# Traffic Conflict Analysis at Signalized Intersection Using Traffic Conflict Technique (TCT) Method at Muncul Intersection, South Tangerang City

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***Abstract--*** *Traffic safety at intersections is a critical aspect of urban transportation systems, particularly at intersections with high traffic volumes and complex vehicle interactions. This study aims to evaluate traffic conflict potential at the Muncul Four-Leg Signalized Intersection using the Traffic Conflict Technique (TCT) method with a Time to Accident (TA) approach. The TCT method is applied to identify traffic conflict events that have the potential to cause accidents without waiting for actual crash occurrences. Data collection was conducted through field surveys during a 1-hour period in the afternoon, recording conflict types, vehicle speeds, inter-vehicle distances, driver evasive actions, and conflict severity levels. Traffic conflicts were classified into crossing, merging, and diverging conflicts, and further categorized into serious and non-serious conflicts based on Time to Accident values. Results indicate that crossing conflicts are the most dominant type at the study location. In terms of severity, serious conflicts account for 56% of total observed conflicts, while non-serious conflicts represent 44%. These findings suggest that during the observation period, the traffic safety risk at the Muncul Intersection is relatively high. The occurrence of traffic conflicts is influenced by traffic flow characteristics dominated by motorcycles, driver behavior, and limitations in traffic control and supporting facilities. To reduce traffic conflicts, several measures are recommended, including improvement of road facilities, evaluation and adjustment of traffic signal control, and enhancement of traffic enforcement and monitoring. The findings of this study are expected to support traffic safety management and improvement strategies at urban intersections.*

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## 1. INTRODUCTION

South Tangerang City, Banten Province, is one of the regions experiencing rapid economic development and infrastructure growth due to its strategic position within the metropolitan area, namely DKI Jakarta, Bogor Regency, Tangerang Regency, and Tangerang City. This location drives significant increases in population mobility and vehicles, which impacts the growing complexity of urban transportation problems. The growth in private vehicle ownership not balanced with optimal traffic management has the potential to cause various problems, such as congestion, decreased travel time efficiency, and increased risk of traffic accidents [1]. Traffic accidents remain a major concern in transportation engineering, as they result in economic losses, injuries, and fatalities [2].

One location of concern is the Muncul Four-Leg Intersection, which is a signalized intersection with four main approaches: Jalan Raya Serpong, Jalan Raya Puspiptek, Jalan Raya Serpong–Parung, and Jalan Raya Muncul. The traffic signal control system at this intersection uses three phases in one cycle, so there are phases serving more than one vehicle flow simultaneously, which has the potential to cause conflicts due to intersection and interaction between traffic flows [3]. Additionally, high vehicle volumes during peak hours, motorcycle dominance, and driver behavior lacking discipline, such as marking violations and signal running, further increase the potential for traffic conflicts [4]. The availability of road safety facilities, such as signs, markings, special stopping spaces for motorcycles, and pedestrian crossing facilities, is also not yet fully functioning optimally, which can worsen safety conditions and intersection performance.Understanding traffic conflict mechanisms is essential for proactive safety management. Traffic conflicts can be defined as observable situations where two or more road users approach each other in time and space to such an extent that a collision is imminent if their movements remain unchanged [5]. The Traffic Conflict Technique (TCT) has been developed as a surrogate safety measure that allows for safety assessment without waiting for actual crash data, which are often rare and statistically unreliable [6].

In efforts to improve traffic safety, an approach capable of identifying conflict potential proactively before accidents occur is needed. One method that can be used is the Traffic Conflict Technique (TCT), which is a traffic safety analysis method by identifying conflict events as indicators of accident potential through Time to Accident (TA) parameters. This method enables safety level evaluation based on vehicle interactions and driver responses to conflict situations in the field [7]. Time to Accident is defined as the time that elapses from the moment a evasive action is taken until the moment of potential collision, assuming no changes in speed or direction occur [8].

Based on preliminary observations at the Muncul Intersection, Setu District, South Tangerang City, several problems were found, such as signal phase settings not fully aligned with vehicle movement patterns, limited space on intersection approaches, and lack of supporting traffic safety facilities. These conditions are exacerbated by undisciplined driver behavior, thereby increasing the likelihood of traffic conflicts occurring. Therefore, this study was conducted to analyze traffic conflict potential at the Muncul Intersection using the Traffic Conflict Technique (TCT) method to identify dominant conflict types and their contributing factors.

Previous studies have successfully applied TCT in various intersection settings. Research at unsignalized intersections in Lombok Timur Regency found that crossing conflicts were the most dominant type, with serious conflicts reaching 58% of total observed conflicts [9]. Similarly, studies at signalized intersections in Tasikmalaya City demonstrated that motorcycle dominance significantly contributes to conflict occurrence, with serious conflict proportions exceeding 50% during peak hours [10]. These findings highlight the importance of location-specific conflict analysis for developing targeted safety interventions.

## 2. METHODOLOGY

### 2.1 Research Location

This research was conducted at the Muncul Intersection, Setu District, South Tangerang City, which is a four-leg signalized intersection with high traffic volume and convergence of vehicle flows from the Parung, Pamulang, Cisauk, and Serpong directions. The intersection serves as a critical node connecting several arterial roads in the region.

### 2.2 Data Collection

Data collection was conducted through field surveys during a 1-hour period from 17:00 to 18:00 WIB on Friday, February 6, 2026. This time period was selected as it represents relatively high traffic activity periods with high potential for vehicle interactions at the study location. This research used a quantitative approach utilizing primary data obtained through direct observation and video recording to identify traffic conflict events using the Traffic Conflict Technique (TCT) method [11]. The data collection stages followed established TCT procedures [11]:

a) Observing irregular behavior such as sudden braking, swerving, and acceleration of road users during movements at the signalized intersection.
b) Measuring the speed (v) of road users taking evasive actions in response to irregular behavior of other road users, from just before the conflict until the moment of conflict occurrence.
c) Measuring or estimating the distance (d) between road users involved in the conflict to the potential collision point or conflict point, which was previously marked per 1 meter on the road surface or intersection.

Data collection was conducted through direct field observation to obtain primary data required for TA analysis. The traffic conflict data collection method was performed through manual counting [12]. This method requires several surveyors as each is assigned to record vehicle types at different points, enabling optimal field observation. The collected data included:

1) Average Daily Traffic (ADT) volume
2) Vehicle speeds
3) Number of conflicts and conflict occurrence patterns

Road geometric data were obtained through direct field surveys by measuring road width and length of the studied road segments [13]. After data collection, researchers transcribed and analyzed video recordings according to Traffic Conflict Technique parameters.

### 2.3 Data Analysis

Data analysis followed the Traffic Conflict Technique procedures outlined in The Swedish Traffic Conflict Technique Observer's Manual [8]. The analysis stages included:

1) Analysis of speed and distance data with conversion using time to accident tables to obtain TA values.
2) Plotting TA values on the conflict graph to determine whether they are classified as serious conflict or non-serious conflict types.
3) Classifying conflict severity levels at the signalized intersection using indicators of the number of conflicts and conflict types.

According to the Traffic Conflict Technique (TCT) method, conflicts can be distinguished into three main categories: serious conflict, minor conflict, and potential conflict. Serious conflict is the highest severity conflict type, where drivers must perform extreme evasive maneuvers such as sudden braking, abrupt direction changes, or very short inter-vehicle time gaps. This condition is typically characterized by low Time to Accident (TA) values, less than 0.5 seconds, indicating high collision risk if evasive maneuvers are not performed [14].Time to Accident (TA) is the time interval from when an evasive action is taken until the potential collision occurrence, assuming no changes in vehicle speed and direction by road users. Time to Accident (TA) values can be calculated using the following equation [9]:

$$TA=vd \tag{1}$$

Where:

- $d$ = distance to potential collision point (meters)
- $v$ = vehicle speed at the moment of evasive action (m/s)

After estimating distance ($d$) and vehicle speed ($v$), the values are plotted to obtain TA (Time to Accident) values, which can be seen in Table 1.

**Table 1.** Time to Accident (TA) determination table

| Speed | | Distance, m | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| km/h | *m/s* | 0,5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| 5 | *1,4* | 0,4 | 0,7 | 1,4 | 2,2 | 2,9 | 3,6 | 4,3 | 5,0 | 5,8 | 6,5 | 7,2 | | | | | | | | | |
| 10 | *2,8* | 0,2 | 0,4 | 0,7 | 1,1 | 1,4 | 1,8 | 2,2 | 2,5 | 2,9 | 3,2 | 3,6 | 5,4 | 7,2 | 9,0 | | | | | | |
| 15 | *4,2* | 0,1 | 0,2 | 0,5 | 0,7 | 1,0 | 1,2 | 1,4 | 1,7 | 1,9 | 2,2 | 2,4 | 3,6 | 4,8 | 6,0 | 7,2 | 8,4 | 9,6 | | | |
| 20 | *5,6* | 0,1 | 0,2 | 0,4 | 0,5 | 0,7 | 0,9 | 1,1 | 1,3 | 1,4 | 1,6 | 1,8 | 2,7 | 3,6 | 4,5 | 5,4 | 6,3 | 7,2 | 8,1 | 9,0 | 9,9 |
| 25 | *6,9* | 0,1 | 0,1 | 0,3 | 0,4 | 0,6 | 0,7 | 0,9 | 1,0 | 1,2 | 1,3 | 1,4 | 2,2 | 2,9 | 3,6 | 4,3 | 5,0 | 5,8 | 6,5 | 7,2 | 7,9 |
| 30 | *8,3* | 0,1 | 0,1 | 0,2 | 0,4 | 0,5 | 0,6 | 0,7 | 0,8 | 1,0 | 1,1 | 1,2 | 1,8 | 2,4 | 3,0 | 3,6 | 4,2 | 4,8 | 5,4 | 6,0 | 6,6 |
| 35 | *9,7* | 0,1 | 0,1 | 0,2 | 0,3 | 0,4 | 0,5 | 0,6 | 0,7 | 0,8 | 0,9 | 1,0 | 1,5 | 2,1 | 2,6 | 3,1 | 3,6 | 4,1 | 4,6 | 5,1 | 5,7 |
| 40 | *11,1* | 0,0 | 0,1 | 0,2 | 0,3 | 0,4 | 0,5 | 0,5 | 0,6 | 0,7 | 0,8 | 0,9 | 1,4 | 1,8 | 2,3 | 2,7 | 3,2 | 3,6 | 4,1 | 4,5 | 5,0 |
| 45 | *12,5* | | 0,1 | 0,2 | 0,2 | 0,3 | 0,4 | 0,5 | 0,6 | 0,6 | 0,7 | 0,8 | 1,2 | 1,6 | 2,0 | 2,4 | 2,8 | 3,2 | 3,6 | 4,0 | 4,4 |
| 50 | *13,9* | | 0,1 | 0,1 | 0,2 | 0,3 | 0,4 | 0,4 | 0,5 | 0,6 | 0,6 | 0,7 | 1,1 | 1,4 | 1,8 | 2,2 | 2,5 | 2,9 | 3,2 | 3,6 | 4,0 |
| 55 | *15,3* | | 0,1 | 0,1 | 0,2 | 0,3 | 0,3 | 0,4 | 0,5 | 0,5 | 0,6 | 0,7 | 1,0 | 1,3 | 1,6 | 2,0 | 2,3 | 2,6 | 2,9 | 3,3 | 3,6 |
| 60 | *16,7* | | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,4 | 0,4 | 0,5 | 0,5 | 0,6 | 0,9 | 1,2 | 1,5 | 1,8 | 2,1 | 2,4 | 2,7 | 3,0 | 3,3 |
| 65 | *18,1* | | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,5 | 0,6 | 0,8 | 1,1 | 1,4 | 1,7 | 1,9 | 2,2 | 2,5 | 2,8 | 3,0 |
| 70 | *19,4* | | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,5 | 0,5 | 0,8 | 1,0 | 1,3 | 1,5 | 1,8 | 2,1 | 2,3 | 2,6 | 2,8 |
| 75 | *20,8* | | 0,0 | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,5 | 0,7 | 1,0 | 1,2 | 1,4 | 1,7 | 1,9 | 2,2 | 2,4 | 2,6 |
| 80 | *22,2* | | 0,0 | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,5 | 0,7 | 0,9 | 1,1 | 1,4 | 1,6 | 1,8 | 2,0 | 2,3 | 2,5 |
| 85 | *23,6* | | 0,0 | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,4 | 0,4 | 0,6 | 0,8 | 1,1 | 1,3 | 1,5 | 1,7 | 1,9 | 2,1 | 2,3 |
| 90 | *25,0* | | 0,0 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,6 | 0,8 | 1,0 | 1,2 | 1,4 | 1,6 | 1,8 | 2,0 | 2,2 |
| 95 | *26,4* | | 0,0 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,4 | 0,6 | 0,8 | 0,9 | 1,1 | 1,3 | 1,5 | 1,7 | 1,9 | 2,1 |
| 100 | *27,8* | | 0,0 | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,4 | 0,5 | 0,7 | 0,9 | 1,1 | 1,3 | 1,4 | 1,6 | 1,8 | 2,0 |

Source: *The Swedish Traffic Conflict Technique Observer's Manual, 2018*

The time-to-accident approach classifies the danger level of vehicle interactions based on instantaneous speed dynamics and relative time intervals to the theoretical collision point. The determination of confrontation status between road users is highly dependent on their position relative to the standard curve line; speed and TA values exceeding the curve line indicate serious conflicts with high potential to become actual accidents. On the other hand, incidents that nearly trigger accidents but remain below or outside the curve coverage are defined as non-serious conflicts. Technically, the X-axis of this instrument describes the remaining reaction time (seconds) to the potential impact point, while the Y-axis represents the conflict intensity classification. The relationship between these two variables is linear with the danger level: the higher the value on the Y-axis, the higher the conflict urgency occurring. A comprehensive comparison of the boundaries of these two conflict categories is presented in Figure 1.

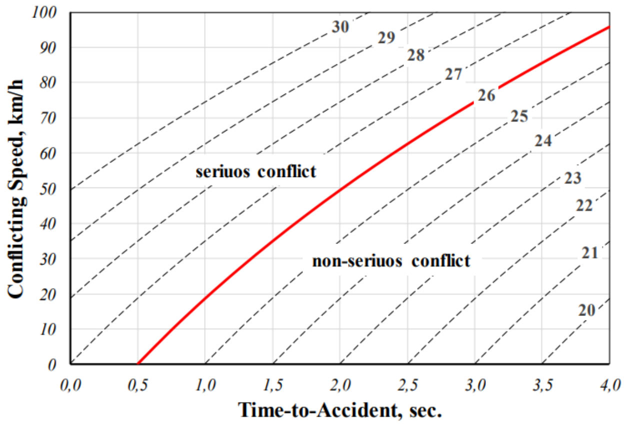


**Figure 1.** Serious Conflict and Non-Serious Conflict boundary graph
Source: *The Swedish Traffic Conflict Technique Observer's Manual, 2018*

## 3. RESULTS AND DISCUSSION

### 3.1 Intersection Geometry

Geometric data generally describes the geometric conditions at each intersection, including number of lanes, width of each lane, and shoulder width. Intersection geometric data are geometric measurements at each arm or leg of the studied intersection. The geometric survey results (Figure 2) show that the Muncul Four-Leg Intersection has varying road widths on each approach.

The north approach, Jalan Raya Serpong, has a road width of 10 meters with a two-way traffic system. The east approach, Jalan Raya Puspiptek, has different width characteristics based on movement direction: 9.5 meters for the direction toward the intersection and 16.6 meters for the direction exiting toward Jalan Raya Puspiptek. The south approach, Jalan Raya Serpong–Parung, has an 8-meter road width with a two-way system, which is the smallest width among all intersection arms. Meanwhile, the west approach, Jalan Muncul, has the largest road width of 15 meters with a two-way system.

### 3.2 Traffic Volume Survey Results

Traffic volume surveys were conducted at each arm of the Muncul Four-Leg Intersection to determine the magnitude of vehicle flows passing during the observation period. Traffic data were grouped by vehicle type, namely motorcycles (MC), passenger cars (PC), public transport (PT), pickups (PU), trucks (T), to describe the existing traffic conditions at each intersection approach. The data collected were one-direction data (Table 2)

**Table 2.** Vehicle volume at Muncul Four-Leg Intersection

| Approach | Number of Vehicles (veh) | | | | | Total Vehicles |
|---|---|---|---|---|---|---|
| | MC | PC | PT | PU | T | |
| Jl Raya Serpong (North) | 1628 | 384 | 13 | 160 | 180 | 2365 |
| Jl Raya Puspiptek (East) | 1322 | 371 | 9 | 120 | 182 | 2004 |
| Jl Raya Serpong-Parung (South) | 1152 | 454 | 0 | 68 | 7 | 1681 |
| Jl Muncul (West) | 1131 | 262 | 0 | 104 | 152 | 1649 |

Survey results show that traffic volume during the observation period indicates that the north approach, Jalan Raya Serpong, has the highest traffic volume compared to other approaches with a total of 2,365 vehicles. The lowest volume was recorded at the west approach, Jalan Muncul, with 1,649 vehicles. The east approach, Jalan Raya Puspiptek, and the south approach, Jalan Raya Serpong-Parung, each have total volumes of 2,004 vehicles and 1,681 vehicles, respectively. At all intersection arms, motorcycles are the most dominant vehicle type across all approaches, comprising approximately 65-70% of total traffic volume. This motorcycle dominance is consistent with urban traffic characteristics in Indonesian cities [4]. The presence of heavy vehicles (trucks) is notably higher on the north, east, and west approaches, which serve as primary routes for freight distribution in the area (Figure 2)

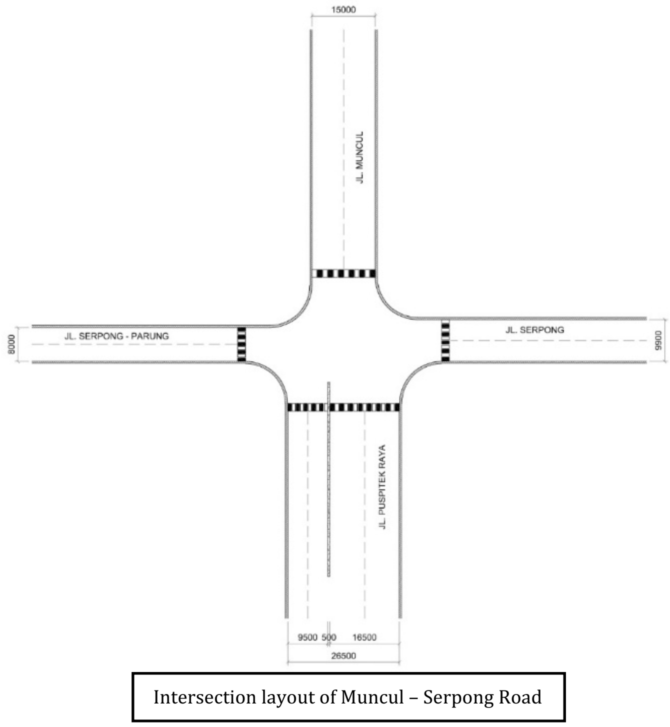


**Figure 2.** Muncul Four-Leg Intersection geometry (units in millimeters (mm))

### 3.3 Conflict Potential Analysis

During the 1-hour observation period, several conflict events were recorded. The following are examples of conflict events (Figure 3) :

#### First Conflict

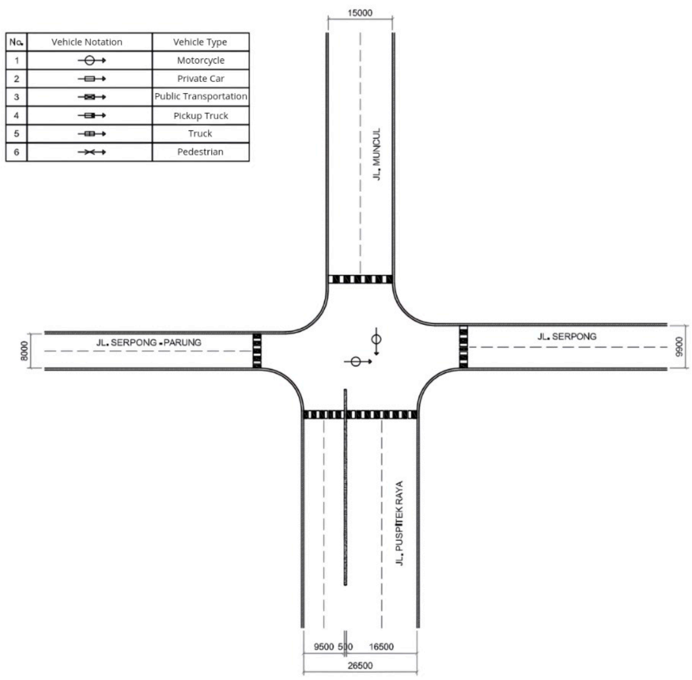


**Figure 3.** Conflict between motorcycle and motorcycle (units in millimeters (mm))

Based on Figure 3, this conflict occurred between road users, namely a motorcycle rider and another motorcycle rider. Motorcycle rider 1 from Jl. Serpong Parung traveling straight toward Jl. Serpong at a speed of 22.5 km/h, while motorcycle rider 2 from Jl. Muncul moving straight toward Jl. Raya Puspiptek. Motorcycle rider 2 committed a traffic light violation, and the evasive action taken was braking, preventing a collision between the two riders. The distance between the two riders was 1 meter, yielding a TA value of 0.2 seconds. This conflict is classified as a serious conflict. To calculate the TA value using the formula (1): *TA=vd*, with $d$ = 1 meter, and $v$ = 22.5 km/h = 6.3 m/s

$$TA = \frac{1\ meter}{6.3\ {}^{m}/_{s}} = 0.2\ seconds$$

After obtaining the TA value, to determine whether the conflict is serious or non-serious, the speed and TA values are plotted on the boundary graph between Serious Conflict and Non-Serious Conflict.

**Second Conflict**

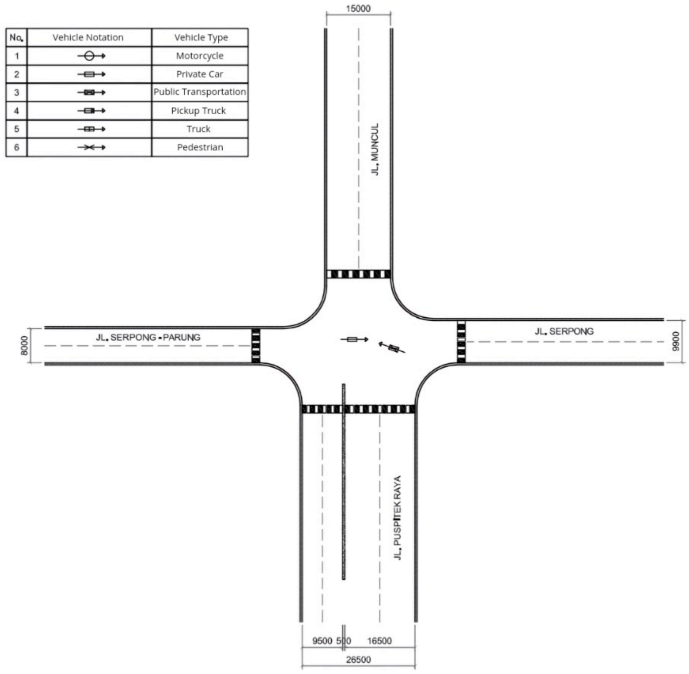


**Figure 4.** Conflict between private car and public transport (units in millimeters (mm))

Based on Figure 4, this conflict occurred between road users, namely a private car driver and a public transport vehicle. The private car driver from Jl. Serpong Parung traveling straight toward Jl. Serpong at a speed of 25.4 km/h, while the public transport driver from Jl. Serpong made a U-turn toward Jl. Raya Serpong to pick up passengers on the roadside of Jl. Raya Serpong. The evasive action taken was braking, preventing a collision between the two drivers. The distance between the two vehicles was 2.7 meters, yielding a TA value of 0.4 seconds. This conflict is classified as a serious conflict.

### 3.4 Conflict Types

During the observation period of 1 hour between 17:00 and 18:00 WIB, a number of traffic conflicts were identified and categorized as near-miss conflicts. The conflicts analyzed in this study were classified into three main types: crossing conflicts, merging conflicts, and diverging conflicts.

Based on the graph of the number of conflicts by conflict type (Figure 5), it can be seen that crossing conflicts dominate with a total of 31 events, much higher than merging conflicts with 6 events and diverging conflicts with 2 events. The dominance of crossing conflicts indicates that interactions between intersecting flows at the intersection are the main source of traffic conflict potential, especially during straight and turning movements occurring simultaneously. This finding is consistent with research by Freitas et al. [11] which found that crossing conflicts constitute the majority of conflicts at signalized intersections due to the inherent conflict points in intersection design.

The relatively low number of merging and diverging conflicts indicates that conflicts due to merging or diverging vehicle flows occur with lower frequency compared to crossing conflicts. However, the presence of these conflicts still has the potential to reduce safety levels and user comfort. Merging conflicts typically occur when vehicles from different approaches attempt to join the same traffic stream, while diverging conflicts occur when vehicles separate from the main stream to turn [14].

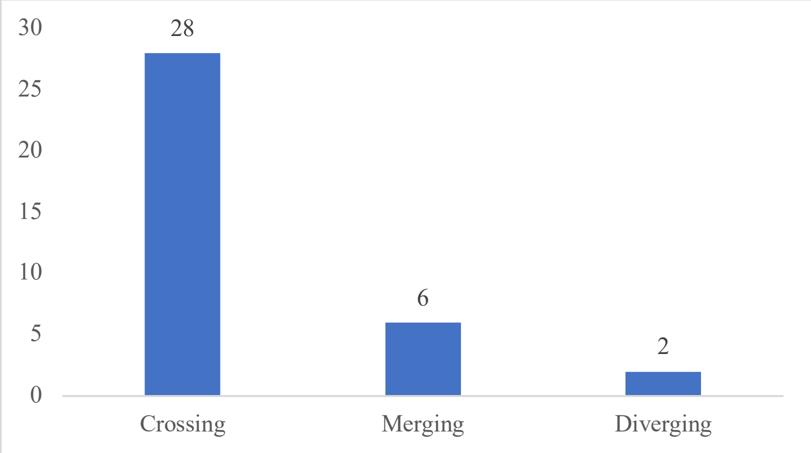


**Figure 5.** Number of conflicts by conflict type

### 3.5 Driver Actions During Near-Miss Accident Events

Several actions were taken by drivers during near-miss accident events, including braking, swerving, and accelerating. The following presents the number of drivers performing these maneuvers (Figure 6).

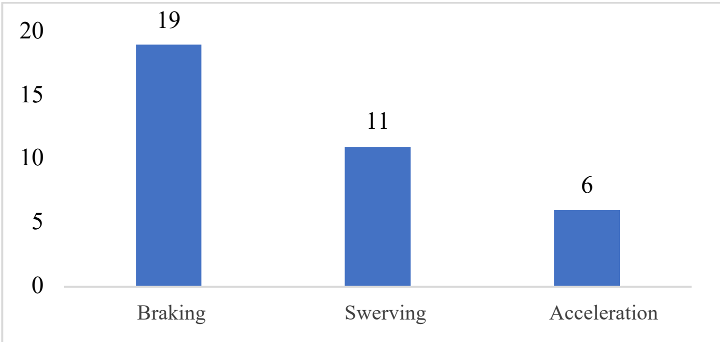


**Figure 6.** Number of driver actions during near-miss accident events

Based on the graph, the most frequent action taken by drivers was braking, with a total of 19 events. This indicates that most drivers respond to potential traffic conflicts by performing sudden deceleration to avoid collisions. Swerving actions were recorded in 11 events, while acceleration was the least frequent action, with only 6 events. The low frequency of acceleration indicates that drivers prefer to reduce speed or change direction rather than accelerate when facing risky situations.The dominance of braking and swerving actions indicates that drivers are often confronted with situations requiring quick responses to avoid potential traffic conflicts. This finding aligns with research by Modanggu et al. [14] which found that braking is the most common evasive action in near-miss situations, particularly in crossing conflicts where the time available for reaction is limited.

### 3.6 Time to Accident Analysis

Estimation of time-to-accident values for each conflict phenomenon was obtained through data extraction. Technically, the X-axis of this instrument describes the remaining reaction time (seconds) to the potential impact point, while the Y-axis represents the conflict intensity classification. The relationship between these two variables is linear with the danger level: the higher the value on the Y-axis, the higher the conflict urgency occurring. The plotting results between TA and vehicle speed will determine the position of events within the conflict zone, as illustrated in Figure 7.

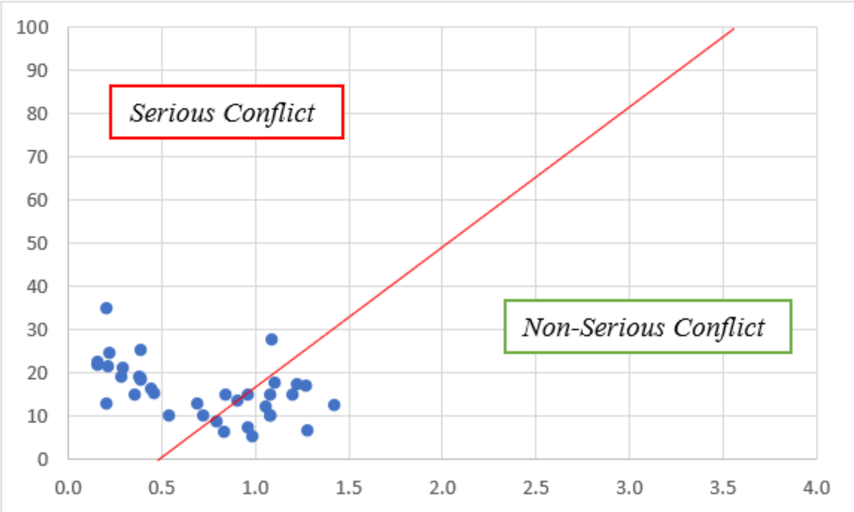


**Figure 7.** Serious Conflict and Non-Serious Conflict boundary graph

Based on the mapping results of time to accident (TA) values and vehicle speeds on the serious conflict and non-serious conflict boundary graph, 20 serious conflict events and 16 non-serious conflict events were identified. Generally, conflicts with lower TA values and relatively higher speeds tend to be categorized as serious conflicts, while conflicts with larger TA values and lower speeds are included in non-serious conflicts. The distribution of points on the graph shows that the majority of conflicts are located in the serious conflict area, indicating dominance of conflicts with relatively high severity levels during the observation period. This condition indicates that the study location has a relatively high traffic safety risk level, especially during the observation hour, thus requiring special attention in traffic management. The occurrence of traffic conflicts is influenced by a combination of traffic flow characteristics, driver behavior, and existing intersection control.

The relationship between TA values and conflict severity is well established in traffic safety literature. Lower TA values indicate that less time was available for evasive action, corresponding to higher severity potential [8]. In this study, conflicts with TA values below 0.5 seconds were consistently classified as serious, consistent with the threshold used in Swedish TCT applications [5].

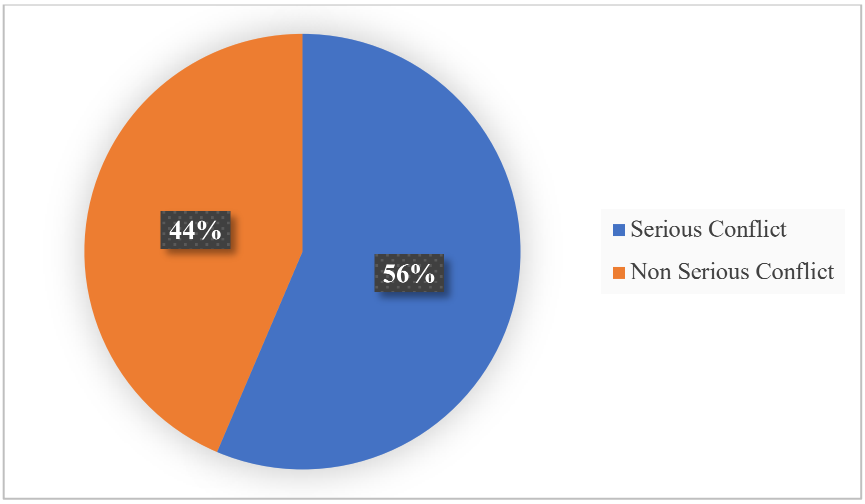


**Figure 8.** Conflict level percentage

Based on the conflict level percentage (Figure 8), serious conflict reached 56% of total identified conflicts, while non-serious conflict accounted for 44%. This proportion indicates that conflicts with relatively high severity levels are more dominant than non-serious conflicts during the observation period. This finding is comparable to studies at similar urban intersections in Indonesia, where serious conflict proportions ranged from 50-60% during peak hours [10].

The high proportion of serious conflicts at the Muncul Intersection can be attributed to several factors. First, the three-phase signal timing allows simultaneous movements that create multiple crossing conflict points. Second, motorcycle dominance combined with undisciplined behavior, such as red light running and improper lane positioning, increases the probability of serious conflicts. Third, geometric constraints, particularly the narrow south approach, create capacity limitations that lead to risky driver behaviors [9].

### 3.7 Conflict Reduction Recommendations

Based on traffic survey results, intersection geometric analysis, and existing condition observations at the Muncul Four-Leg Intersection, traffic conflict potential remains present, influenced by differences in vehicle volume, road width variations, and less-than-optimal traffic control. Therefore, improvements to traffic facilities are needed to enhance safety and vehicle movement order.

The proposed recommendations include adding and improving road markings, such as lane markings, stop lines, and directional arrows, to provide clearer guidance to road users and reduce conflicts due to irregular lane changes. Clear and well-maintained markings help establish expected vehicle paths and reduce uncertainty, which is a primary contributor to conflicts [15].

Additionally, providing crossing facilities in the form of zebra crossings is necessary to improve pedestrian safety and reduce potential conflicts with vehicles [16]. Pedestrian-vehicle conflicts are a significant safety concern at urban intersections, and dedicated crossing facilities with proper signal timing can substantially reduce these interactions.

Implementation of special stopping spaces (Ruang Henti Khusus/RHK) for motorcycles is also recommended to separate motorcycle stopping positions from other vehicles, considering motorcycle dominance in traffic flow, thereby improving queue order and reducing conflicts during the initial movement phase [17]. RHK has been shown to improve safety at signalized intersections by providing dedicated space for motorcycles at the stop line, reducing the tendency for motorcycles to queue between lanes or in front of vehicles [18]. Another recommendation is the implementation of yellow box junctions at the intersection center area to prevent vehicles from stopping in the conflict area and maintain smooth movement between signal phases [19]. Yellow box junctions help keep the intersection clear, ensuring that vehicles from different approaches can move through without obstruction when their phase begins.

Furthermore, evaluation and adjustment of the traffic signal control system (APILL) are needed, specifically changing the system from three phases to four phases to separate potentially conflicting vehicle flows. The current three-phase system creates situations where multiple movements share the same right-of-way, increasing conflict probability. A four-phase system would provide exclusive right-of-way for each major movement, reducing conflict points. Addition and adjustment of green time duration for each phase also need to be conducted according to traffic volume characteristics on each approach. These efforts are expected to reduce traffic conflicts, improve road user safety, and optimize overall intersection performance. Implementation of these recommendations should be accompanied by public education and enforcement to ensure compliance with new traffic control measures.

## 4. CONCLUSIONS

The traffic conflict level at the Muncul Four-Leg Intersection is classified as high, indicated by the dominance of serious conflicts (56%) compared to non-serious conflicts (44%). This serious conflict dominance indicates that the intersection has a significant safety risk level and has the potential to increase the likelihood of traffic accidents if improvement efforts are not implemented. The high conflict level is influenced by large vehicle volumes, traffic movement complexity, and limitations in the traffic control system that has not been fully able to accommodate existing vehicle flow characteristics. Crossing conflicts are the most dominant conflict type, reflecting high interaction between intersecting vehicle flows at the intersection area. Motorcycles are the vehicle type most frequently involved in conflicts, indicating that traffic characteristics dominated by two-wheeled vehicles contribute to increased conflict potential. These findings confirm that driver behavior factors, traffic composition, and traffic control systems have important roles in influencing safety levels at intersections. The research results contribute empirical information regarding traffic conflict characteristics and levels as early indicators of accident potential. Practical implications of this research include the need for evaluation and optimization of traffic signal control, improvement of road safety facilities, and enhancement of traffic management to reduce conflict potential and improve road user safety. Thus, the Traffic Conflict Technique (TCT) method can be used as a proactive approach in supporting traffic safety planning and management, particularly at signalized intersections in urban areas.

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