EFFECTIVENESS OF WAITING AREA FOR MOTORCYCLISTS AT SIGNALIZED INTERSECTION

YOUSSEF SALAHELDIN HEGAZY ABDRABOU

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2022

EFFECTIVENESS OF WAITING AREA FOR MOTORCYCLISTS AT SIGNALIZED INTERSECTION

By

YOUSSEF SALAHELDIN HEGAZY ABDRABOU

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

August 2022

UNIVERSITI SAINS MALAYSIA

Appendix A8

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2021/2022

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: Effectiveness of waiting area for motorcyclists at signalized intersection

Name of Student: Youssef Salaheldin Hegazy Abdrabou

I hereby declare that all corrections and comments made by the supervisor and examiner have been taken into consideration and rectified accordingly.

Signature:

Youssef

Date : 09/08/2020

Approved by:

(Signature of Supervisor)

Name of Supervisor : ASSOC. PROF. DR. LEONG LEE VIEN

Date : 10/08/2022

Approved by:

(Signature of Examiner)

Name of Examiner : **Prof. Dato' Dr. Ahmad Farhan bin Mohd Sadullah**

Date : **10th August 2022**

ACKNOWLEDGEMENT

This work would not have been possible without the constant support, guidance, and assistance of my supervisor Assoc. Prof. Ir. Dr. Leong Lee Vien for her guidance, patience, knowledge, and ingenuity is something I will always keep aspiring to. I would also like to thank my colleagues Mostafa, Anas and Mohd Rizal for helping me during my study.

Last but not least, I would like to express my heartfelt thanks to my family for their constant support, patience, and encouragement, since none of this would have been possible without them.

ABSTRAK

Motosikal adalah salah satu pilihan yang paling menjimatkan dan berdaya maju untuk pengangkutan mampu milik di kebanyakan negara membangun. Malaysia menderita akibat kemalangan motosikal, menyumbang kepada lebih 60 peratus kematian jalan raya setiap tahun. Walaupun pelbagai tindakan balas seperti pengasingan fizikal penunggang motosikal daripada kenderaan lain telah dilaksanakan, kawasan konflik yang tinggi seperti persimpangan masih menjadi isu. Penyediaan ruang khusus untuk penunggang motosikal di persimpangan dalam bentuk ruang menunggu bukanlah sesuatu yang baharu; menyediakan kenderaan yang disasarkan permulaan apabila isyarat lalu lintas berubah daripada merah kepada hijau. Majlis Bandaraya Pulau Pinang (MBPP) baru-baru ini mengguna pakai penggunaan ruang menunggu untuk penunggang motosikal, kajian ini dilakukan untuk menentukan tingkah laku penunggang motosikal yang ketara di tempat menunggu di persimpangan bertanda, keberkesanan kotak ruang menunggu untuk penunggang motosikal, dan masa yang hilang semasa permulaan. disebabkan oleh penunggang motosikal kepada pengguna jalan raya yang lain. Pengumpulan data dilakukan untuk mengumpul tingkah laku penunggang motosikal di kawasan menunggu, penggunaan ruang menunggu oleh penunggang motosikal, dan penambahan masa yang disebabkan oleh penunggang motosikal di persimpangan isyarat selepas kawasan menunggu beroperasi. Kajian mendapati penunggang motosikal tersebut cenderung memasuki ruang menunggu berdasarkan keputusan yang diperoleh daripada data yang diekstrak. Keberkesanan ruang menunggu bergantung kepada penggunaan ruang menunggu dan kadar penghunian yang digunakan untuk menentukan keberkesanan. Pendekatan arah selatan dan arah utara dipilih di persimpangan isyarat antara Jalan Jelutong, dan Jalan Sungai Pinang di negeri Pulau Pinang berdasarkan kesesuaian lokasi. pendekatan arah selatan dan arah utara memberi kesan positif kepada kawasan menunggu

pada waktu puncak pagi dan petang. Di samping itu, kadar penghunian pagi dan petang menghala ke selatan masing-masing ialah 77.22% dan 55.56%, manakala pendekatan arah utara untuk waktu puncak pagi dan petang masing-masing ialah 50.00% dan 50.83%. Kadar penghunian menunjukkan bahawa keberkesanan ruang menunggu untuk kedua-dua pendekatan di persimpangan isyarat antara Jalan Jelutong dan Jalan Sungai Pinang adalah melebihi 50%, dianggap berkesan. Walau bagaimanapun, data yang diperoleh untuk masa kehilangan permulaan menunjukkan peningkatan yang ketara dalam masa tambahan. Bagi pendekatan arah selatan pagi dan petang, masa tunda masing-masing ialah 7.79 saat dan 7.30 saat, manakala bagi pendekatan arah utara, masa tunda pagi dan petang adalah masing-masing 7.53 saat dan 7.42 saat.

ABSTRACT

The motorcycle is one of the most economical and viable options for affordable transport in most developing countries. Malaysia suffers from the onslaught of motorcycle crashes, contributing to more than 60 percent of road deaths yearly. While various countermeasures such as physical segregation of motorcyclists from other vehicles have been implemented, high conflict area such as the intersections remains an issue. The provision of a dedicated space for motorcyclists at intersections in the form of waiting area is not something new; providing targeted vehicles a head starts when the traffic signal changes from red to green. The City Council of Penang Island (MBPP) of the Penang state has recently adopted the use of waiting areas for the motorcyclist, this study was done to determine the significant motorcyclist's behaviour in the waiting area at a signalized intersection, the effectiveness of the waiting area box for the motorcyclist, and the start-up lost time caused by the motorcyclist to the other road users. Data collection was conducted to collect the motorcyclist's behaviour in the waiting area, the utilization of the waiting area by the motorcyclist, and the additional time caused by the motorcyclist at a signalized intersection after the waiting area is in operation. The study found that the motorcyclist tends to enter the waiting area based on the results obtained from the extracted data. The effectiveness of the waiting area depends on the utilization of the waiting area and the occupancy rate used to determine the effectiveness. The southbound and the northbound approaches were chosen at the signalized intersection between Jalan Jelutong, and Jalan Sungai Pinang in Penang state based on the suitability of the location. the southbound and the northbound approaches positively affects the waiting area during morning and evening peak hours. Additionally, the southbound approach morning and evening occupancy rate is 77.22% and 55.56%, respectively, while the northbound approach for morning and evening peak hours is 50.00% and

50.83%, respectively. The occupancy rate shows that the effectiveness of the waiting area for both approaches at the signalized intersection between Jalan Jelutong and Jalan Sungai Pinang is above 50%, considered effective. However, the data obtained for the start-up lost time showed a significant increase in the additional time. For the southbound approach morning and evening, the delay time is 7.79 seconds and 7.30 seconds, respectively, while for the northbound approach, the delay time morning and evening are 7.53 seconds and 7.42 seconds, respectively.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General

Motorcycle is one of the primary vehicles in urban areas in Asian countries, such as Malaysia, Indonesia, Thailand, and Vietnam. Asian countries experience problems in road safety because of the increase in motorcycles. Due to many motorcycles, almost every road lane is saturated. In this case, Malaysia is one of the countries that have increased in two-wheeled vehicles.

Many vehicle crashes occur yearly in the signalized intersection area, particularly involving vulnerable road users. Although signalized intersections were designed to avoid conflicts, they nonetheless provide an issue in some circumstances, particularly in ASEAN countries where a high number of motorcycles. When the signals at a signalized intersection change phase, this will cause conflicts and delays for other vehicles. At intersections, the combined interaction of vehicles with different types of the road users, such as motorcyclists and pedestrians, caused more conflict. Motorcyclists frequently squeeze between vehicles and wait outside stop lines and painted islands (Ramli et al., 2020).

1.2 Problem statement

Economic conditions and motorization have accelerated in Southeast Asian countries over the last two decades. In this area, the motorcycle has become a standard method of transportation. The reported number of motor vehicles in Pulau Pinang, Malaysia, in June 2018 was estimated to be around 2,695,336 (Malaysian automotive association, 2018).

In Malaysia, as the percentage of motorcyclists increases, the accident rate involving motorcycles has also increased, and this critical issue must be addressed. Due

to the high accident rate, the Penang Island City Council (MBPP) has marked 53 waiting areas for motorcycles at the signalized intersections around George Town as a special zone for motorcycle riders to stop safely. The area of interest in this study is the state of Pulau Pinang.

Traffic congestion causes delays, which have additional negative consequences such as expenses to the individual such as increased travel time, society such as pollution, accident risk, and business daily such as delivery delays. Road congestion has a more substantial effect in urban areas since vehicles frequently share the road with other road users such as cyclists and pedestrians (de Angelis et al., 2019). Start-up lost time is an important parameter in the performance of signalized intersections that can reflect the influence of different drivers' behaviour (Çalışkanelli et al., 2017).

Malaysia Institute of Road Safety Research (MIROS) studied the road accident data in 2011 and found that the cause of road accidents is mainly human behaviour. Therefore, the behaviour of the motorcyclist, utilization of the waiting area, and the start-up lost time can all be computed from the data collected through the video footage taken on-site, using a setup consisting of a video camera and a timer during morning and evening peak hour. The data extracted will be utilized to determine the effectiveness of the waiting area and delay time in the signalized intersection.

1.3 Objectives

The objectives of this project are:

I. To study the behaviour of motorcyclists at the stopping area of signalized intersection

II. To study the effectiveness of waiting area

III. To study the effect of motorcycles stopping in the waiting areas on start-up lost time

1.4 Scope of work

The research focus area is the signalized intersection between Jalan Jelutong and Jalan Sungai Pinang in Pulau Pinang state. The waiting area has been implemented recently in Pulau Pinang. After observing different signalized Intersection between Jalan Jelutong and Jalan Ahmad Nor, signalized Intersection between Jalan Jelutong and Jalan Sungai Pinang and signalized Intersection between Jalan Dato Keramat and Jalan Patani during peak hours, the signalized intersection between Jalan Jelutong and Jalan Sungai Pinang is found to have higher traffic volume than the Signalized Intersection between Jalan Jelutong and Jalan Ahmad nor and the Signalized Intersection between Jalan Dato Keramat and Jalan Patani which makes the location suitable for the study. The waiting area at the signalized intersection was chosen to study the motorcyclist's behaviour and obtain the waiting area effectiveness depending on the number of motorcycles in the waiting area zone and the lost time caused by the motorcyclist at the signal.

Data collection conducted to obtain the objectives, and the data collected will determine how effective the waiting area is at the signalized intersection.

1.5 Significance of this study

The objectives of this study are to study the motorcyclists' behaviour and evaluate the waiting area's effectiveness. Determine the start-up lost time will help the traffic engineers determine the timing signal phasing to achieve optimal efficiency and maximize vehicular throughput at the signalized intersection. Indicating the delay time caused by the motorcyclist to the other road users after implementing the waiting area at a signalized intersection in Penang state will enable the traffic engineers to design the junction more effectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Many studies have found that motorcyclist behaviour influences the possibility of motorcycle crash accidents. Research on risk behaviours has been extensively conducted.

In this chapter, literature reviews on previous studies similar to this study are carried out to understand more about the objectives. In Section 2.2, the advanced stop line (ASL), which is the motorcyclist's waiting area, is reviewed. Based on the research by Mulyadi, (2017a), Mulyadi, (2017b) and Mohamad et al., (2019) the Advanced stop line effectiveness in the signalized intersection is based on the utilization of the waiting area for the motorcyclists. Behaviour of the motorcyclist is discussed according to many studies (J. P. Allen and Brown, 2008; Dula and Geller, 2003; Jafarpour and Rahimi-Movaghar, 2014; Mulyadi and Amelia, 2013; Paiman et al., 2020; Shams and Rahimi-Movaghar, 2009). The risky behaviour of motorcyclists on the roads is reviewed in Section 2.3. In Section 2.4, Traffic conflict caused by the motorcyclist at signalized intersections with consideration of applying a waiting area for the motorcyclist is discussed. Recent literature on the influences of the motorcyclist at a signalized intersection on the operation of the traffic is reviewed in Section 2.5, start-up lost time which is of the important factors in improving the performance of the signalized intersections.

2.2 Advanced stop line (ASL)

Many countries have implemented the ASL for the signalized intersection for many reasons, such as the traffic conflict and the rise in accidents. Malaysia has been suffering from the onslaught of motorcycles crashes, which contributes to more than 60% of road deaths yearly. In 2018, out of 6,284 road fatalities, 65.9% were motorcyclists and pillion riders.

The main attractive factors of the motorcycle used are because of some reasons such as affordable purchase price, cosy of daily usage, easy to use and not required large parking slot. In a study by Mulyadi (2017b) in Bogor, Indonesia, the research focuses on evaluating ASL at signalized intersections before implementing the ASL and after implementing the ASL. The data has been collected at Pajajaran road south and north approaches. The study shows that the motorcycle occupancy rates at the ASL were poor. It was due to the low volume of the motorcyclist that passed by the intersection and was also caused by the four-wheel vehicles stopping at the ASL for the motorcyclist, which blocked the motorcyclist from entering it.

Moreover, in a study conducted by Mulyadi (2017a) in Indonesia to evaluate the influence of dimension box differences and time differences during ASL operations for motorcyclists at signalized intersections, different intersections were selected for the study in different places, as shown below in Table 2.1.

The data collected and analysed at different locations shows that the more significant dimension and longer red time operation has the lowest occupancy, about 31%. Meanwhile, the intersection with the smaller dimension and faster red time operation has the highest occupancy rate of as much as 47%.

Table 2.1: Conditions of the intersections of red box for motorcycles (Mulyadi, 2017a)

TABLE 2. Conditions of the intersections of red box for motorcycles

Intersections	Dimension of Red Box for Motorcycles	Static Space for 1 Motorcycle	Red Box Capacity (Motorcycles)	Red Time Operation (Seconds)
Intersection of Dewi Sartika – Diponegoro	Width 10 m x length 8 m and Width 10 m x length 8 m	1.5 m^2	58	110
Intersection of Sudirman-Puputan	Width 8 m x length 6 m	1.5 m^2	32	110
Intersection of Jendral Sudirman -Yos Sudarso	Width 9 m x length 6 m	1.5 m^2	36	35
Intersection of Puputan-Kusumaatmaja.	Width 9 m x length 6 m	1.5 m^2	36	27

According to research conducted by Mohamad et al. (2019). The study of the effectiveness of ASL at a different signalized intersection in Kuala Lumpur as shown in Table 2.2, a data collection was conducted in different intersections during peak hours to study the effectiveness of the ASL, from the data obtained and analysed. Figure 2.1 shows an example of the ASL in Kuala Lumpur. Details of the selected intersection with ASL shown in Table 2.2 while the occupancy rate for the different intersections was between 5% to 33%, as shown in Table 2.3.

Figure 2.1 : The example of an ASL for motorcycle at one of the signalized intersections in Kuala Lumpur (Mohamad et al., 2019)

Table 2.2 : Details of the selected intersection with ASL (Mohamad et al., 2019)

Location	ID	Intersection Type	ASL Dimension [Width x Length] (m)
Intersection Jalan Sultan Ismail – Jalan Raja Laut	I01	4-legged with 3-way stopped controlled	7.3 m x 14.1 m = 102.9 m
Intersection Jalan Sultan Ismail – Jalan Tuanku Abdul Rahman	I02	4-legged with 3-way stopped controlled	6.3 m x 16.1 m = 101.4 m
Intersection Jalan Raja Laut – Jalan Dang Wangi	I03	4-legged with 2-way stopped controlled	6.6 m x 15.5 m = 102.3 m
Intersection Jalan Tuanku Abdul Rahman – Jalan Mara	I04	3-legged with 2-way stopped controlled	6.1 m x 17.4 m = 106.1 m

Table 2.3: ASL Occupancy Rate (Mohamad et al., 2019)

ID	ASL area (m^2)	Motorcycle area (m^2) [0.8m x 2.0m]	ASL capacity (motorcycle)	Average number of motorcycle / red phase (motorcycle)	Occupancy rate (%)
I01	102.9	1.6	64	9	14
I02	101.4	1.6	63	21	33
I03	102.3	1.6	64	3	5
I04	106.1	1.6	66	4	6

Based on the assessment of occupancy rate suggested by Mulyadi (2017b) , it was clear that all study location indicates poor ASL utilization. The highest occupancy rate of 33% can only be observed at location I02 (Intersection Jalan Sultan Ismail – Jalan Tuanku Abdul Rahman), which may be attributed to the high volume of the motorcycle at the location.

The performance of the ASL was evaluated by the occupancy rate during red light phase where high occupancy rate may indicate the effectiveness of ASL provided and vice versa. Since the study on ASL in Malaysia is still new and limited, the assessment of occupancy rate was adopted from the study conducted by Mulyadi (2017a) as shown in Table 2.3.

Table 2.4 : Assessment of occupancy rate by motorcycle to the ASL capacity (Mulyadi, 2017a)

Occupancy rate by motorcycle to the ASL capacity (%)	Assessment
> 80 %	Good
50 % - 80 %	Marginal
< 50%	Poor

The occupancy rate is defined as the percentage of the number of motorcycles occupying the ASL during the red-light phase to the ASL capacity and can be translated into Eq. (2.1).

Occupancy Rate by Motorcycle to the ASL Capacity =

$$\frac{Average\ number\ of\ motorcycles\ that\ occupied\ the\ ASL}{ASL\ capacity} \times 100\% \quad (2.1)$$

The occupancy rate of ASL was low at all study locations where the maximum occupancy observed was only 33%, i.e., at intersection Jalan Sultan Ismail – Jalan Tuanku Abdul Rahman. At other locations, the occupancy rate was below 15%. The low occupancy rate of ASL was because of the car users stopping at the ASL. A maximum of 7 passenger cars were found occupying the ASL during a single red phase, thus reducing the area available for motorcycles inside the ASL.

Malaysia has implemented a designated waiting area at signalized intersections, known as an Advance Stop Line (ASL) or advance stop box. During the red phase, ASL serves to separate motorbikes from other vehicles. This reduces the chances of a

motorbike crashing with other vehicles. This solution can reduce the number of accidents involving motorcycles and other vehicles. The study aims to compare the conflict rate with and without the provision of ASL at the signalized intersection. The data obtained from this study will be collected by site observation on weekdays in the morning and afternoon. The result shows that the difference in average traffic conflicts rate between signalized intersections without and with the implementation of ASL was 71.2% (Ramli et al., 2020).

2.3 Behaviour of motorcyclist

Positioning of the motorcyclist at ASL is depends on the rider's behaviour during the period between the green and the red time at the signalized intersections, in research done by D. Allen et al., (2005) in Australia, to study the behaviour of the motorcyclist at the ASL due to the red traffic light. Figure the most common positioning for motorcyclist waiting at the junction at ASL sites were in pedestrian crossing area (40% of motorcyclist) and in ASL reservoir (38%). At Beaufort Street the number of the motorcyclist waiting in the pedestrian crossing area, where they are not permitted, was proportionally particularly high (59%). This might be due to site specific characteristics such as visibility splays. At Putney High Street 52% of motorcyclists waited in the pedestrian crossing area, which might be in order to gain good position ahead of the traffic because the arm of the junction is on gradient. At City Road, 58% of motorcyclists waited in the ASL. Highly trafficked sites, such as Borough High Street (control site), tended to have some motorcyclists position themselves amongst the traffic at the junction. At the control sites, 54% of motorcyclists positioned themselves in the pedestrian crossing.

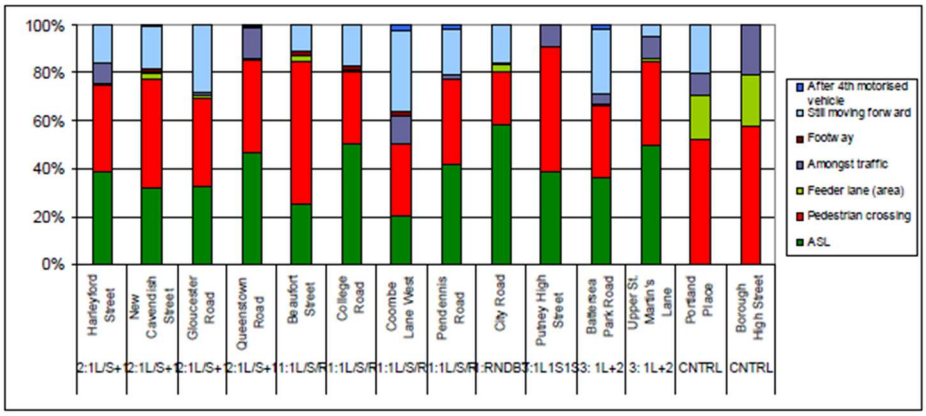

Figure 2.2: Positioning of the motorcyclist at ASL at each site (D. Allen et al., 2005)

Motorcycle use has increased rapidly in Indonesia during the last decade, as do motorcyclists' infractions of traffic rules. Driving recklessly, speeding, and overtaking on the wrong side of the road are some of the most frequent traffic violation behaviours among urban motorcyclists in Indonesia. This study investigates the effects of motorcyclists' attitudes, habits, preferences, and travel patterns on their disregard for traffic restrictions in three Indonesian cities. The theory of planned behaviour and structural equation modelling are employed to explore these relationships. According to past study in developed countries, individual attitudes, societal norms, and perceived behaviour control all have a significant impact on violating traffic regulations. Adults and students are more likely to violate driving laws regularly. Males, on the other hand, are less inclined than females to ignore traffic regulations. The results show that the Indonesian National Traffic Law needs to be changed in terms of how violations are classified and how much they cost and that it also needs to make a clear distinction between violations that are likely to cause deaths, which need more police, and violations that are unlikely to cause deaths, which don't. in a study done by (Mulyadi and Amelia, 2013) .

Motorcycle deaths have increased in Klang Valley in Malaysia in the recent years, with the overall number approaching 60% of all road traffic accidents. Many motorcycle deaths happened at intersections when a driver failed to see a motorcyclist. However, there is no information on how motorcyclists behave while approaching an intersection. The purpose of this study was to evaluate the behaviour of motorcyclists in queues at 3-legged and 4-legged signalized intersections on Klang Valley state roads. Observational data was obtained using microscopic data collected from video one by a research vehicle equipped with an onboard video camera. For ten weeks, the study vehicle performed routine trips across Klang Valley during peak and off-peak hours. The preliminary data indicate three motorcycle approaches to the signalized intersection (SI): (1) weaving/lane splitting, (2) approaching the signalized intersection from the centre of the lane, and (3) approaching the signalized intersection from the left side/shoulder. During a red-light phase, 87% of motorcycles tend to manoeuvre in a queue to avoid obstruction and move forward for a comprehensive and clear field of vision closest to the stop line. According to a study by Paiman et al. (2020) it is proposed that motorcyclists be provided with a designated motorcycle waiting area in order to improve motorcycling safety and road safety in the country.

2.4 Traffic conflict

The research conducted by Mulyadi & Amelia (2013) in Indonesia stated that the motorized vehicle is the most popular transportation model dominating traffic. As the number of motorcyclists increased, traffic flow characteristics changed, and signalized intersection performance decreased. When a motorbike approaches an intersection, it generally causes a traffic conflict with other vehicles. Traffic congestion has the potential to result in an accident. As a result, a red box for a motorcycle at a signalized junction is designated as a waiting area for motorcyclists at a red light. The method developed by Baguley, 1984 was used to obtain traffic conflicts. At this intersection, data were collected before and after implementing the red motorcycle box to assess the impact. Traffic volume and traffic conflict were recorded as data. According to the findings, traffic flow increased by 13%, while traffic conflicts involving motorcycles increased by 39%. Implementing the red motorcycle box has reduced traffic congestion while increasing traffic flow at the Ahmad Yani-Laswi intersection in Indonesia.

One of the most important safety problems for motorcycle riders in developing countries is traffic conflict in congested areas. When traffic becomes congested, motorcycles, unlike vehicles, typically display non-lane-based behaviours such as veering or oblique following a leading vehicle. There have been few studies that have assessed the effects of such non-lane-based movements on traffic congestion. As a result, this research aims to develop an integrated model for analysing motorcycle traffic conflict in congested areas. The proposed model contains a concept of safe space to explain non-lane-based movement by motorcycles, new features developed for traffic conflict evaluation such as acceleration and deceleration indicators, and requirements for selecting a lead vehicle. Calibration data were obtained from two road segments in Ho Chi Minh City. A simulation based on the model was developed to verify the dynamic

non-lane-based movements of motorcycles. Subsequently, the assessment of the traffic conflict will be validated by calculating the probability of sudden braking at each time interval according to the change in the density of motorcycle flow. Our findings point out the fact that increasing flow density may lead to conflicts with a higher chance of sudden braking. There are three categories of motorcycle traffic conflicts, and the proportions of each category were estimated and analysed (Nguyen et al., 2014).

2.5 Start-up lost time

Various research defined the start-up lost time as the time lost by the first few vehicles at the start of green time.

Start-up lost time is the additional time, in seconds, spent by the first few vehicles in a queue at a signalized junction above and beyond the saturation headway due to the need to respond to the start of the green phase and accelerate is defined as lost time.

Start-up lost time is when a traffic signal phase changes from red to green, previously stopped vehicles in the curb line queue require time to accelerate to the required speed (Singh et al., 2018).

2.5.1 Importance of Start-up lost time

Start-up lost time is an important parameter in the performance of signalized intersections, especially when the behaviour of the drivers affecting on signalized intersections, according to the study has been made by Çalışkanelli et al. (2017) to study the parameters affecting the start-up lost time in Turkey with taking into consideration the behaviour of Turkish drivers. To determine the aim of the study, an observation was carried out at eight intersections in Turkey, and from the data analysis shows that saturation headways decrease with the increase in start response since the drivers in the second will take extra time to discharge. The results indicated that start-up lost time is

highly related to the start response time of the first driver in the queue. Also, when the lane width increases, the start-up lost time decreases.

It is used as a critical parameter in the estimation of optimal cycle length in Websters Equation, and according to this equation, this parameter is a very sensitive parameter that impacts the determination of optimum cycle length.

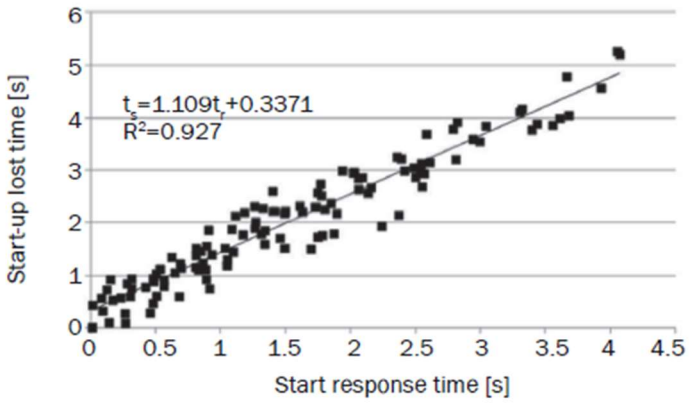

Figure 2.3: Relationship between start response time and start-up lost values (Çalışkanelli et al. 2017)

2.5.2 Determination of Start-up lost time

The most common way to determine the start-up lost time is by observing the signalized intersection, such as the study made by Çalışkanelli et al. (2017). They stated that the study of the effects of start-up lost time on a signalized intersection in Turkey, data collected from eight different intersections to study the effect, as the start-up lost time define as the additional time consumed by the first few vehicles in a queue at a signalized intersection.

Moreover, in the study done by Matsoukis & st. Efstathiadis (2013) to investigate the start-up lost time at a signalized intersection in urban areas, they stated that start-up lost time is defined as the excess time is needed for several vehicles to pass through the signalized intersection, in which data were collected at 11 deferent signalized intersection.

The average starting response time varied from 0.63 to 2.86 seconds, and the response time of successive vehicles ranged from 1 second to 1.75 seconds. 4% to 30% of the drivers are involved in responding to the signal change from the standing queue. However, considering the 2-wheels and 3-wheels vehicles are affecting the lost time by increasing the start-up lost time.

Start-up lost time showed a significant influence on the cycle timing as in a study done by (Matsoukis and st. Efstathiadis, 2013). The study stated that start-up lost time has an average of 0.35 to 1.39 seconds. When all data were analysed, the overall average start-up lost time of 1.34 seconds can be attributed to the first four vehicles, and the average headway after the fourth vehicle was 1.82 seconds.

2.6 Summary

The purpose of this study is to understand the behaviour of the motorcyclist at the stopping area of signalized intersection, evaluate the effectiveness of waiting area and to study the effect of motorcycles stopping in the waiting areas on start-up lost time. Data collection is the most common method to analyse the behaviour of the motorcyclist in stopping area, effectiveness of waiting area and start-up lost time in signalized intersection. While occupancy rate method is found to be more suitable in determining the effectiveness of waiting area at signalized intersections. Moreover, start-up lost time can be determined by different ways which the common way is by observing the signalized intersection.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter describes the methodology of the case study in evaluating the effectiveness of the waiting area boxes for motorcyclists at signalized intersections.

In order to evaluate the effectiveness of the waiting areas at signalized intersection, data collection was conducted using video recording method in which one camera was placed at the road shoulder near to the waiting area to record the behaviour and number of motorcycles stopping in the waiting area. The size of the waiting area in terms of the length and width were also measured at site. Another video camera was placed at the upstream of the signalized intersection to record the time taken by the vehicles behind the stop line to cross the intersection. Analyses were then performed on the data extracted from the recorded video to determine the effectiveness of the waiting area and the start-up lost time. Figure 3.1 shows the overall flowchart of this study.

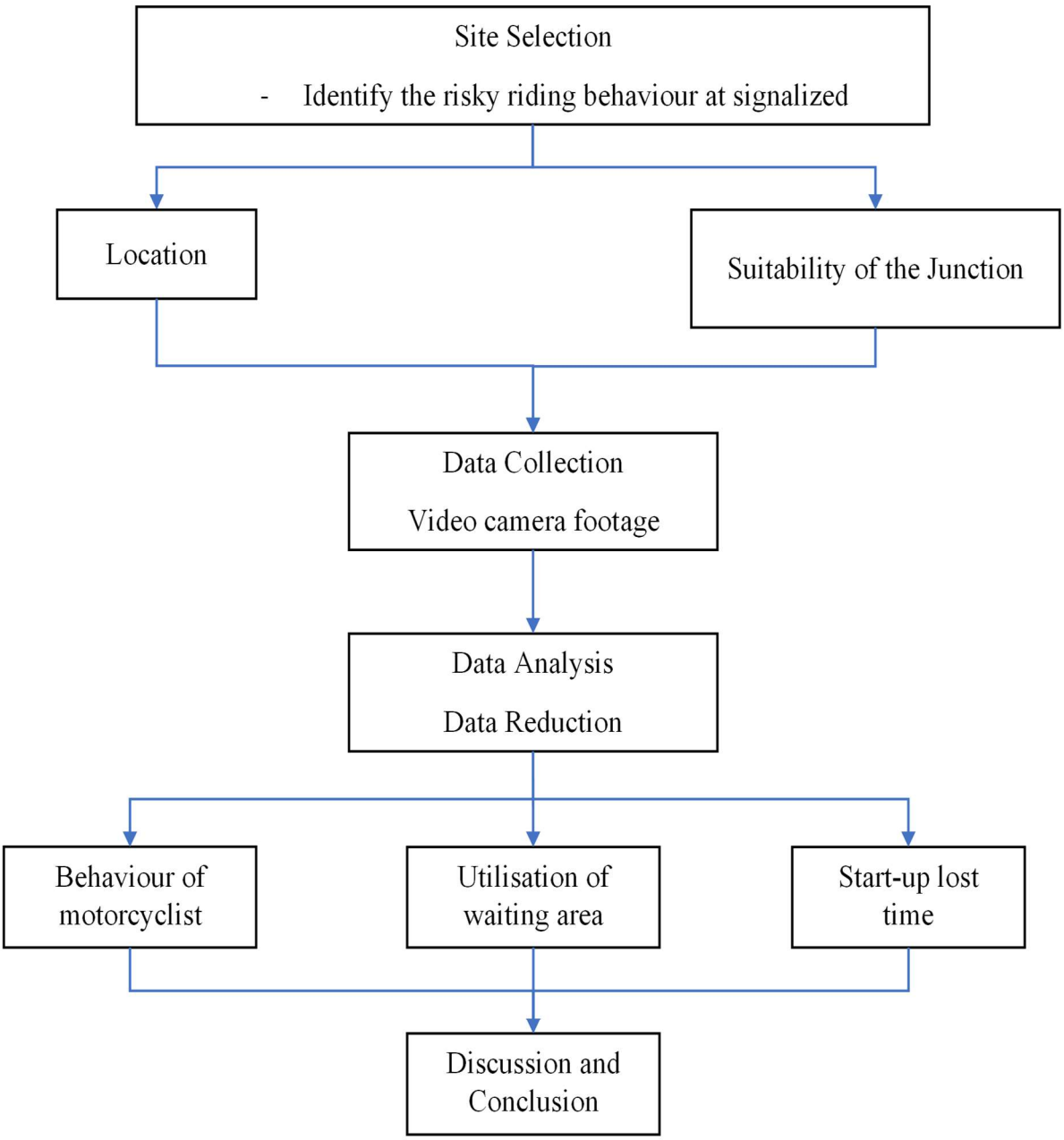

Figure 3.1: Overall flowchart of the study

3.2 Suitability of Location

The suitability of choosing the junction was based on different factors, which were: waiting area boxes availability in the signalized intersection and the capacity of the junction. Three main signalized intersections were investigated namely signalized Intersection between Jalan Jelutong and Jalan Ahmad Nor, signalized Intersection between Jalan Jelutong and Jalan Sungai Pinang and signalized Intersection between Jalan Dato Keramat and Jalan Patani. However, one intersection was chosen based on the criticality of the traffic flow and capacity at the signalized intersections. Followed observation of the intersection between Jalan Jelutong and Jalan Sungai Pinang and information on the traffic flow of each approach. The intersection was a four-legged signalized intersection located in Georgetown in Penang. The southbound and northbound approaches were chosen according to the size of the waiting area and duration of time it took for the traffic lights to change.

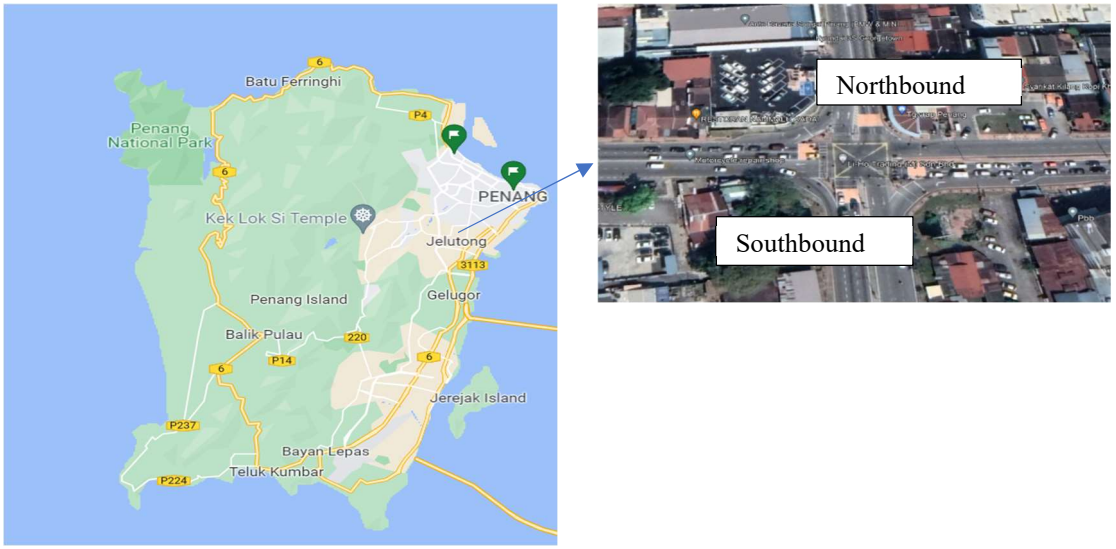

Figure 3.2: Location of the study

Figure 3.2 shows the location of both approaches at the intersection between Jalan Jelutong and Jalan Sungai Pinang. The southbound and the northbound approaches were selected based on the observation conducted during the peak hours and the capacity of the approaches as well.

3.2.1 Peak hour

Studying the effectiveness of waiting areas for motorcyclists at signalized intersections based on the flow of the intersection. Therefore, to check the capacity of the intersections, the maximum capacity during peak hours were obtained. In this study, the junction was observed first during peak hours to determine the effectiveness of the waiting areas and evaluate their utilization and the behaviour of motorcyclists.

3.2.2 Waiting Areas boxes

This study focused on the waiting areas for the motorcyclists at the signalized intersection, marked by Majlis Bandaraya Pulau Pinang (MBPP). The waiting areas separated motorcyclists from other vehicles during the red phase. Moreover, this study focused on effectiveness of the waiting areas. The waiting areas at Jalan Jelutong were not standardized, which means that in the four approaches, the box sizes were different due to the flow of the junction as discussed in Section 3.3.1.

3.3 Data collection

In order to determine the effectiveness of the waiting areas for motorcycles at signalized intersections, details on-site observations regarding traffic flow, waiting area size, and cycle signalized control time were taken at the intersection between Jalan Jelutong and Jalan Sungai Pinang. The selected locations showed a significant fluctuation in traffic flow, signalized intersections based on the scope of work were selected in locations that offer advantages for conducting surveys and large motorcycle volumes in the waiting areas during peak hours. The video method, manual counting, and measurement were used to collect data from surveys. The data used in this study include the motorcyclist's behaviour, which can determine the effectiveness of the waiting area and the start-up lost time caused by the motorcyclist to the other vehicles. Figure 3.3 shows the video camera that has been used to collect the data.

Figure 3.3: Video camera

3.3.1 Data at intersection between Jalan Jelutong and Jalan Sungai Pinang

The observation was taken from the intersection between Jalan Sungai Pinang and Jalan Jelutong, due to the suitability of intersection discussed in Section 3.2 which this study considered only southbound and northbound approaches to the intersection for this study. The intersection was attractive to many traffic users and had a very high motorcycle volume. Therefore, the traffic composition included passenger cars, motorcycles, and buses. When the traffic was low, the signalized control system was operated as pre-time control. Otherwise, the police control the traffic by themselves. Data collection was carried out during peak periods from 7:10 AM to 8:40 AM and from 4:10

PM to 5:40 PM. The traffic flow at the intersection was essential, so the study focused on the motorcyclists in the waiting areas. The waiting areas widths were different for the southbound approach taken was 6.2 m and the northbound approach was 7.9 m. At the time, motorcycles had a more significant impact on traffic flow in Malaysia.

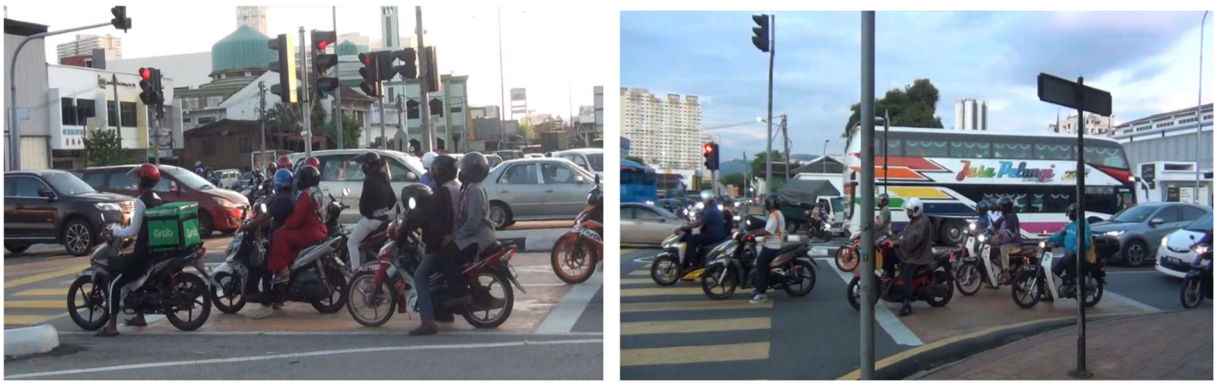

Figure 3.4: Waiting area for motorcyclist at the signalized intersection

3.4 Data Analysis

The data was extracted from the video footage, then analyzed, and a histogram was created to show the average lost time at the signalized intersection between Jalan Jelutong and Jalan Sungai Pinang and the effectiveness of the waiting area during peak hours. The effectiveness of the waiting area for the motorcyclist at signalized intersections will be determined based on the motorcyclist's behaviour and use of the waiting area, and the analyses will lead to knowing how the waiting area for the motorcyclist affects the cycle timing.

3.4.1 The behaviour of the motorcyclist

Waiting area boxes are built for motorcyclists at signalized intersections to prevent them from waiting between vehicles or behind them. The behaviour of the motorcyclists in the waiting area is one of the main factors affecting road operation. The method used to determine motorcyclist behaviour is to count the number of motorcyclists in the waiting area at the Jalan Jelutong intersection during peak hours.

3.4.2 Utilization of the waiting area

The effectiveness of the waiting area for the motorcyclist at a signalized intersection is one of the main factors in this study, as the waiting area has been recently marked. The effectiveness of the waiting area has been indicated based on the box size and the number of motorcyclists inside the box. The method used to determine the effectiveness of the motorcyclist in the waiting area at a signalized intersection is to collect data on the number of motorcyclists inside the waiting area, taking into account the area of the waiting area in the southbound and the northbound approaches, the area of the motorcycle, and from that, knowing the capacity of the waiting area for the motorcyclist, or how many motorcycles can be in the waiting area.

The formula used to know the effectiveness of the waiting area for the motorcyclist developed by Mulyadi (2017b) is as mentioned below in Eq. (3.1)

Effectiveness of the waiting area =

$$\frac{AVERAGE\ NUMBER\ OF\ MOTORCYCLIST\ INSIDE\ WAITING\ AREA}{CAPACITY\ OF\ WAITING\ AREA}\ x\ 100\% \qquad (3.1)$$

3.4.3 Start-up lost time

Start-up lost time is essential in signalized intersections, particularly in Malaysia, where motorcyclists account for many road users. Start-up lost time is defined as additional time, in seconds, consumed by the first vehicle discharged when the signal turns green and after the motorcyclist discharges from the waiting area at the intersection.

Start-up lost time was determined by using a timer and observing the signalized intersection to know the additional time after discharging the motorcyclists from the waiting areas.

3.5 Summary

In overall, three major parameters were analysed, behaviour of the motorcyclist at stopping area, effectiveness of waiting area for the motorcyclist and the effect of motorcycles stopping in the waiting areas on start-up lost time. Data collection were being conducted to understand the behaviour of the motorcyclist at the stopping area at signalized intersection, evaluate the effectiveness of the stopping area for the motorcyclist and indicating the delay time caused by the motorcyclist to the other road users after implementing the waiting area at a signalized intersection in Penang state.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview

In this chapter, the study of the effectiveness of the waiting area box for the motorcyclist at a signalized intersection are discussed. A simple and direct preliminary study analysis was conducted to know the behaviour of the motorcyclists toward the waiting area box in terms of percentage. Subsequently, the effectiveness of the waiting area is indicated by the amount of motorcyclist in the box, and with consideration of the waiting area box and data collection were conducted to know the utilization of the waiting area in southbound and northbound approaches. The significant factors were determined based on the observed signalized intersection.

Moreover, start-up lost time was observed at the signalized intersection to show the lost time caused by the motorcyclist for the other road users at the signalized intersection. An estimated value was obtained from the data collection and presented in a histogram to show the average lost time in seconds caused by the motorcyclist.