categories were identified. Data for traffic flow and traffic conflicts was recorded by video camera during off peak hours at times with relatively low volume. Two kinds of traffic conditions, with and without the presence of IO, were observed. Analysis focused on the category with the potential to cause the most conflicts of a serious nature, and attendance of private police was included as a factor in the analysis. The results show that the attendance of an IO did not influence the incidence of traffic accidents (see Table 3). A traffic conflict study identified that serious conflict in this intersection could be reduced by installing a sign or a traffic signal for right turn movement. This sign or traffic signal could warn the vehicles entering the intersection of dangerous traffic conditions.

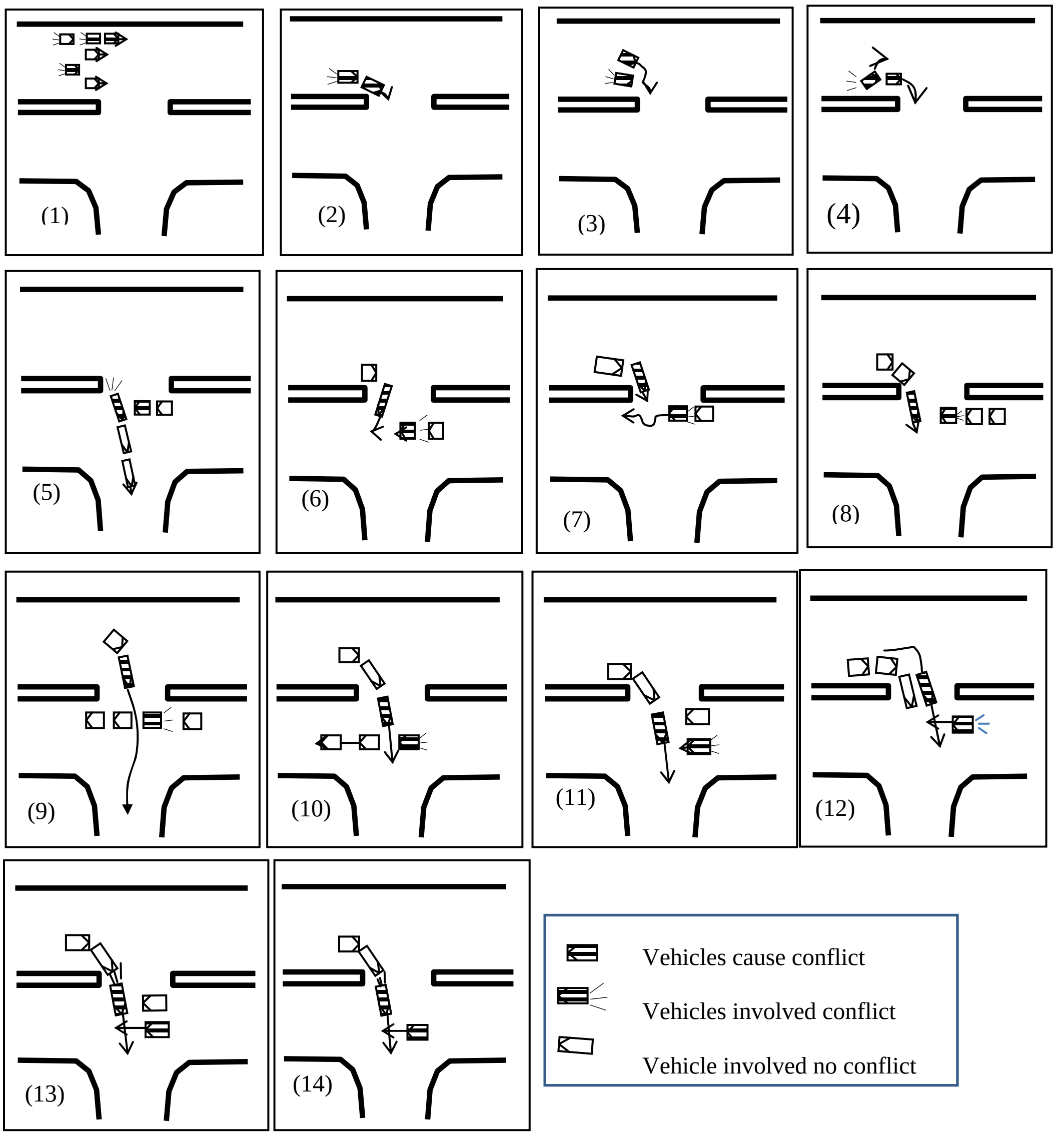
Table 3 Traffic conflict rate with and without illegal officer

Type of Severity	Without IO			With IO		
	Conflict	(%)	Conflict / 1000 intersection vehicle	Conflict	(%)	Conflict / 1000 intersection vehicle
Light	369	17	26	206	12	17
Serious	1,787	83	126	1,527	88	124
Sum of Conflict	2,156	100		1,733	100	

Source: Lawalata, 2006

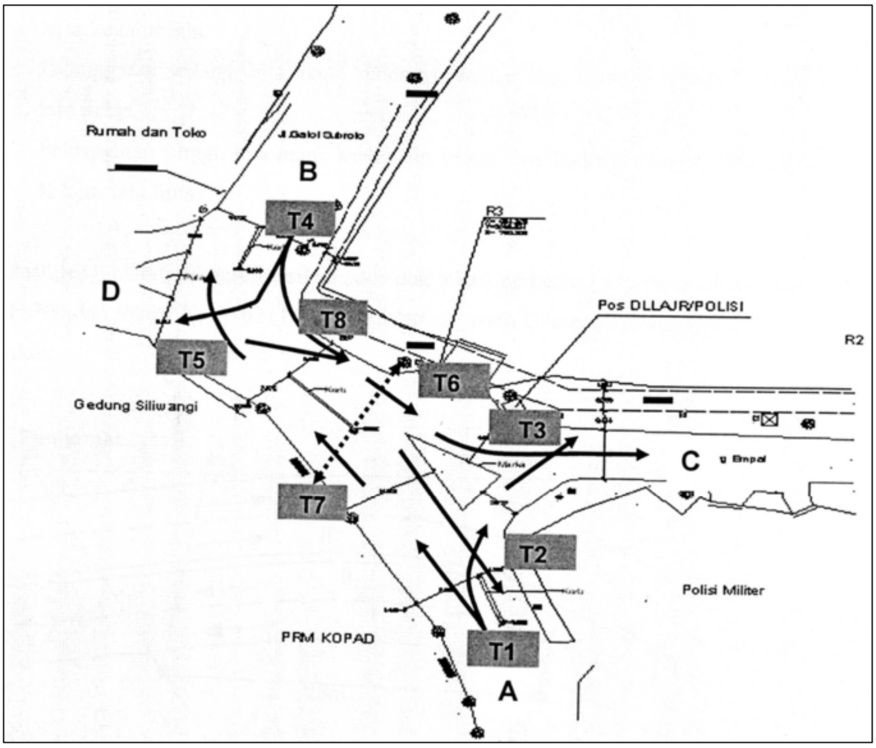
2.3.3. Intersection improvement at Cimahi

Intersection improvement at Cimahi, West Java was designed to achieve safer conditions. Assessment (Idris, 2009; Tanan, 2008) using TRRL conflict analysis was undertaken after improvement had taken place. Eight points regarded as the most likely sites for potential conflict to occur were selected (see Figure 3). Four types of conflict were categorized and observation was conducted by one observer per each leg. Each point selected was observed three times per 10-minute period during off peak hours. For each point all types of conflict were summed up to determine total and average conflict rates per 10-minute periods; total vehicle flow was used as comparative data. Measure is use ratio compare to a total of 1000 vehicles flow (see Table 3). It is found that traffic conflict typically as crossing conflict between small vehicles public transport with the right turn flow traffic. Another typical conflict was a side collision that occurred between right turn vehicles and through traffic, and vice versa. Recommended intersection improvements include minimizing potential conflict with redesign of road geometry, installment of signs and markings, and a pedestrian facility. The improvement of road geometry included adding a road separator and a road island. Line marking was added to guide road users past this intersection. Pedestrian facilities are such provide zebracross and trotoar. Results of the conflict survey showed that improvements could decrease the number of conflicts (see Table 3).



Source: Lawalata, Greece Maria, 2006

Figure 2 Traffic conflict for conflict categories 1 to 14



Source: Tanan, 2008

Figure 3 Points of conflict

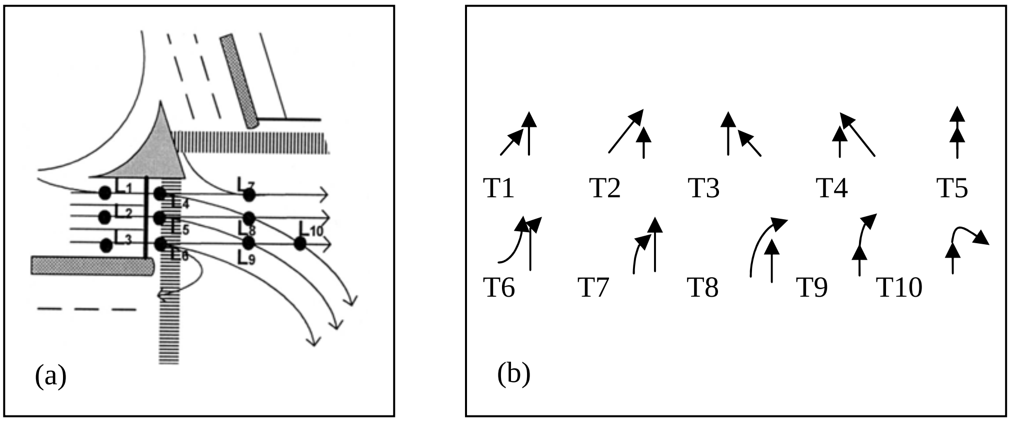
Table 3 Traffic conflict data before and after improvement in conflict location

Time	Conflict location								Sum
	T1	T2	T3	T4	T5	T6	T7	T8	
Before improvement	10.6	33.3	31.3	23.9	10.8	10.2	8.8	12.3	141.2
After improvement	5.4	14.1	23.0	21.9	13.3	0.0	0.0	4.2	81.9

2.3.4. Special Stopping Space (SSS) at intersection

Special Stopping Space (SSS) was designed to provide safer road conditions at intersections with a relatively high percentage of motorcycles during traffic flow. This special space is positioned in the intersection area to allow motorcycles waiting for right-of-way during the red light phase in front of other cars. The space is provided in the downstream of flow and after stop line to give better chances of smooth maneuvering and flow by allowing motorcycles to leave an intersection earlier than the rest of the waiting vehicles. The study was undertaken at one intersection on Buah Batu Street in Bandung (Idris, 2009), and four other intersections: Ahmad Yani-Riau intersection-Bandung, Dr. Djunjunan-Pasirkaliki intersection-Bandung, Gatot Subroto-HOS Cokroaminoto intersection-Denpasar Bali, and Dewa Ruci intersection-Bandung (Amelia, 2010). Survey method and analysis followed the TRRL model to evaluate effectiveness and benefits of SSS scheme in reducing traffic conflict, especially between motorcycles and other vehicles.

All flow movement with four legs was manually observed and counted at 15 minute intervals and supported by video camera recordings. A video camera was installed 9 meters high and at a distance of 25 meters from the existing intersection to cover all possible vehicle movement within the intersection areas. Observations were taken for 1 hour in order to see the different types of movement per each leg of intersection. Ten conflict categories were identified for right turn vehicles at intersections as a most frequent movement (Figure 4). All types of conflict identified in the sites were summed up to find total conflicts and to estimate an average value per 15 minute intervals. To measure the rate of occurrence, the average number was compared with total vehicle flows. The conflict rate is the occurrence ratio per 1,000 vehicles. Conflict was divided based on similar categories, as shown in Figure 4. To evaluate effectiveness, improvement before and after traffic studies were undertakenOne area of results is shown in Table 5. Special Space for motorcycles separated motorcycles from four wheel vehicles (Figure 5), decreasing traffic conflict between motorcycles and four wheel vehicles.



Source: Idris, 2009

Figure 4 Type of conflicts (a) and location of study (b)

Source: Idris, 2009; RHK=SSS

Figure 5 SSS model at Buah Batu intersection-Bandung

Table 5 Traffic conflict rate before and after improvement at Buahbatu intersection-Bandung

Time	Morning		Afternoon	
	L1-L6	L7-L10	L1-L6	L7-L10
Before improvement	107.7	25.6	84.6	26.5
After improvement	24.2	0.5	23.7	0.43

3. DISCUSSION

Traffic conflict studies have been initiated and accepted in many countries, because data and evaluation of safety treatment problems can be collected in a short period of time. Some traffic conflict study techniques have been developed using space-time trajectories; however, this technique requires tools and sophisticated equipment such as a traffic conflict image analyzer with video camera, or safety software.

In Indonesia, conventional traffic conflict study techniques still in practice rely on the abilities of the observer. TRRL is dominantly used conflict based on severity.

There are always some differences in opinion among observers, Pusat LITBANG Jalan dan Jembatan Ministry of Public Works has developed guidelines on traffic conflict studies/ field observations to overcome deficiencies and promote more efficiency for budget purposes.

Observers should be trained prior to assignments at targeted sites in order to give them the necessary skills in identifying classification of conflict. Number of observers and period of observation should be designated for each intersection and conflict type, and pilot surveys are advisable.

A combination of manual field observation staffed by two or three persons and a good quality video camera will give a better portrait of traffic conditions to identify possible vehicle conflict. It is to be noted that the video camera at each intersection should be in the right position to cover and record all conflicts.

A rate of conflict with the unit of number of conflicts per 1000 vehicles is proposed for use in analysis and evaluation.
Countermeasures should be standardized for the most common types of collision. For example:

a) Conflict caused by crossing action indicates r head-to-head crash. Possible countermeasure is to install traffic light or sign, or to redesign signal cycle time for turning flow.
b) Same direction conflict indicates back-to-head crash. Possible countermeasure may be more obvious directional line marking or use of a separator.
c) Conflict caused by overtaking action will cause a side collision; countermeasure to overcome is clear directional line marking or use of a separator.
d) Conflict with pedestrian could be minimized by providing a pedestrian crossing or evaluating the function of an available pedestrian facility.

To assess or administer a traffic conflict analysis, some activities should be prepared:

a) Training for observers should be held a few days by identifying traffic conflict from camera video and at field.
b) Conflict category and location of video camera installation should be defined after pilot survey.
c) Data to cross check traffic conflict and traffic volume can be obtained from video camera.
d) Conflict category could be translated as potential risk of accident that should decrease with some countermesure.

4. CONCLUSION

Results of this research led to the following conclusions:

1. Traffic conflict study developed by TRRL was preceded by efficient training of observers in classifications of traffic conflicts at intersections.
2. Compared to modern techniques, the traffic conflict analysis developed by TRRL is cheaper than using video cameras installed at very high elevations. Such techniques require heavy equipment to install at high elevation.
3. Traffic conflict analysis can be used to decide appropriate countermeasures.

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