STUDY ON THE BEHAVIOR OF RIGHT-TURNING VEHICLES AT DIFFERENT TYPES OF UNSIGNALISED INTERSECTIONS IN MALAYSIA

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By

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ABSTRAK

Kajian lapangan dijalankan di pelbagai jenis simpang T termasuk simpang T biasa (Jenis A) dan simpang T (Jenis B dan Jenis C) yang mempunyai lorong percantuman. Simpang Jenis B mempunyai lorong keluar pusing kanan yang pendek manakala Simpang Jenis C mempunyai lorong keluar terus yang pendek.Menurut kajian ini, purata kelajuan kenderaan yang membelok kanan dari lorong minor sebaik sahaja melepasi kawasan konflik ialah 30.09 km/jam dan 31.66 km/jam untuk simpang Jenis B dan Jenis C. Oleh itu, perlakuan mencantum kenderaan yang membelok kanan dari lorong minor adalah serupa untuk kedua-dua simpang. Peratusan kenderaan yang bergerak terus di lorong major akan mengurangkan kelajuan sama dengan atau lebih daripada 5 km/jam ketika berinteraksi dengan kenderaan yang membelok kanan di simpang Jenis B dan Jenis C ialah 24.24% dan 56.00%. Justeru, lorong percantuman yang pendek di simpang Jenis B dapat mengurangkan konflik antara kenderaan yang membelok kanan dari lorong minor dan kenderaan yang bergerak terus di lorong major di lorong yang jauh. Tingkah laku penerimaan sila berhenti selepas sela lebih daripada 12s di simpang Jenis A dan 11s untuk simpang Jenis B dan Jenis C. Nilai sela kritikal pembelokan kanan dari lorong minor untuk simpang Jenis A, Jenis B dan Jenis C adalah 5.12s, 4.29s dan 3.50s. Oleh itu, simpang Jenis C lebih berkesan dalam mengurangkan nilai sela kritikal tersebut. Masa susulan di simpang Jenis A lebih panjang (3.30s) daripada simpang Jenis B dan Jenis C (kedua-dua 2.97s) kerana pemandu di simpang Jenis A mengalami konflik yang lebih banyak. Simpang Jenis B didapati lebih baik kerana konflik kenderaan membelok kanan dari lorong minor dikurangkan. Walaupun simpang Jenis C mengurangkan nilai sela kritikal pembelokan kanan dari lorong minor, tetapi pergerakan lancar kenderaan yang bergerak terus di lorong major dijejaskan.

ABSTRACT

Field study was carried out at different types of T-junctions which include a typical T-junction (Type A) and T-junctions (Type B and Type C) with short merging lane on the receiving approach. Type B junction has a short right-turn exit lane while Type C junction has a short through exit lane. From this study, the mean speed of vehicles making a right-turning maneuver from minor road as soon as they clear the conflict area were found to be 30.09 km/hr and 31.66 km/hr for Type B and Type C junctions respectively. Hence, the merging behavior of right-turning vehicles from minor road are similar for both junctions. There were 24.25% and 56.00% of major through movement vehicles reduced speed equal to or more than 5 km/hr when interacting with right-turning minor vehicles at Type B and Type C junctions respectively. Hence, the short merging lane in Type B junction reduces the conflict between right-turning vehicles from minor road and major road through movement vehicles in the far lane. The driver gap acceptance behavior was found to cease beyond gaps longer than 12s at Type A junction and 11s for both Type B and Type C junctions. The critical gap of right-turning minor vehicles for Type A, Type B and Type C junctions are 5.12s, 4.29s and 3.50s respectively. Therefore, Type C junction is more effective in reducing the critical gap of right-turning movement from minor road. The follow-up time at Type A junction is longer (3.30s) than Type B and Type C junction (both 2.97s) as drivers at Type A junction experienced more conflict. Type B junction was found to be better as it reduces the conflict of right-turning vehicles from minor road. Even though Type C junction reduces the critical gap of right-turning movement from minor road, but it affects the smooth movement of major through movement vehicles.

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CHAPTER 1

INTRODUCTION

1.1 Background

Intersection is an important element in the road network. This is an area where traffic flows in different directions converge. Its main function is to guide vehicles to change their route directions. There are various types of intersections which are signalised intersection, unsignalised intersection, roundabout and grade-separated intersection.

Unsignalised intersection is at-grade intersection where the right-of-way for vehicles and pedestrians are not controlled by a traffic signal. Priority control such as yield control or stop control is the most common type of traffic control implemented at unsignalised intersections to resolve conflicts between crossing and merging vehicles. Unsignalised intersection can be categorised by number of approach legs such as three-legged intersection (or T-junction) and four-legged intersection (or cross junction).

The behavior of drivers at unsignalised intersection are more complicated than those at signalised intersection as drivers have no signal indication when it is appropriate to enter the intersection from minor road. The drivers on the controlled movement at unsignalised intersection must decide and select a suitable size of gaps along the major road to cross into it. A hierarchy of streams which have different levels of priority or rank of movements is introduced at unsignalised intersection where the driver trying to enter the traffic stream must yield to those drivers which have priority over him/her. Priority is granted to traffic flow along the major approaches whereas traffic at minor approaches is controlled by traffic signs such as yield sign or stop sign.

Traffic conflict is defined as an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged. The number and type of conflicts at an unsignalised intersection are different for different types of junctions. Increase in approaches lanes will lead to increase in number of potential conflicts. The type of conflicts occurs at an unsignalised intersections include diverging conflicts, merging conflicts and crossing conflicts. Figure 1.1 illustrates all the possible movements and conflict points at a typical T-junction.

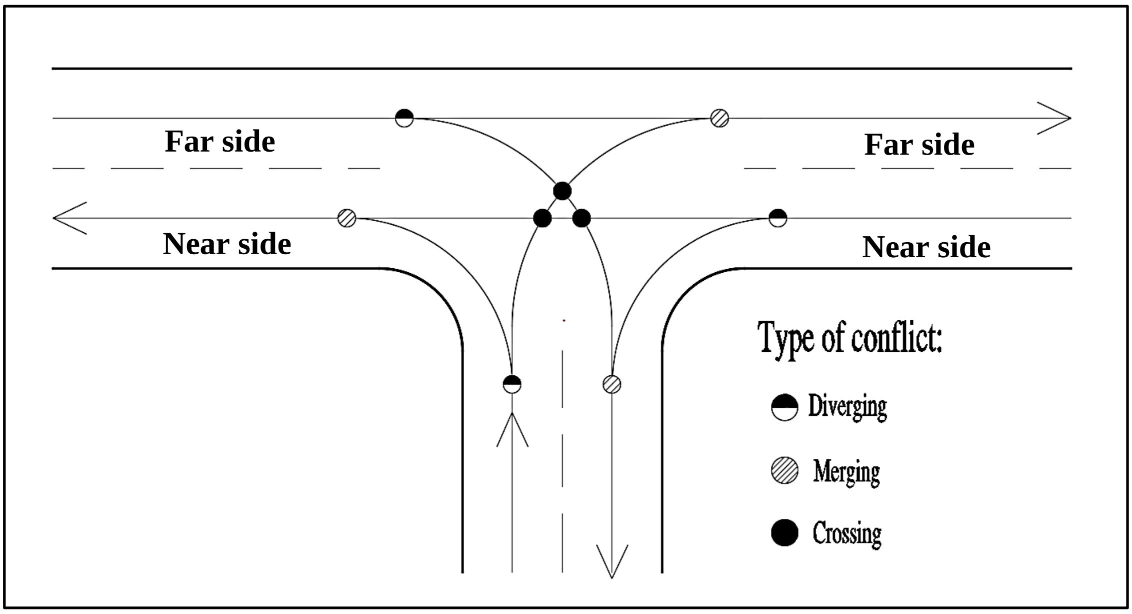

Figure 1.1: Conflict points at T-junction.

Vehicles making through movement on major road have priority over all the other conflicting traffic whereas vehicles turning right from the major road onto the minor road must yield to through and left-turning vehicles on the major road. The left-turning vehicles from the minor road onto the major must yield the right-of-way to through movement vehicles in the near side traffic. Vehicles making right turn from minor road onto the major road have the least priority and experience most conflicts. Thus, right-turning vehicles from minor road onto major road must yield to all other conflicting movements.

The focus of this study is on the behavior of right-turning vehicles from minor road onto major road at different types of T-junctions. The field study is carried out to determine the effects of different types of T-junctions on the behavior of right-turning vehicles from minor road onto the major road in terms of merging behavior, conflicting movements, and gap acceptance behavior. At the end of the study, the critical gap and follow-up time of right-turning vehicles from minor road onto major road at different types of T-junctions were identified and compared.

In Malaysia, the vehicles composition registered annually consists mainly of passenger cars, motorcycles, buses, taxi, hire and drive cars and goods vehicles as shown in Table 1.1. It clearly shows that the percentage of passenger cars and motorcycle registered annually is about 44-45% and 45-46% respectively.

Table 1.1: Percentage of registered vehicles in Malaysia. (Ministry of Transport Malaysia, 2016a)

Year	Motorcycle	Passenger car	Bus	Taxi	Hire Car	Goods Vehicles	Others
2012	46.69	44.00	0.27	0.42	0.22	4.76	3.64
2013	46.55	44.23	0.26	0.42	0.23	4.69	3.62
2014	46.33	44.62	0.26	0.42	0.23	4.62	3.52
2015	45.98	45.14	0.25	0.41	0.24	4.55	3.42

Table 1.2 also shows the traffic composition by type of vehicle at 14 selected stations in Malaysia. It shows the composition of passenger cars is higher as compared to other vehicle types. Even though the percentage of registered motorcycles is higher than percentage of registered passenger cars, passenger cars still covered the majority of traffic composition on road. Therefore, this study will focus on the behavior of the passenger cars only.

Table 1.2: Traffic composition by type of vehicle at 14 selected stations in Malaysia, 2016. (Ministry of Transport Malaysia, 2016b)

No.	Station	16 Hours Traffic	Type of Vehicle					
			Passenger Cars	Light Lorry	Medium Lorry	Heavy Lorry	Bus	Motorcycle
Peninsular Malaysia								
1	JR 204	110,498	81,730	8,478	5,121	1,846	1,990	11,334
2	JR 501	15,336	8,866	1,208	719	470	91	3,982
3	NR 501	10,984	6,663	1,032	775	516	70	1,928
4	PR 115	41,309	23,469	2,660	2,665	872	284	11,358
5	AR 301	24,654	16,515	1,594	2,058	839	283	3,365
6	KR 501	18,221	10,800	1,210	1,127	650	97	4,337
7	CR 805	6,841	3,992	1,022	571	394	28	834
8	CR 902	10,514	6,018	1,772	690	836	76	1,122
9	TR 402	34,408	24,129	2,470	879	190	226	6,515
10	DR 802	21,969	13,028	3,447	1,337	527	150	3,480
Sabah								
11	HR 201	15,999	8,936	4,381	1,071	536	123	952
12	HR 501	11,694	3,885	4,252	1,469	885	62	1,141
Sarawak								
13	SR 103	34,950	19,426	5,676	1,585	1,409	275	6,579
14	SR 402	7,428	3,146	2,489	444	702	105	542

1.2 Problem Statement

Unsignalised intersections in Malaysia are more prone to accidents compared to signalised intersections as drivers have no indication on the appropriate time to cross the intersection. As Malaysia's traffic followed left-hand rules, right-turning vehicles from minor road onto major road is the critical movement that experienced most conflicts and have the least priority at unsignalised intersections. Field studies were carried out by past researchers to investigate the behavior of right-turning vehicles from minor road onto the major road at unsignalised intersections (Abdul Manan, 2014; Ashar Ahmed et al.,2016; Karthika and Bino, 2014; Nabaee and Hurwitz, 2011).

Currently, a short merging lane is implemented on the receiving approach of the major road at unsignalised intersections to increase the capacity of unsignalised intersections and to reduce the conflicts at unsignalised intersections. Besides, it is believed to give positive impacts on the gap acceptance behavior of minor road vehicles that make right turn onto the major road. However, most of the study are mainly focus on typical unsignalised intersections. Therefore, there is lack of past knowledges on the effects of implementing a short merging lane on receiving approach of the major road on the behavior of right-turning vehicles from minor road onto major road.

1.3 Objectives

The objectives in this study are:

1. To investigate the merging behavior which is the mean speed of vehicles making a right-turning maneuver from minor road onto major road as soon as they clear the conflict area at different types of unsignalised intersections.

2. To determine conflicting movement for right-turning vehicles from minor road onto major road with major through movement vehicles in the far lanes at different types of unsignalised intersections.

3. To compare the critical gap and follow-up time of vehicles making a right-turning movement from minor road onto major road at different types of unsignalised intersections.

1.4 Significance of Study

Vehicles that make right-turning maneuver from minor road onto major road at unsignalised intersection are the most critical movement and more likely to be involved in an accident. The implementation of short merging lane on the receiving approach of major road has great potential to reduce the conflicts at the intersections. In this study, field study is carried out at different types of T-junctions which include a typical T-junction and T-junctions with short merging lane on the receiving approach where one of the junctions has a short right-turn exit lane while the other has a short through exit lane. The results of this study can provide data and detail study on the effects of implementing a short merging lane on receiving approach of the major road on the behavior of right-turning vehicles from minor road onto major road. In addition, the outcome of this study can act as a guide to design the unsignalised intersection to reduce the conflicts which directly improve the safety of the intersection.

1.5 Scope of Study

The field study is carried out at three different types of T-junctions and is categorized as Type A, Type B and Type C junctions. Figure 1.2 shows the types of T-junctions selected for this study.

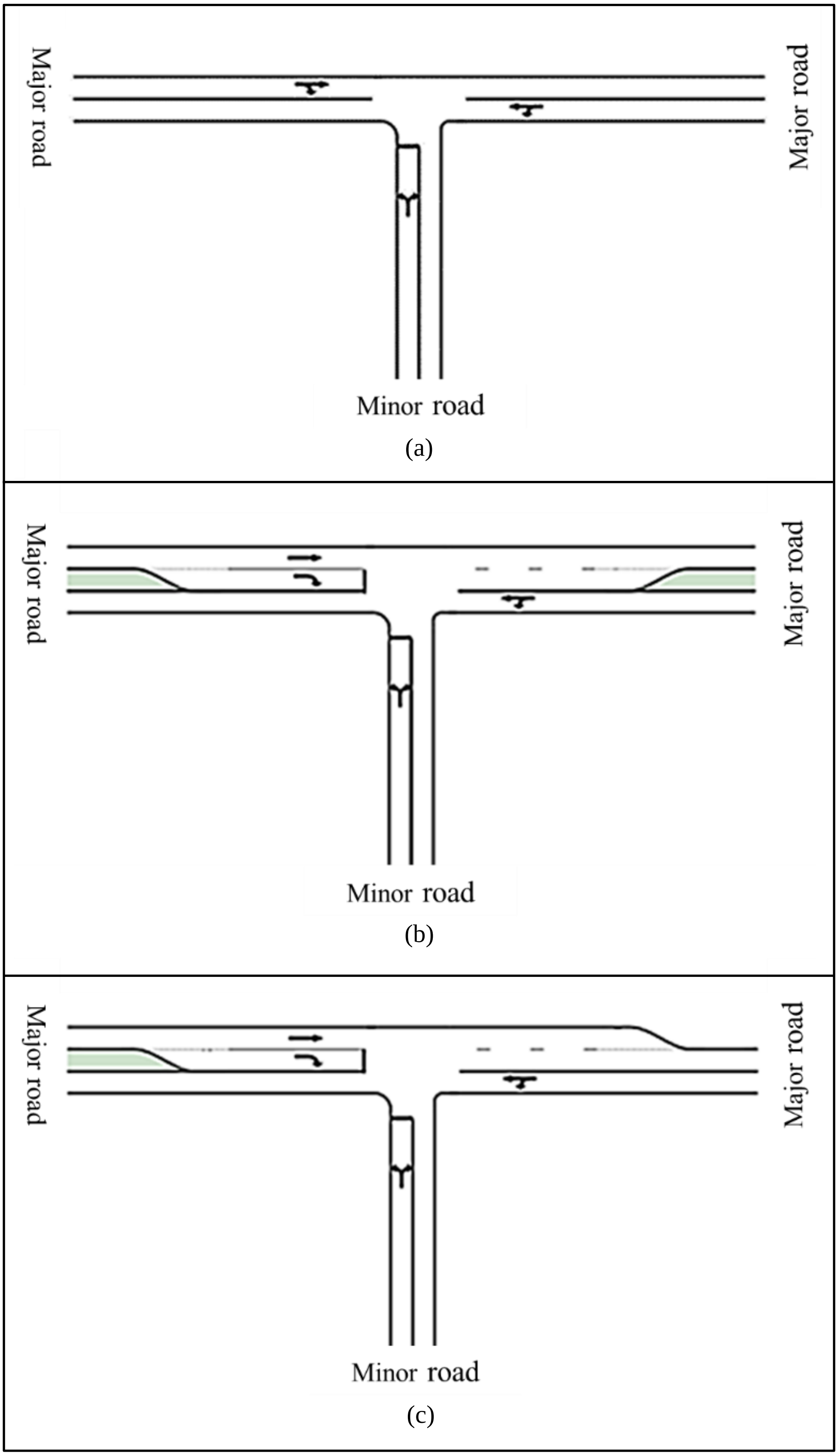

Figure 1.2: Types of T-junctions selected for this study. (a) Type A, (b) Type B and (c) Type C junctions.

In this study, only passenger cars are observed as the traffic composition of passenger cars are higher compared to others vehicle type according to Table 1.2. Besides, motorcyclists that making right-turn movement from minor road onto major road tend to not follow the rules which made the analysis become more complicated.

The critical movement which have the lowest rank of movement is analysed in this study. This critical movement is the right-turn movement from minor road onto major road. Figure 1.3 illustrates the rank of movements at a typical T-junction in Malaysia and the critical movement is represented as number 7.

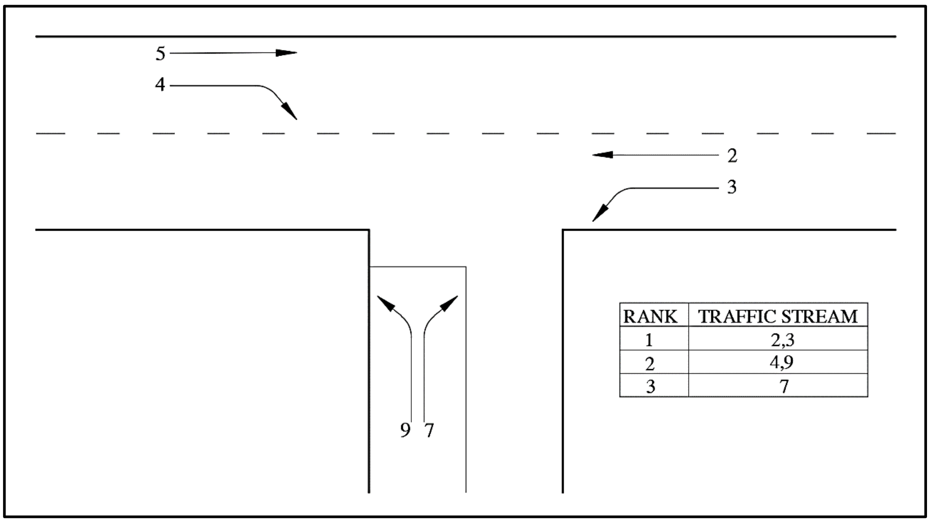

Figure 1.3: Illustration of rank of movements at typical T-junction in Malaysia.

The merging behavior in terms of mean speed and the conflicting movement is observed and compared among Type B and Type C junctions. The critical gaps of three different types of T-junctions are determined by using Raff's method where accepted and rejected gaps of the right-turning vehicles from minor road have to be observed and determined. In addition, the follow-up time which is the time between the exit of a vehicle on the minor road and the exit of a successive vehicle using the same gap is measured under continuous queue condition.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In Malaysia, unsignalised intersections are the probable source where accident normally happen. The movements at unsignalised intersection are dependent on driver's judgement and decision on when, where and how it is safe to cross the intersection. Subramanian and Lombardo (2007) mentioned that unsignalised intersections have higher fatality rates compared to signalized intersections thus more hazardous.

Driver's behavior has intrigued many researchers as different driver will react differently even under a same situation. Ashar Ahmed et al. (2016) noted that past researches on traffic behavior at unsignalised intersections were mainly focused on gap acceptance behavior. Critical gap is one of the parameter that has been used to analyse the capacity of unsignalised intersection.

In this chapter, literature review on previous study similar to this study are carry out to understand more about the objectives of this study. In section 2.2, current literatures on the unsignalised intersection are reviewed. Section 2.3 and Section 2.4 discussed driver's behavior and conflicting movement at unsignalised intersection. Current literatures on the gap acceptance behavior including the parameters such as gap, lag, follow-up time and critical gap and factors affecting gap acceptance behavior are reviewed in section 2.5. Besides, different models to estimate the critical gap are reviewed in section 2.5 as well. The current data collection methods adopted by similar studies are introduced in section 2.6. Meanwhile, the application of Raff's method to determine the critical gap of right-turning movement from minor road onto major road at unsignalised intersection is discussed in section 2.7.

2.2 Introduction to Unsignalised Intersection

Unsignalised intersection is widely used to resolve merging and crossing conflicts at intersection. However, it is suitable for roads with low volume due to lower capacity compared to other intersections. Unsignalised intersection can be categorised into three types which are two-way stop controlled, all-way stop controlled and roundabouts. At two-way stop-controlled intersection, the approaches control by a stop sign is referred as minor approaches whereas major approaches are those not controlled by stop sign. Highway capacity manual 2000 mentioned that a three-legged intersection (or T-junction) is a standard type of two-way stop controlled where the minor approaches is controlled by a stop sign.

According to Troutbeck and Brilon (1997), unsignalised intersections have a hierarchy of streams where some streams have absolute priority, while others have to yield to higher order streams. Consider a three-legged intersection, the major road through vehicles have priority over all the conflicting traffic. Meanwhile, the Highway Capacity Manual (2000) left turning vehicles (right-turn in Malaysia) from minor road onto major road have the least priority and are required to yield the right of way to all other conflicting movements.

In previous study by Abdul Manan (2014) vehicles that make a right-turning maneuver from minor road to major road at unsignalised intersections in Malaysia experience more conflicts as compared to left turning vehicles. Vehicles making right turn from minor road onto major road have to experience crossing conflict with the major through movement vehicles in the near lane and vehicles making right turn from major road onto minor as well as merging conflict with the major through movement vehicles in the far lane.

2.3 Drivers' Behavior

Drivers' behavior at unsignalised intersections is more complicated as compare to that at signalized intersections. Each driver must make decisions based on his/her judgement on suitable gap and perceptions of distance and velocity to complete a movement.

Greenshields (1934) wrote that past researchers were interested on traffic behavior since 1930s. Liu et al. (2017) studied on the crossing behavior of drivers and primarily focus on drivers' risk perception at unsignalised intersections in China. Muttart et al. (2011) related drivers' behavior at unsignalised intersection with their compliance to stopping rule in their study. Ashar Ahmed et al. (2016) studied the movement type of vehicle making right turn from minor road onto major road. The movement types include conventional right-turn and unique right-turning maneuver termed as the "Weaving Merging right-turn". However, Ashar Ahmed et al. (2016) also noted that past researches on drivers' behavior at unsignalised intersections were mainly focused on gap acceptance behavior only.

2.4 Conflicting Movement

Amundsen and Hyden, (1977) defined traffic conflicts as an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged.

Highway Capacity Manual (2000) wrote that each movement at an unsignalised intersections will experienced different set of traffic conflict. The left turn from the minor road at a T-junction, for example, is in merging conflict with only the major-street through movement in the near lane into which left-turners will merge. Meanwhile, vehicles making right turn from major road conflict with the total opposing through and left-turn flows. They experience crossing conflict with the through flow and merging conflict with the left turn flow. Vehicles making right turn from minor road onto the major road have the least priority and most conflicts. They experience crossing conflict with the major through movement vehicles in the near lane and the opposing right turn from major road onto minor road as well as merging conflict with the major through movement vehicles in the far lane.

2.5 Gap Acceptance

Unsignalised intersections do not control and tell drivers when to leave the intersection. Troutbeck and Brilon (1997) wrote that the driver must look for a safe opportunity or “gap” in the traffic stream to enter the intersection. This technique has been described as gap acceptance approach. According to Troutbeck and Walsh (1994), this approach assumes that drivers from the minor road wait until there is a satisfactory gap in the traffic stream on the major road before entering the intersection. Highway Capacity Manual (2000) defined the gap acceptance as the process by which a minor road vehicle accepts an available gap in conflict stream to complete his/her maneuver.

Highway Capacity Manual (2000) mentioned that the gap acceptance theory has three basic elements. First, the size and distribution (availability) of gaps in the major traffic stream. Second, the usefulness of these gaps to the minor stream drivers. Third, the relative priority of the various traffic streams at the intersection. Meanwhile, Troutbeck and Walsh (1994) wrote that there are two basic elements in gap acceptance theory which quantify the usefulness of gaps of a particular size or opportunities to enter the intersection and the proportion of gaps of a particular size to enter the intersection and their associated arrival patterns are also required.

Troutbeck and Brilon (1997) mentioned that the drivers are assumed to be consistent and homogenous in the theory used in most guides for unsignalised intersections around the world. A consistent driver is expected to behave the same way every time at all similar situations whereas a homogenous population, all drivers are expected to behave in the same way. However, it is known that drivers will have different judgements on distance and speeds and thus react differently towards the same gap. Previous study by Catchpole and Plank (1986) have indicated that the entry capacity will decreased if the drivers are heterogeneous. According to Troutbeck (1988), if drivers are inconsistent then the capacity would be increased. However, the difference in the predictions is only a few percent if drivers are assumed to be both consistent and homogeneous, rather than more realistically inconsistent and heterogeneous. Therefore, for simplicity, drivers are always assumed to be consistent and homogeneous.

2.5.1 Gap

Gap is measure of time interval between two consecutive vehicles that travel in the same direction on the traffic stream. The gap is measured from the rear bumper of the front vehicle to the front bumper of the next vehicle. Figure 2.1 illustrated gap between two consecutive vehicles.

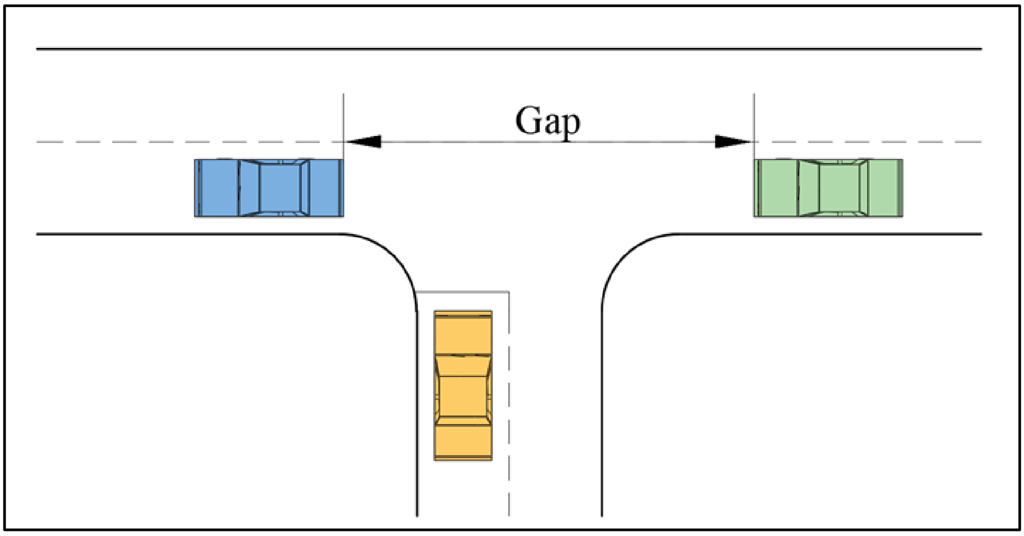

Figure 2.1: Gap between two consecutive vehicles.

2.5.2 Lag

Lag is different with gap, it measures time interval between two consecutive vehicles on different roads. Generally, lag is the time taken of the major road vehicles to reach the front bumper of the vehicle on the minor road. Figure 2.2 shows lag between two consecutive vehicles on different roads.

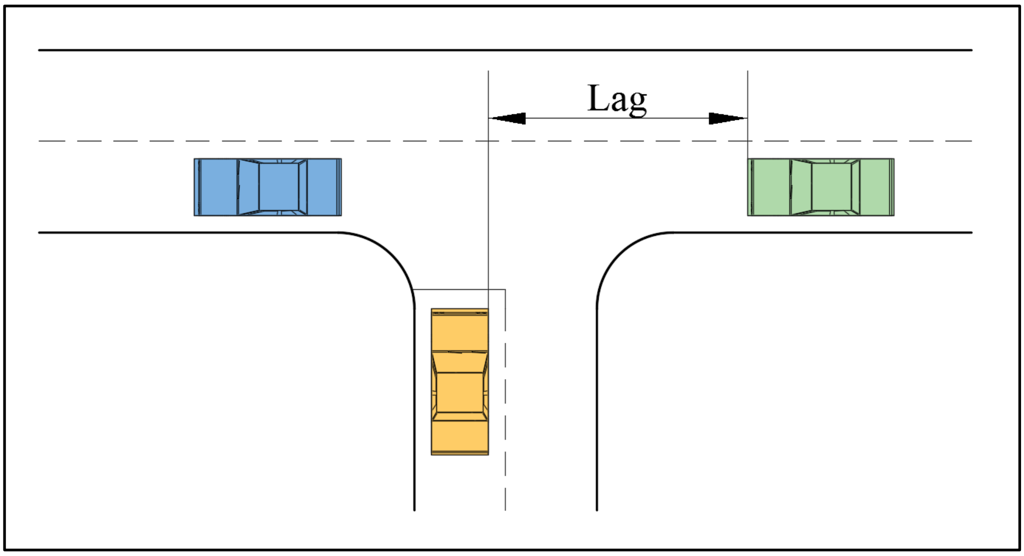

Figure 2.2: Lag between two consecutive vehicles.

2.5.3 Follow-up Time

Rodríguez (2006) mentioned that follow-up time is defined as the time between the exit of a vehicle from the minor road and the exit of a second vehicle using the same gap. It is measured under continuous queue conditions only. Figure 2.3 shows the follow-up time of vehicles making right-turn from minor road.

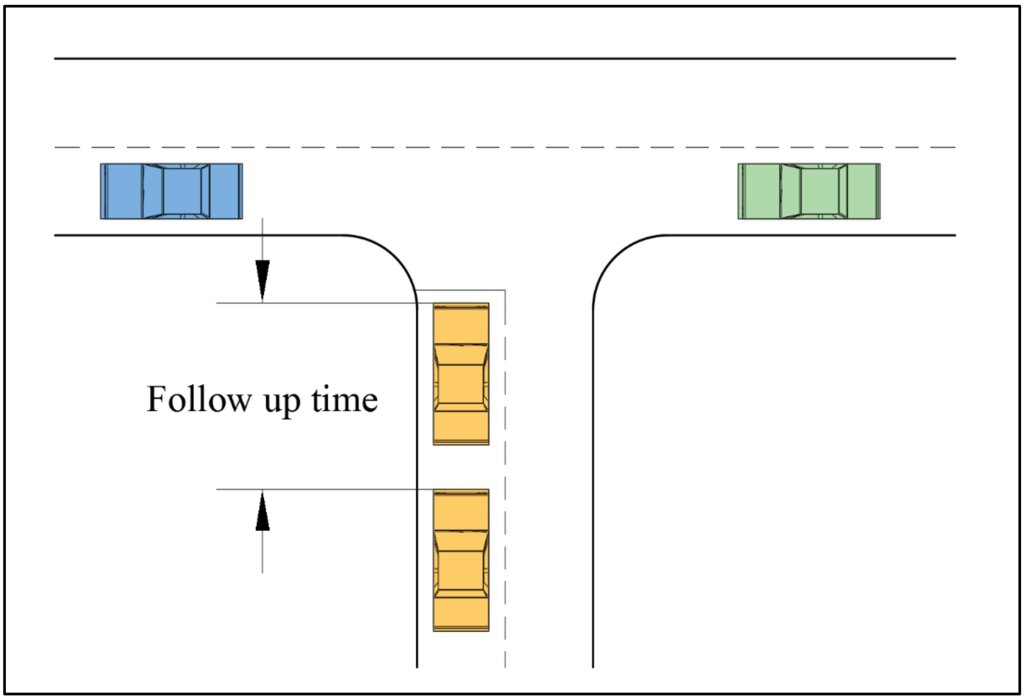

Figure 2.3: Follow-up time between two consecutive vehicles.

2.5.4 Critical Gap

The Highway Capacity Manual (1985) defined critical gap as the median time headway between two successive vehicles in the major road traffic stream that is accepted by a driver in a subject movement that must cross and/or merge with the major street flow. However, Kyte et al. (1994) mentioned that some researchers questioned this definition, as the median value is a weak representation of the overall gap acceptance data. Meanwhile, Kittelson and Vandehey said the correct approach is to consider both accepted and rejected gap data when estimating the size of the critical gap (cited in Gattis and Low, 1998).

The estimation of critical gap is a difficult task in empirical traffic engineering science. Andrea (2012) mentioned that different models have been introduced to estimate the critical gap including method of Raff (1950), Maximum Likelihood Method (MLM) of Troutbeck (1992) and method of Wu (2006).

2.5.4.1 Model of Troutbeck

Maximum Likelihood Method (MLM) was used for estimating gaps in the model of Troutbeck (1992). The probability of the critical gap is calculated through the Maximum Likelihood Method (MLM) in Troutbeck's microscopic model. Andrea (2012) mentioned that the model assumes the log-normal distribution of accepted and maximum rejected gaps and only the accepted gap and the maximum rejected gap of each vehicle are treated pair wise. In brief, one accepted gap and one corresponding maximum rejected gap must be observed from one individual minor street driver. The maximum rejected gap refereed to the largest values of all rejected gaps for one minor street driver. According to Andrea (2012) the best known standard manuals for traffic engineering including HCM 2000 and HBS 2001 have recommended this method to estimate the critical gaps. However, one of the disadvantage of this model is that it assumes that the driver behaviour is both homogeneous and consistent. Furthermore, the model of Troutbeck (1992) was noted to be very complicated to common use for traffic engineers.

2.5.4.2 Wu’s Method

A new model for estimating the critical gaps was presented by Wu (2006) in which the probability equilibrium between the rejected and the accepted gaps is the theoretical foundation of this model. Wu (2006) mentioned that the equilibrium is established macroscopically from the cumulative distribution of the rejected and accepted gaps. Unlike model of Troutbeck (1992), this model takes into account all the rejected gaps rather than taking the maximum rejected gaps only. In previous study by Amin and Maurya (2015), Wu's model was found to produce similar results for the mean critical gap as obtained from Troutbeck's model when using maximum rejected gap instead of all rejected gaps and if considering all rejected gaps, mean critical gaps would be shorter than previous results. However, the model is suitable for little sample size only as in the observation data, the minimum accepted gap should be smaller than the utmost rejected gap.

2.5.4.3 Raff's Method

Raff's method (1950) is the most common method used to determine the critical gap of an intersections due to its simplicity. This method is based on macroscopic model. Troutbeck (2016) mentioned that Raff defines critical gap as the number of accepted lags shorter than the critical lag is equal to the number of rejected lags longer than the critical lag. Amin and Maurya (2015) mentioned that the original Raff theory uses solely lag data which was thought of as statistically wasteful by some previous literatures. Therefore, to remedy this disadvantage, Raff's method assumed critical gap have the same value as critical lag. Hence, both gap and lag are used to determine critical gap. Besides, to avoid over-representing cautious drivers, Raff et al. decided to use only the first rejected gap instead of the largest gap (cited in Gattis and Low, 1998). Amin and Maurya (2015) also mentioned that the only disadvantage of this method is its sensitiveness to the traffic volumes.

2.5.5 Factors Affecting Gap Acceptance Behavior

Previous study carried out by Hamed et al. (1997) have indicated that gap acceptance is significantly influenced by such factors as the expected waiting time at the head of the queue, driver socioeconomic characteristics, and time of day. Meanwhile, the study also indicated that the waiting time of a driver at the head of the queue was affected by intersection channelization, gender, and work trips. The results showed that intersections with left turn lane and median, male drivers and traveling during the off-peak period tend to decrease the expected waiting time and increase the hazard rate.

Kyte et al. (1991) mentioned that a long queue-waiting time may reduce the driver's gap acceptance time. The longer the queue-waiting time, the better the driver able to estimate the size of upcoming gaps and the driver tends to accept a shorter gap. Previous study by Wager (1966) also indicated that drivers accept smaller lags and gaps during peak periods than during off-peak hours. According to Akcelik (1994), the gap acceptance behavior was dependent on the traffic volume and the arrival pattern of vehicles on the major road. Karthika and Bino (2014) noted that types of vehicles will affect the driver's gap acceptance behavior as different vehicles will have different operational characteristics like speed, dimensions, power weight ratio and response to presence of vehicles in traffic stream.

2.6 Data Collection Methods

Different ways had been introduced to collect gap acceptance data. Daganzo (1981) mentioned that the best method to observe driver's gap acceptance behavior is through field investigation. Video recording is the most common method use to record the driver's behavior at intersection and process it off site. This approach had been used in study conducted by Fitzpatrick (1991), Teply et al., (1997), Yang (2012), etc.

However, Currin (cited in Nabaee et al., 2011) mentioned that there was a challenge to find a suitable location for video recording as the camera need to be in inconspicuous place so that it will not affect the behavior of driver, while allowing for a full view of the study intersection.

Meanwhile, a study conducted by Gattis and Low (cited in Nabaee et al., 2011) at a typical stop-controlled intersection used a traffic classifier which located at the upstream of the intersection to collect approach speeds and arrival times. In the study conducted by Ashar Ahmed et al. (2016) MetroCount MC5600 data loggers was used in addition to video cameras to collect the time stamp, type of vehicle, direction of travel, speed and distance from the preceding vehicle at the intersection.

2.6.1 Data Collection using Video-Based Systems

Video data collection produced higher quality data than manual methods as it constitutes a permanent record. The real situation at site is recorded and researchers can process the data off site and review the situation several times. Bonneson and Fitts (1995) mentioned that researchers can easily obtain event-times data with accuracy of 0.1 second. Gattis and Low (1998) mentioned that by using the frame-by-frame replaying feature, a researcher can exercise careful and unhurried judgement when unusual, complicated, or rapid events occur.

2.7 Application of Raff's Method

According to gap acceptance studies carried out by Rodríguez (2006), Raff's method involved developing a gap acceptance graph to determine movement's critical gap. Garber and Hoel (1997) mentioned that to develop a gap acceptance graph, two cumulative distribution curves are drawn as shown in Figure 2.4. One of them relates gap lengths t with the number of accepted gaps less than t, and the other relates t with the number of rejected gaps greater than t. The intersection of these two curves gives the value of t for the critical gap.

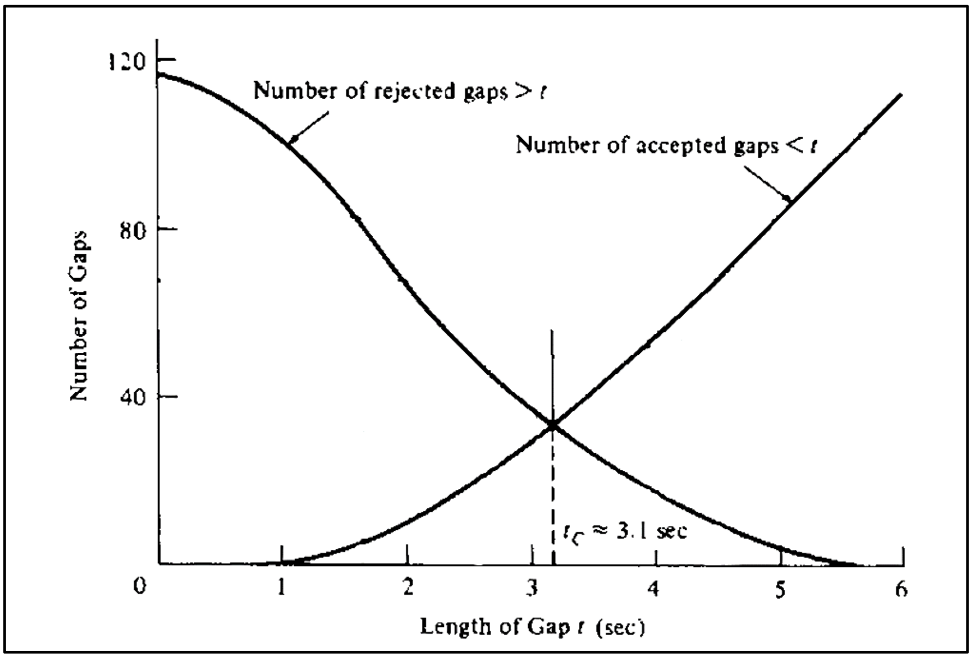

Figure 2.4: Cumulative distribution curve for accepted and rejected gaps (Garber and Hoel, 1997).

Gattis and Low (1999) mentioned that a 12s to 15s gap are large enough to be accept by most of the drivers and it should not be used for analysis as it does not reflect the driver's gap acceptance behavior (cited in Nabaee et al., 2011). Kittleson and Vandehey (1991) studies about gap acceptance behavior and indicated that most drivers will accept 12s gaps (cited in Pollatschek et al., 2002). In Rodríguez (2006) study, all accepted are grouped into different classes which are from class 1 (0 to 0.99s), class 2 (1.0s to 1.99s) until 12s are reached. The number of observed acceptance are accumulated to develop a distribution curve for accepted gaps. The same process is repeated for rejected gaps, but the number of rejected observations is subtracted from the total number of observations until 0s is reached instead of accumulating it.

2.8 Summary

Vehicles making right turn from minor road onto the major road have the least priority and most conflicts. The objective of this study is to determine the impact of the existence of short merging lane on the behavior of right-turning vehicles from minor road. Gap acceptance study is one of the most common behavior study that have been carried out previously. Critical gap and follow up time are the main parameters in gap acceptance study. Meanwhile, Raff's method is found to be the most common method in estimating the critical gap due to its simplicity. Besides, video recording is the best method for field investigation as it records real-time situation which can be process off site.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter presents the research methodology to study the behavior of right-turning vehicles at different types of unsignalised intersections. Field study is conducted at three types of unsignalised intersections. Suitable intersections are selected based on intersection geometry and traffic volume. Google Maps and preliminary site survey are used to identify suitable intersections. Then, site survey is conducted to ensure that the junctions selected meet the required criteria. The traffic data including time stamp, vehicles types, direction of travel and speed of vehicles are collected by using Metrocount Vehicle Classifier System. Meanwhile, the behavior of right-turning vehicles from minor road is observed by using video camera. The data collected from Metrocount and Video Camera are extracted and statistically analysed. The merging behavior which is the mean speed of right-turning vehicles from minor road to major road is determined and compared between Type B and Type C junctions. Meanwhile, the conflicting movement of right-turning vehicles from minor road with major through movement vehicles in the far lane at Type B and Type C junctions are identified. The gap acceptance behavior which include critical gap and follow-up time of right-turning vehicles from minor road at each intersection is determined and compared as well. The developed methodology is outlined in a flowchart as shown in Figure 3.1.

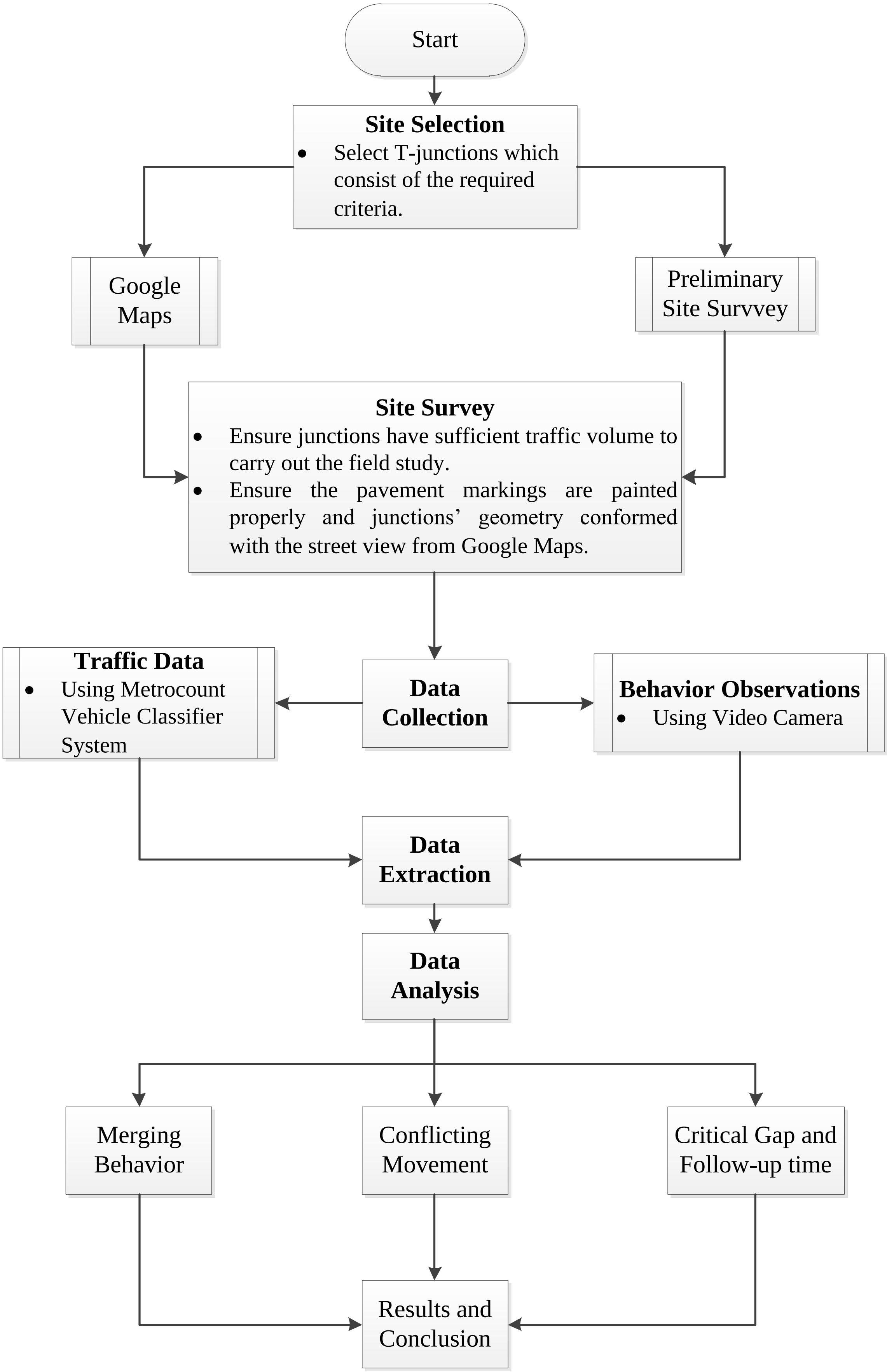

Figure 3.1: Flowchart for developed methodology.

3.2 Site Selection

Preliminary site selection is conducted by using Google Maps to identify suitable intersections for this study. Street View function in Google Maps is used to have a clear look on the intersections that conformed in different criteria or had certain characteristics, both operational and geometrical. Besides, preliminary site survey is also performed across the urban areas in Nibong Tebal and Parit Buntar to identify suitable intersections. Three different types of T-junctions are selected for this study. All the intersections selected are two way stop-controlled intersection where the minor approach is controlled by a stop sign. The major and minor road vehicles must be able to make both left and right turns. There must be no traffic signal nearby the intersection as traffic signal will cause platoon on the major traffic stream. Besides, staggered T-junction which may increase the traffic conflict at intersections is avoided. The stop line at the minor approach and the lane marking in the middle to separate the traffic moving in the opposite direction must be painted properly. Flat access grade is also one of the criteria used to select the intersections for this study. The three different types of T-junctions are categorised into Type A (typical T-junction), B and C junctions.

3.2.1 Type A junction (Typical T-junction)

A typical T-junction with no channelizing islands or auxiliary lanes to restrict the movement or guiding the path of the turning vehicles respectively is selected for this study. Geometrical characteristics including flat access grade and one lane per direction are considered in site selection. Figure 3.2 shows the diagram of Type A junction.