CERTIFICATION OF APPROVAL

EFFECT OF GEOGRAPHICAL LOCATION ON THE EFFECTIVENESS OF COUNTDOWN TIMER AT SIGNALIZED INTERSECTIONS

by

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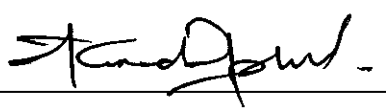
CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



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ABSTRACT

Occurrence of red light running is when vehicles cross an intersection after the traffic light turns to red. This behavior is dangerous and can cause harm to other motorists and also pedestrians. Data provided from previous study in Ipoh shows that the effectiveness of a countdown timer varies between intersections. It is also generally noted that people from different states behave differently. They have their own sets of culture and understanding of their surroundings which could affect the behavior when crossing at intersections. Therefore, this study is done to determine whether geographical locations affect the effectiveness of countdown timers and to justify its efficiency in reducing red light running. Eight random locations with and without timers in Penang were chosen to conduct this study. Video camera is used to capture the movements of the vehicles entering the intersection. By using Chi-square statistical analysis, it is found that there is no significant difference between Penang and Ipoh for the intersections with countdown timer but there is a significant difference for intersections without countdown timer. This justifies that a countdown timer works efficiently in reducing red light running. It is also noted that drivers between these two cities behave differently at intersections without countdown timer.

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LIST OF ABBREVIATIONS

FHWA	Federal Highway Administration
HCM	Highway Capacity Manual
IIHS	Insurance Institute for Highway Safety
LOS	Level of Service
PCU	Passenger Car Unit
RLR	Red Light Running
UVC	Uniform Vehicle Code

CHAPTER 1
INTRODUCTION

1.1 Background Study

Traffic light consists of three colors which are green, amber and red. Green light indicates that vehicles can pass thru the intersection, amber or yellow indicates that the green light is about to change to red and red lights indicate that vehicles has to stop at the intersection. Unsuitable time interval for the amber lights can create a dilemma zone.

Intersections have been one of the most dangerous locations on the road. Often accidents occur at intersections due to various reasons. One of the major reasons is red light running occurrence. It has been an issue for a long time that is yet resolved effectively.

In order to prevent or minimize the occurrence of red light running, various methods has been used such as installing red light cameras to control the behavior of motorists and to capture red light violators. In the recent years the usage of countdown timer is rapidly growing around the world. Other than Malaysia, it has been installed in China, Indonesia, Taiwan, and other countries.

1.2 Problem Statement

Red light running (RLR) is an action that occurs at intersections. This behavior contributes to accidents and deaths to either other motorists or pedestrians. Therefore a countdown timer is installed in order to provide visual information and guidance to drivers regarding the amount of time remaining to safely cross an intersection.

From previous study done in Ipoh on the effect of countdown timer on red light running, it was concluded that effect of countdown timer varies between intersections. Therefore, more study on other locations has to be done to support the previous study.

1.3 Objective

The objectives of this project are:

1. To determine whether geographical location affects the effectiveness of countdown timer at signalized intersections.
2. To justify the effectiveness of countdown timers in reducing red light running.

1.4 Scope of Study

The study is done by gathering data on red light running issues and also research that has been done on the subject matter. Eight random locations with and without timers in Penang were chosen to conduct this study. Video camera is used to capture the movements of the vehicles entering the intersection. The data summary of the survey will be converted into percentage and Chi-Square analysis will be performed. The analysis will determine the significant of installing countdown timers and to compare the results between Penang and Ipoh.

CHAPTER 2
LITERATURE REVIEW

2.1 Effect of Red Light Running

Red light running occurs when a vehicle enters a signalized intersection after the traffic light signal has turned red. It is responsible for about 260,000 crashes and 750 fatalities each year in the US (Retting, Ulmer, & Williams, 1999, Accident Analysis & Prevention). It has been determined that red light running occur more frequently during daylight hours [8] and causes more fatal crashes than other unsafe driving behaviors [9]. According to a study on cause of collisions, 22% of urban crashes are due to red light running cases [10]. The number of deaths and the rates per 100,000 people in cities and states of United States caused by red light running are shown in Table 2.1.

According to the Insurance Institute for Highway Safety, disregarding red lights and other traffic control devices is the leading cause of urban crashes, representing 22 percent of the total number of crashes. The economic impact is estimated at $7 billion yearly in medical costs, time off work, insurance rate increase and property damage.

Table 2.1 States with the Highest Death Rates in Red Light Running Crashes per 100,000 People, 1992 – 1998

State	Population	Deaths	Rates per 100,000
Arizona	4,280,998	305	7.1
Nevada	1,529,841	59	3.9
Michigan	9,655,540	355	3.7
Texas	18,677,046	663	3.5
Alabama	4,255,686	143	3.4
New Mexico	1,670,580	56	3.4
Florida	14,197,723	434	3.1
California	31,645,023	434	3.1
Deleware	717,499	21	2.9

Source: Fatality Analysis Reporting System, United States Department of Transportation

2.2 Definition of Red Light Running

According to the Federal Highway Administration (FHWA) [1], "Red-light-running occurs when a driver enters an intersection after the traffic signal has turned red. A motorist, who is already in an intersection when the signal changes to red, such as when waiting to make a left turn, is not a red-light-runner."

According to the Insurance Institute for Highway Safety (IIHS) [2], "A violation occurs when a motorist enters an intersection (often deliberately) some time after the signal light has turned red. Motorists inadvertently in an intersection when the signal changes to red when waiting to turn, for example are not red light runners."

According to the Uniform Vehicle Code (UVC) [3], a motorist facing a steady circular red signal shall stop at a clearly marked stop line, but if none, before entering the crosswalk on the near side of the intersection, or if none, then before entering the intersection and shall remain standing until an indication to proceed is shown" (section §11-202). The law as stated in the UVC is considered a permissive-yellow law, meaning that the driver can enter the intersection during the entire yellow interval and be in the intersection during the red indication as long as he/she entered the intersection during the yellow interval.

2.3 Factors Influencing Red Light Running

2.3.1 Intersection Characteristics

Bonneson et al. (2001) reviewed many past studies regarding various intersection characteristics as they relate to red-light running. Three intersection characteristics were highlighted as exposure factors including flow rate, number of signal cycles and phase termination by max-out. Field studies support the logical conclusion that as more vehicles are exposed to the potential of red-light running, the violation rate increases. The findings from that report are summarized below [5]

2.3.1.1 *Intersection Flow Rates*

Every vehicle approaching the intersection at the onset of the yellow is exposed to the potential of red-light running. A decision must be made to stop or proceed through the intersection. As the number of approaching vehicles increases, the number of red-light runners will likely increase. [5]

2.3.1.2 *Frequency of Signal Cycles*

The more times the yellow phase is displayed, the more potential for red-light running. Hence, researchers should report that violation rates normalized by the number of signal cycles. [5]

2.3.1.3 *Phase Termination by Max-out*

Actuated signal systems operate using green extension time as long as the approach is occupied. However, the green may reach its maximum limit and "max-out" forcing the green phase to end regardless of whether the approach is occupied. Conversely, the signal may "gap-out" because the approach has been unoccupied for a set period of time. There is greater potential for red-light running as the frequency of max-out increases. [5]

2.3.1.4 *Vehicle Speed*

The speed at which a driver is approaching an intersection plays a role in the decision of whether to stop at the intersection. Assuming the same travel time to the intersection, high-speed drivers tend to be less likely to stop than low-speed. Differences between high-speed drivers and low-speed drivers tend to decrease, however, as the travel time to the stop line (assuming a constant approaching speed) decreases. [6]

2.3.1.5 *Travel Time to the Stop Line*

The probability of stopping before the stop line when the light changes to yellow depends on the location of the vehicle and the travel time to the stop line. In general, as the available travel time to the stop line increases, the probability of stopping also increases. This relationship is not linear, as Figure

1 shows. The response in the probability of stopping is particularly strong for travel times in the 2–5 second range. This observation is important because it helps to identify ranges in the duration of the yellow interval—which is usually based on estimates of travel time to the stop line—for which there is a good probability that drivers will be able to stop before the stop line at the onset of yellow. [6]

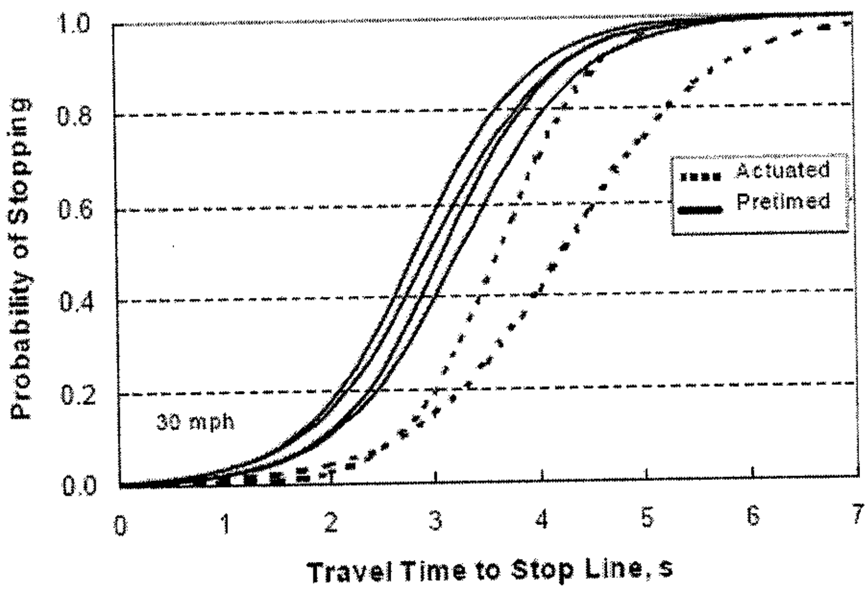

Figure 2.1 Probability of Stopping as a Function of Travel Time and Control Type (Bonneson, Brewer, and Zimmerman 2001)

2.3.1.6 Type of Signal Control

The type of signal control plays a role in the exposure of drivers to red light running situations. Highway corridors with vehicle-actuated traffic control tend to produce more compact vehicle platoon configurations than pretimed traffic control (Van der Horst, 1998). The result is an increase in the number of drivers who may be exposed to the yellow and/or red indications during "max out" phase terminations in the operation of the system and a reduction in the probability of stopping before the stop line after the light changes to yellow. Figure 2.1 illustrates this effect by showing a lag in the probability of stopping curve for actuated control systems (Van der Horst, 1998; Bonneson, Brewer, and Zimmerman, 2001).[6]

2.3.1.7 Duration of the Yellow Interval

There is a correlation between the duration of the yellow interval and red light running events. Van der Horst (1998) observed a substantial reduction in the number of red light running events after increasing the duration of the yellow interval from 3 to 4 seconds (in urban areas) and from 4 to 5 seconds (in rural areas). Van der Horst observed a small adjustment in the drivers' stopping behavior, which he attributed to the relatively low increase in the duration of the yellow interval. He noted, however, that long yellow interval durations tend to result in greater variability in the decision making, which could result in an increase in the number of rear-end collisions. [6]

2.3.1.8 Approach Grade

The approach grade has an effect on the probability that drivers will stop. Drivers on downward approaches are less likely to stop (at a given travel time to the stop line) than drivers on level approaches or upward approaches (Chang, Messer, and Santiago, 1985). The effect is particularly noticeable in the 2–6 second travel time range (Bonneson, Brewer, and Zimmerman, 2001). [6]

2.3.1.9 Signal Visibility

Signal visibility has long been recognized as a critical factor contributing to red light running. Examples of sight restrictions that can limit the driver's view of the signal include tree foliage, parked vehicles in the immediate vicinity of the intersection, inadequate intersection geometric layouts, and inadequate signal head physical characteristics (such as insufficient number of signal heads, small lens sizes, insufficient lens brightness, and insufficient background contrast). [6]

2.3.2 Human Factor

Human behavior contributes largely on the red light running cases. A research was done by FHWA on driver's attitudes and behaviors at intersections by different age categories. For older drivers, stopping is their planned, default driving behavior in this situation. For middle-aged drivers, going through the light is their default strategy, unless they thought that the vehicle in front of them was going to stop. For younger drivers, traffic and driving conditions, being in a rush, and the behaviors of a lead vehicle are all factors that lead them to go through the light. For most drivers, additional factors that influence their behavior in this scenario include the status of cross traffic, obstructions, roadway conditions (e.g., visibility, traction), congestion levels, and the presence of pedestrians. Younger drivers are generally less likely to go through the light if their parents are in the car with them. [7] Following are two main human factors for occurrence of red light running:

2.3.2.1 Vision

Visual impairments have an obvious effect on driving performance, particularly in the case of older driver. Less clear is the relationship between visual impairments and safety. There are three visual factors that affect the processing of dynamic information play a critical role on crash rates: dynamic visual acuity, angular movement, and movement in depth. Dynamic visual acuity refers to the task of seeing objects that are moving with respect to the eye, whereas angular movement and movement in depth refer to the task of judging the speed of objects crossing or approaching the path of travel. [6]

2.3.2.2 Driver Attention

Factors that hinder driver's attention are distraction, inattentiveness, improper lookout, and sleepiness. Driver attention is critical at intersections because of the additional cognitive demands required of drivers at those locations. Hancock, Lesch, Simmons, and Mouloua (2001) observed a 15 percent increase in the number of non-responses to red light activations at signalized intersections while the drivers were using in-vehicle phones. Where drivers reacted to the red light activation, their reactions were slower and drivers braked more intensely. [6]

2.4 Intersection

According to the UVC, intersection can be defined as the area embraced within the prolongation or connection of the lateral curb lines, or if none, then the lateral boundary lines of the roadways of two highways which join one another at, or approximately at right angles, or the area within which vehicles traveling upon different highways joining at any other angle may come in conflict. [12]

Intersection can be classified depending on the number of road segments (arms) that come together at the intersection. It can vary from 3-way up to 6-way intersection. 3-way intersection is also known as T-junction or Y-junction. The most common intersection of all is 4-way intersection because it involves crossing over of two streets or roads. Another way to classify intersection is by traffic control. An intersection is uncontrolled if it is without signs or signals and controlled if the intersection is a signalized intersection which is normally associated to traffic lights.

2.5 Level of Service

Level of service is a measure to determine the quality of service of transportation devices or transportation infrastructure. In this study, level of service is used to measure the operating performance of the intersection. The efficiency of the intersection is highly dependent on the level of service. Therefore, if improvements were to be made to the intersection, it will increase the operating performance. Factors that affect the level of service at intersections include the flow and the distribution of traffic, the geometric characteristics, and the signalization system.

Signalized intersection level of service (LOS) is defined in terms of the average total vehicle delay of all movements through an intersection. Vehicle delay is a method of quantifying several intangible factors including driver discomfort, frustration, and lost travel time. Specifically, LOS criteria are stated in terms of average delay per vehicle during a specified time period. Vehicle delay is a complex measure based on many variable including signal phasing, signal cycle length, and traffic volumes with respect to intersection capacity. Table 2.2 shows LOS criteria for signalized intersections, as described in the Highway Capacity Manual 2000.

Table 2.2 LOS Criteria for Signalized Intersections (Highway Capacity Manual 2000)

LOS	Average Control Delay (sec/veh)	General Description
A	< 10	Free Flow
B	> 10 – 20	Stable Flow (slight delays)
C	> 20 – 35	Stable Flow (acceptable delays)
D	> 35 – 55	Approaching unstable flow (tolerable delay)
E	> 55 – 80	Unstable flow (intolerable delay)
F	> 80	Forced flow (jammed)

Unsignalized intersection LOS criteria can be further reduced into two intersection types: all-way stop-controlled and two-way stop-controlled. All-way, stop-controlled intersection LOS is expressed in terms of the average vehicle delay of all of the movements, much like that of a signalized intersection. Two-way, stop-controlled intersection LOS is defined in terms of the average vehicle delay of an individual movement(s). This is because the performance of a two-way, stop-controlled intersection is more closely reflected in terms of its individual movements, rather than its performance overall. For this reason, LOS for a two-way, stop-controlled intersection is defined in terms of its individual movements. With this in mind, total average vehicle delay for a two-way, stop-controlled intersection should be viewed with discretion. Table 2.3 shows LOS criteria for unsignalized intersections (both all-way and two-way, stop controlled).

Table 2.3 LOS Criteria for Unsignalized Intersections (Highway Capacity Manual 2000)

LOS	Average Control Delay (sec/veh)	General Description
A	0 – 10	Free Flow
B	> 10 – 15	Stable Flow (slight delays)
C	> 15 – 25	Stable Flow (acceptable delays)
D	> 25 – 35	Approaching unstable flow (tolerable delay)
E	> 35 – 50	Unstable flow (intolerable delay)
F	> 50	Forced flow (jammed)

2.6 Previous Study

Previous study was done by Laila Bt Che Long on the effect of countdown timer on red light running. The study was done in Ipoh City Center on three separate locations. From the statistical analysis done, it is shown that effect of countdown timer on the number of red light running on 2 stations was not significant at 95% confidence level. Only 1 station was at 95% significant level. [11]

From the study, it was concluded that effect of countdown timer on red light running varies between different intersections. One of the factors that contributed to this result is the LOS of the intersection. In the report, the countdown timer had no effect when installed at upstream intersection that had poorer LOS than the downstream LOS. The analyses also concluded that the countdown timer had significantly reduced the number of red light running at signalized intersection. [11]

From a study done by Ibrahim, Kidwai and Karim (2005) on seven intersections in non-CBD areas in Kuala Lumpur, the rate for red light violation for intersection with countdown timer is 37.1% while the rate for non countdown timer is 66.2%. This shows that the count down timer serves it purpose in reducing RLR. [14]

Another study done by Ibrahim, Kidwai and Karim (2008) on six signalized intersections in Kuala Lumpur, it was found that rate of red light violation at intersections with countdown timer is 30% while the rate for non countdown timer is 24%. It is expected that RLR should be higher for intersections without timer but the results shows the opposite. [15]

2.7 Summary of Literature Review

The RLR is responsible for more than quarter of a million crashes and hundreds of fatalities in the United States. Billions of dollars are spent each year comprising medical costs, insurance and property damage. Therefore, preventing is better that curing the effects of RLR.

A vehicle that enters an intersection when the signal light turns red is considered as a red light runner. Most of the factors of the intersection characteristics have an influence on the outcome of the study. All locations of study in Penang uses a pretimed signal control, a standard 3 seconds yellow interval and a level approach grade. Therefore, the phase termination by max-out, type of signal control, duration of yellow interval and approach grade are not a factor to be considered in this study.

A clear human factor that contributes to the RLR occurrence is the age of the drivers whereby young and middle aged drivers tend to violate the red light compared to older drivers. The age factor is surrounded by other factors such as the behavior of the drivers, vision and driving focus.

All intersections in this study is either three ways or four ways and at right angles. Quality of the intersection can be measured using LOS. The efficiency of the intersection is highly dependant on LOS. However LOS is not taken into consideration since this study only focuses on the violation of red light.

The percentage of RLR from a study done Laila Bt. Che Long is based on number of vehicles violating the red light. However Ibrahim, Kidwai and Karim did a different approach by using number of cycles that have red light violations. Therefore, the percentage of RLR is much larger from the study by Ibrahim, Kidwai and Karim compared to Laila Bt. Che Long. Both approaches yielded different results but shows that the effectiveness of the countdown timers varies at different locations.

CHAPTER 3
METHODOLOGY

3.1 Reconnaissance Survey

Reconnaissance survey is done by locating suitable intersections for the study. Suitable time outside the peak hour is identified. Free flow is required to conduct this study. Characteristics of the intersections and the traffic signal are listed in Table 3.1. The map of the area of study can be viewed in Appendix C.

Table 3.1 Characteristics of the Road and Traffic Signal

Station No.	Name of Station	Area	Type	Timer
1	Jalan Masjid Negeri	Georgetown	2 Way	Yes
2	Jalan Scotland	Georgetown	4 Way	Yes
3	Jalan Baru	Perai	2 Way	Yes
4	Jalan Macalister	Georgetown	4 Way	Yes
5	Jalan Tanjung Tokong	Tanjung Tokong	4 Way	No
6	Jalan Sultan Azlan Shah	Gelugor	4 Way	No
7	Jalan Sultan Azlan Shah	Bayan Lepas	2 Way	No
8	Jelutong Expressway	Jelutong	4 Way	No

Eight locations were identified and are shown in Figure 3.1 to Figure 3.8.

Figure 3.1 Jalan Masjid Negeri

Figure 3.2 Jalan Scotland

Figure 3.3 Jalan Baru

Figure 3.4 Jalan Macalister

Figure 3.5 Jalan Tanjung Tokong

Figure 3.6 Jalan Sultan Azlan Shah (Gelugor)

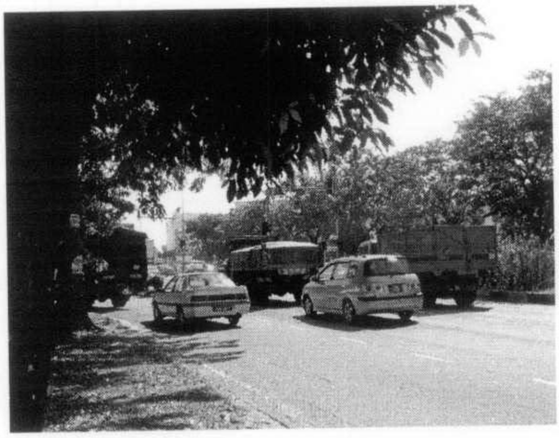

Figure 3.7 Jalan Sultan Azlan Shah (Bayan Lepas)

Figure 3.8 Jelutong Expressway

3.2 Preliminary Traffic Survey

Preliminary traffic survey is conducted on the locations selected. This is to ensure that the location is suitable for the study. Problems faced during the survey are identified and best solutions and alternatives are justified so that the real traffic survey will run smoothly.

3.3 Traffic Survey

The traffic survey is done by having video camera at intersections to record the traffic flow and to identify red light running occurrence. The video camera is run for 90 minutes continuously when the traffic is in a free flow. The time of the recording is at 9.30a.m. to 11a.m. on weekdays.

3.4 Traffic Count

Traffic count is done by observing the video recorded during traffic survey. The number of road users that comply with the red light, users that cross the intersection during amber and users that violates the red light is tabulated. The traffic count can be referred in Appendix A.

3.5 Data Analysis

Data analysis is done when all data recorded form the video camera is tabulated. The data summary of the survey is converted into percentage and Chi-Square analysis is performed. The analysis will determine the significant of having a countdown timer at signalized intersections.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Red Light Violations

Table 4.1 and Table 4.2 shows the data summary for the traffic volume in Passenger Car Unit (PCU). The study was done for 90 minutes from 9.30 a.m to 11.00 a.m.

Table 4.1 Data Summary of Intersection with Countdown Timers

	Jalan Masjid Negeri	Jalan Scotland	Jalan Baru	Jalan Macalister
9.30 a.m to 10.00 a.m				
Comply with red light	1412	1370	759	475
Cross during amber	18	16	6	11
Violates red light	2	0	1	0
10.00 a.m to 10.30 a.m				
Comply with red light	1437	1327	850	483
Cross during amber	17	10	16	11
Violates red light	1	0	13	3
10.30 a.m to 11.00 a.m				
Comply with red light	1335	1273	862	464
Cross during amber	17	8	2	13
Violates red light	2	0	8	2

Table 4.2 Data Summary of Intersection without Countdown Timers

	Jalan Tanjung Tokong	Jalan Sultan Azlan Shah (I)	Jalan Sultan Azlan Shah (II)	Jelutong Expressway
9.30 a.m to 10.00 a.m				
Comply with red light	519	490	382	881
Cross during amber	21	7	14	9
Violates red light	6	1	3	9
10.00 a.m to 10.30 a.m				
Comply with red light	562	451	474	994
Cross during amber	16	2	14	15
Violates red light	9	0	7	15
10.30 a.m to 11.00 a.m				
Comply with red light	595	458	432	815
Cross during amber	10	5	17	14
Violates red light	6	3	2	15

4.2 Statistical Analysis of the Traffic Count Data

4.2.1 Percentage of Red Light Running

The analyses were carried out on the data obtained for the whole duration of 90 minutes. Figure 4.1 to Figure 4.4 shows the percentage of RLR at intersections with countdown timer and Figure 4.5 to Figure 4.8 shows the percentage of RLR at intersections without countdown timer.

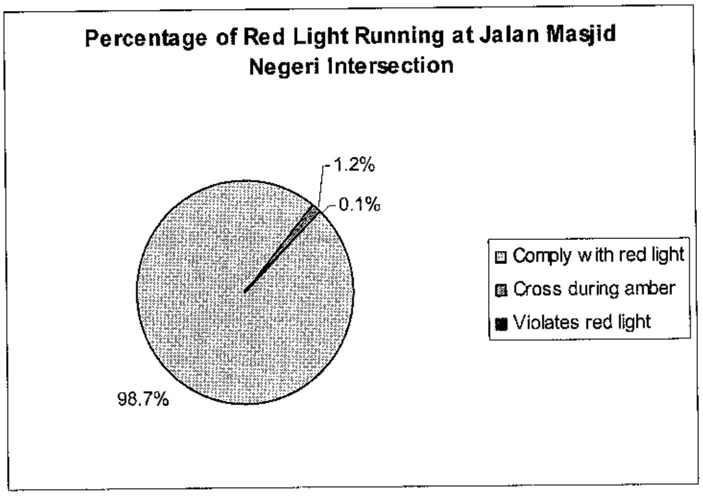

Figure 4.1 Percentage of Red Light Running at Jalan Masjid Negeri Intersection

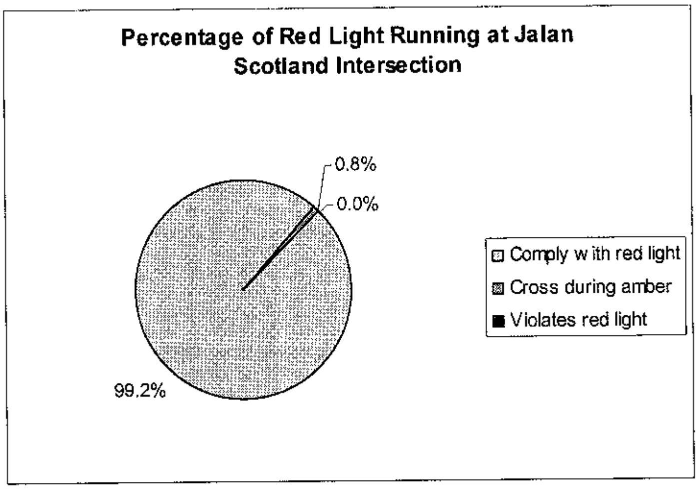

Figure 4.2 Percentage of Red Light Running at Jalan Scotland Intersection

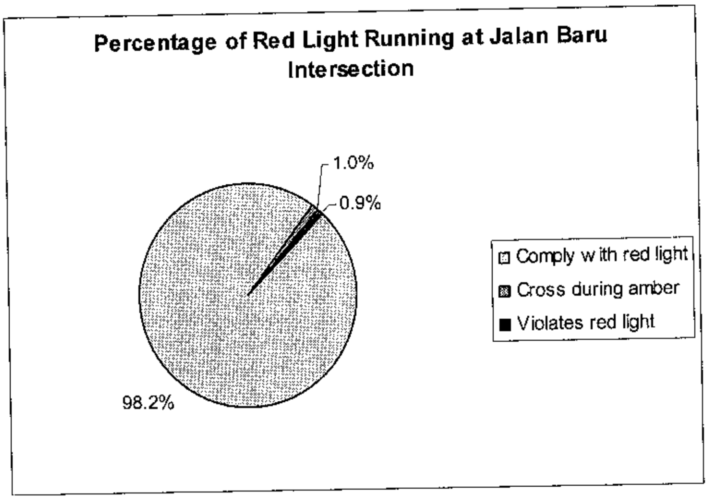

Figure 4.3 Percentage of Red Light Running at Jalan Baru

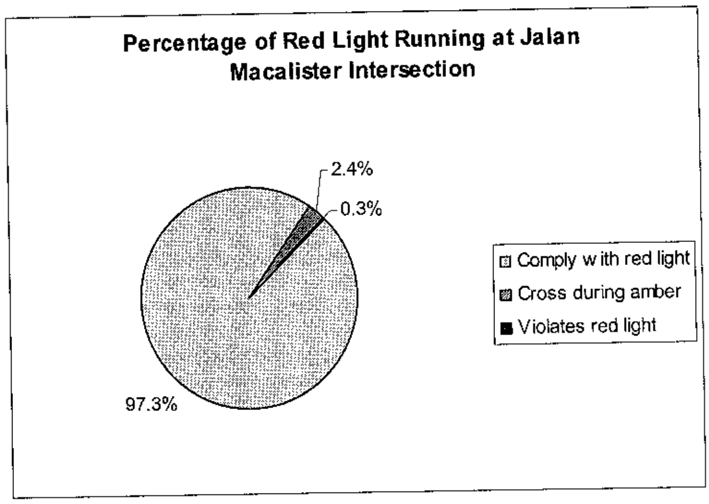

Figure 4.4 Percentage of Red Light Running at Jalan Macalister Intersection

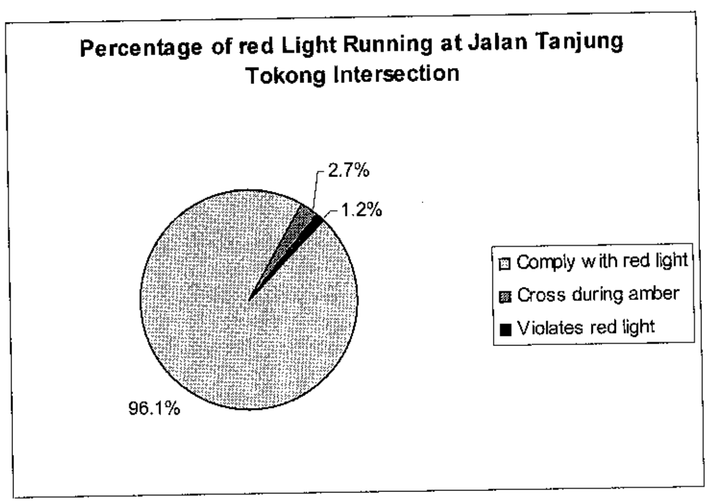

Figure 4.5 Percentage of Red Light Running at Jalan Tanjung Tokong

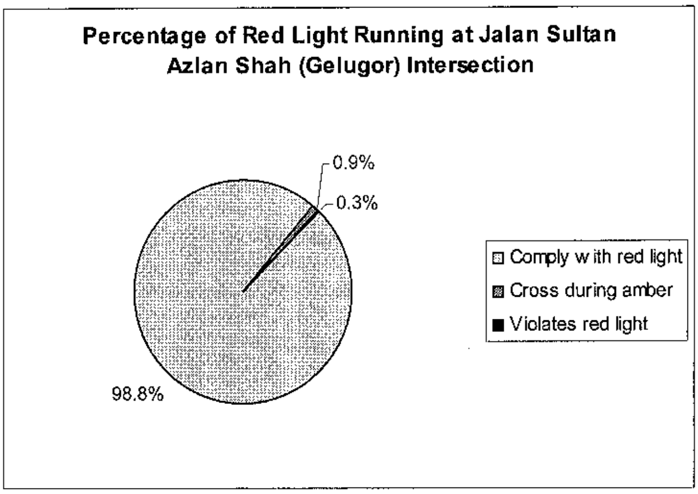

Figure 4.6 Percentage of Red Light Running at Jalan Sultan Azlan Shah (Gelugor) Intersection

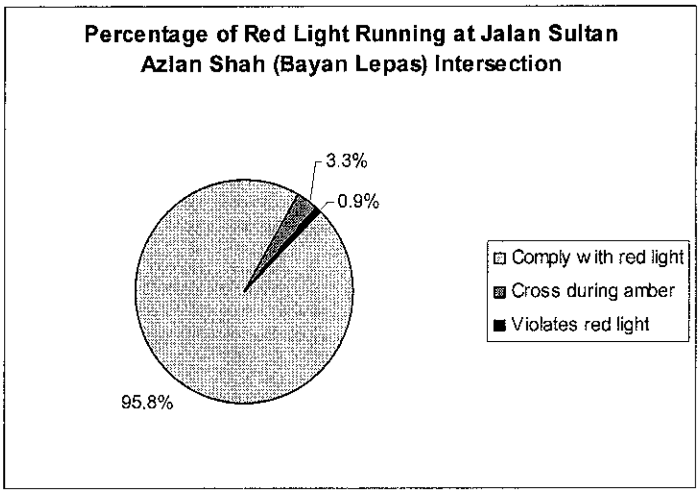

Figure 4.7 Percentage of Red Light Running Jalan Sultan Azlan Shah (Bayan Lepas) Intersection

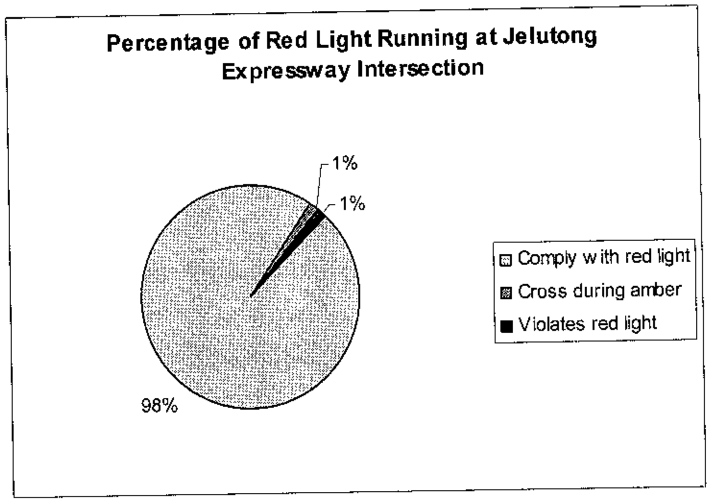

Figure 4.8 Percentage of Red Light Running at Jelutong Expressway Intersection

From Figure 4.1 to Figure 4.4, it can be seen that one out of the four intersections has a quite high percentage of RLR. The Jalan Baru intersection has a percentage of 0.9% percent of RLR which is relatively high compared to the other intersections which are below 0.3%. It is expected that intersections with countdown timer to have a very low rate of RLR.

From observation, it is suspected that the geometry of the intersection is main the reason for the unexpected result from the Jalan Baru intersection apart from the driver's behavior themselves. Jalan Baru is a major road consist of 2 ways 3 lanes but the intersection itself consist of five lanes for the Bukit Mertajam direction and four lanes for the Butterworth direction. Two extra lanes and one extra lane are designated for right turns entering Jalan Perai Jaya respectively. Ignorant drivers took advantage from this condition because it takes a longer timer for vehicles from the Jalan Perai Jaya to make a turn into the main road since it has to cross 4 lanes.

From Figure 4.5 to Figure 4.8, it can be seen that three out of four stations behave as expected with a percentage higher than the intersection with countdown timers. The Jalan Sultan Azlan Shah, Gelugor recorded a relatively low rate of RLR compared to the other intersections. Therefore, the intersection is very efficient and does not need a countdown timer to prevent RLR.

4.2.2 Chi-square Statistical Analysis

Chi-square statistical analysis is performed on all the intersections studied in Penang and Ipoh. The analysis is also performed for the results between Penang and Ipoh to determine the significance difference and is shown in Table 4.3 and Table 4.4.

Table 4.3 Chi-square Statistics for Penang and Ipoh

Location	Penang			Ipoh		
	With Timer	Without Timer	Comparison	With Timer	Without Timer	Comparison
Chi-square Statistics	50.09	11.72	48.36	11.93	22.8	15.35
95% confidence Interval	9.348	9.348	5.024	9.348	9.348	5.024

Table 4.4 Chi-square Statistics for Comparison between Penang and Ipoh

Timer Availability	With Timer	Without Timer
Chi-square statistics	0.9918	5.7
95% confidence interval	5.024	5.024

4.2.2.1 Hypothesis Result for Intersections in Penang

i. Penang - With timer

   Since 50.09 > 9.348, the hypothesis was rejected. Therefore the difference was significant.

ii. Penang – Without timer

   Since 11.72 > 9.348, the hypothesis was rejected. Therefore the difference was significant.

iii. Penang - Comparison

   Since 48.36 > 5.024 the hypothesis was rejected. Therefore the difference was significant.

4.2.2.2 Hypothesis Result for Intersections in Ipoh

i. Ipoh – With timer

Since 11.93 > 9.348 the hypothesis was rejected. Therefore the difference was significant.

ii. Ipoh – Without timer

Since 22.80 > 9.348 the hypothesis was rejected. Therefore the difference was significant.

iii. Ipoh – Comparison

Since 15.35 > 5.024 the hypothesis was rejected. Therefore the difference was significant.

4.2.2.3 Hypothesis Result for Comparison between Penang and Ipoh

i. Penang and Ipoh – Comparison with timer

Since 0.001 < 0.9918 < 5.024 the hypothesis was accepted. Therefore the difference was not significant.

ii. Penang and Ipoh – Comparison without timer

Since 5.70 > 5.024 the hypothesis was rejected. Therefore the difference was significant.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

By percentages, one out of the four intersections has a relatively high percentage of RLR. Intersection at Jalan Baru, Perai has a percentage of 0.9% percent of RLR compared to the other intersections which is below 0.3%. It is expected that intersections with countdown timer to have a very low rate of RLR.

For intersections without countdown timer, it can be seen that three out of four intersections behave as expected with a percentage higher than the intersections with countdown timers. Intersection at Jalan Sultan Azlan Shah, Gelugor recorded a relatively low rate of RLR compared to the other intersections. Therefore the intersection is very efficient and does not need a countdown timer to prevent RLR.

The statistical analysis performed shows that all intersections in eight locations in Penang have significant difference. When compared between Penang and Ipoh, the analysis shown that intersection with countdown timers was not significant at 95% confidence level. This justifies the claim that countdown timers are a very efficient countermeasure to tackle the RLR issue. However, the analysis also shown that at intersections without countdown timers was significant at 95% confidence interval. This means that behavior of drives in Penang and Ipoh when crossing at intersections without countdown timers differs.

It can be concluded that geographical location does not have an affect on the effectiveness of countdown timers at signalized intersections. However, it affects the behavior of drivers at intersections without countdown timers. This study also justifies that countdown timers are effective in reducing red light running.

5.2 Recommendation

This study was conducted on intersections randomly. All the intersections differs in its geometry , capacity and location It would be ideal if the study can be done on a before-and-after approach which can eliminate the intersection factors. However, the approach was not significant with the period of time of the study. Involvement of the local authorities for installing the countdown timer will take long period of time to get approval and other official matters.

The time of the day to conduct the study should be varied such as during peak hours. One of the factors of red light running is the intersection flowrates. As the number of vehicles increases, the occurrence of RLR will also increase.

Since this study only compares the result between two locations, it is suggested that the study is to be performed at least on one more location preferably at cities that are less populated such as Kelantan and Terengganu. Sabah and Sarawak would also be interesting locations since its geography is different from Peninsular of Malaysia.

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APPENDIX A

RED LIGHT VIOLATION COUNT

Table A-1: Traffic Volume Count for Intersection at Jalan Masjid Negeri

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	140	8	1	149	3	1
2	121	15	0	136	1	1
3	125	7	0	132	3	0
4	130	17	1	148	0	0
5	104	4	0	108	0	0
6	136	11	1	148	3	0
7	120	10	0	130	3	0
8	139	8	0	147	3	0
9	127	12	1	140	1	0
10	106	9	0	115	0	0
11	104	6	0	110	2	0
12	114	11	0	125	1	0
13	122	13	0	135	1	1
14	92	9	0	101	0	0
15	123	7	0	130	2	0
16	109	10	0	119	4	0
17	125	17	0	142	3	0
18	121	10	1	132	2	0
19	113	10	0	123	0	0
20	101	8	0	109	1	0
21	126	15	0	141	0	0
22	113	10	0	123	1	0
23	94	10	0	104	0	0
24	122	21	0	143	3	0
25	119	12	1	132	3	0
26	113	12	0	125	1	0
27	93	13	0	106	0	0
28	107	8	1	116	1	0
29	85	16	3	104	3	2
30	89	4	1	94	2	0
31	68	13	1	82	0	0
32	113	9	1	123	2	0
TOTAL	3614	345	13	3972	49	5

Table A-2: Traffic Volume Count for Intersection at Jalan Scotland

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	100	8	1	109	1	0
2	116	6	0	122	3	0
3	91	4	0	95	0	0
4	110	5	1	116	1	0
5	104	6	0	110	0	0
6	118	4	0	122	0	0
7	100	6	0	106	1	0
8	91	11	0	102	1	0
9	103	7	0	110	2	0
10	100	7	0	107	2	0
11	102	7	0	109	2	0
12	116	4	0	120	2	0
13	107	3	0	110	0	0
14	98	6	4	108	0	0
15	91	5	0	96	1	0
16	108	3	0	111	2	0
17	95	7	1	103	0	0
18	107	7	0	114	2	0
19	103	6	2	111	0	0
20	107	10	0	117	1	0
21	101	4	0	105	0	0
22	103	2	0	105	0	0
23	94	4	0	98	1	0
24	102	5	0	107	2	0
25	112	7	1	120	1	0
26	111	2	1	114	0	0
27	113	3	0	116	0	0
28	97	11	1	109	0	0
29	102	9	0	111	0	0
30	99	1	2	102	1	0
31	111	7	0	118	1	0
32	105	4	0	109	1	0
33	104	4	1	109	0	0
34	100	10	0	110	2	0
35	108	3	1	112	1	0
TOTAL	3629	198	16	3843	31	0

Table A-3: Traffic Volume Count for Intersection at Jalan Baru

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	40	6	1	47	0	0
2	43	3	2	48	0	0
3	56	3	1	60	0	0
4	48	4	1	53	0	0
5	56	8	2	66	1	0
6	49	4	2	55	0	2
7	55	6	1	62	0	0
8	46	5	1	52	0	0
9	41	4	0	45	0	0
10	58	3	1	62	0	0
11	47	4	0	51	0	1
12	51	5	0	56	2	0
13	44	10	0	54	0	1
14	50	11	1	62	3	1
15	58	6	1	65	2	1
16	52	7	0	59	1	0
17	55	9	1	65	2	1
18	46	7	1	54	1	0
19	53	7	1	61	1	0
20	66	6	0	72	0	1
21	54	9	1	64	1	1
22	55	6	1	62	0	0
23	46	3	0	49	0	0
24	58	10	2	70	0	2
25	51	8	1	60	2	4
26	49	2	1	52	0	0
27	54	7	0	61	1	0
28	61	8	2	71	0	0
29	55	9	1	65	0	0
30	50	5	2	57	1	0
31	44	14	0	58	0	0
32	61	8	1	70	0	0
33	54	7	1	62	1	0
34	52	8	0	60	0	0
35	56	4	2	62	0	3
36	38	7	2	47	0	1
37	52	11	2	65	0	1
38	44	6	0	50	0	0
39	51	6	0	57	0	2
Total	1999	256	36	2291	19	22

Table A-4: Traffic Volume Count for Intersection at Jalan Macalister

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	17	0	0	17	0	0
2	28	0	0	28	1	0
3	18	0	1	19	0	0
4	27	0	0	27	0	0
5	19	0	0	19	0	0
6	18	0	0	18	0	0
7	19	0	0	19	1	0
8	29	2	0	31	0	0
9	15	1	0	16	0	0
10	22	1	0	23	0	0
11	22	0	0	22	2	0
12	15	2	0	17	1	0
13	24	0	1	25	1	0
14	29	0	0	29	0	0
15	20	2	0	22	1	0
16	24	0	0	24	2	0
17	17	0	0	17	1	0
18	25	0	0	25	0	0
19	17	0	0	17	0	0
20	30	0	0	30	1	0
21	20	2	0	22	0	0
22	10	0	0	10	0	0
23	22	0	0	22	0	0
24	22	0	1	23	0	0
25	18	2	0	20	0	0
26	18	0	0	18	0	0
27	24	0	0	24	1	0
28	15	0	0	15	0	0
29	18	0	0	18	1	0
30	28	0	0	28	0	0
31	16	0	0	16	0	0
32	26	0	0	26	2	1
33	19	0	0	19	2	0
34	24	1	0	25	0	1
35	20	0	0	20	0	0
36	17	0	0	17	1	0
37	25	0	1	26	2	0
38	27	1	2	30	1	0
39	27	2	0	29	0	0
40	21	2	0	23	0	0
41	19	2	0	21	0	1
42	16	1	0	17	0	0
43	25	1	0	26	0	0
44	22	0	0	22	0	0
45	25	0	0	25	0	0
46	20	1	0	21	3	0
47	21	1	0	22	0	0
48	27	0	0	27	0	0
49	24	0	0	24	0	0

50	14	1	1	16	0	0
51	19	2	1	22	1	0
52	18	1	0	19	0	0
53	24	1	0	25	0	0
54	29	0	0	29	0	0
55	23	0	0	23	2	0
56	24	1	0	25	0	0
57	15	1	1	17	0	0
58	19	0	0	19	1	0
59	24	1	0	25	0	1
60	28	1	0	29	2	0
61	22	1	0	23	0	1
62	14	0	0	14	0	0
63	24	1	0	25	2	0
64	12	1	0	13	0	0
65	23	0	0	23	1	0
Total	1383	36	9	1428	33	5

Table A-5: Traffic Volume Count for Intersection at Jalan Tanjung Tokong

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	22	0	0	22	0	0
2	9	0	0	9	0	0
3	28	0	1	29	0	0
4	17	0	0	17	0	0
5	9	0	0	9	1	0
6	15	0	0	15	0	0
7	26	0	0	26	0	0
8	13	1	1	15	1	0
9	13	0	0	13	3	2
10	10	1	1	12	1	0
11	8	0	0	8	0	0
12	6	0	0	6	0	0
13	25	1	1	27	0	0
14	17	0	0	17	0	0
15	24	1	0	25	1	0
16	26	0	0	26	3	0
17	17	0	0	17	1	1
18	8	0	0	8	1	1
19	17	1	1	19	0	0
20	34	2	0	36	0	0
21	28	0	0	28	1	1
22	10	0	1	11	2	0
23	26	0	0	26	0	0
24	28	0	0	28	0	0
25	18	0	0	18	1	0
26	27	0	1	28	3	0
27	8	1	0	9	2	1
28	25	3	0	28	0	0
29	26	1	0	27	0	0
30	22	0	0	22	0	1
31	23	0	0	23	2	0
32	10	0	0	10	1	0
33	24	1	0	25	0	0
34	24	0	0	24	2	1
35	10	0	0	10	1	0
36	28	1	0	29	1	0
37	22	0	0	22	0	0
38	10	1	0	11	2	3
39	25	1	0	26	0	0
40	31	2	0	33	1	1
41	29	0	1	30	0	0
42	5	0	1	6	0	0
43	36	0	0	36	0	0
44	26	2	0	28	0	0
45	35	0	0	35	0	1
46	14	1	0	15	1	0
47	11	0	0	11	0	0
48	18	1	0	19	0	0
49	12	0	0	12	0	2

50	18	1	0	19	0	0
51	28	2	0	30	0	0
52	21	0	0	21	0	0
53	16	0	0	16	1	0
54	19	0	0	19	2	0
55	12	1	0	13	1	0
56	24	2	0	26	0	0
57	24	0	0	24	1	2
58	11	0	0	11	0	0
59	27	0	0	27	0	0
60	16	0	0	16	0	0
61	20	0	0	20	0	1
62	1	0	0	1	0	1
63	24	0	0	24	0	0
64	35	0	0	35	0	0
65	30	0	0	30	0	0
66	33	0	0	33	0	0
67	34	0	0	34	0	0
68	21	1	0	22	0	0
69	10	0	0	10	0	0
70	15	0	0	15	0	0
71	30	1	0	31	1	0
72	36	1	1	38	1	0
73	12	0	0	12	1	0
74	18	0	0	18	0	0
75	25	0	1	26	1	0
76	38	0	0	38	1	0
77	23	0	0	23	0	0
78	23	0	0	23	1	1
79	21	0	0	21	3	0
80	25	0	1	26	0	0
81	21	0	0	21	0	1
TOTAL	1666	31	12	1709	46	21

Table A-6: Traffic Volume Count Intersection at Jalan Sultan Azlan Shah (Gelugor)

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	28	4	0	32	0	0
2	25	4	1	30	0	0
3	32	7	0	39	1	0
4	37	8	2	47	1	0
5	46	0	0	46	0	0
6	39	4	2	45	0	0
7	40	4	1	45	0	0
8	29	3	1	33	0	0
9	24	6	1	31	1	0
10	46	6	0	52	1	1
11	48	5	0	53	1	0
12	34	6	1	41	0	0
13	29	0	0	29	0	0
14	43	2	0	45	0	0
15	38	2	1	41	0	0
16	38	4	0	42	0	0
17	24	0	0	24	0	0
18	42	2	2	46	0	0
19	32	4	0	36	0	0
20	36	1	0	37	0	0
21	36	2	0	38	1	0
22	46	3	1	50	0	0
23	38	3	0	41	1	0
24	33	4	1	38	1	1
25	35	3	1	39	0	0
26	41	4	1	47	1	0
27	41	2	0	43	0	1
28	54	4	1	59	0	0
29	30	3	0	33	1	0
30	41	3	0	44	1	0
31	41	3	0	44	0	0
32	45	2	2	49	0	1
Total	1191	108	19	1319	11	4

Table A-7: Traffic Volume Count for Intersection at Jalan Sultan Azlan Shah (Bayan Lepas)

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	24	3	1	28	0	0
2	13	3	0	16	1	0
3	15	4	1	21	0	0
4	24	4	0	28	1	0
5	18	6	0	24	0	0
6	24	6	0	30	2	1
7	19	3	0	22	2	1
8	26	4	0	30	0	0
9	19	2	0	21	0	0
10	14	1	0	15	0	0
11	24	3	0	27	0	0
12	18	4	0	22	4	0
13	30	2	0	32	0	0
14	23	4	0	27	0	1
15	17	0	0	17	2	0
16	25	3	0	28	2	1
17	33	5	0	38	0	1
18	20	4	1	25	1	0
19	21	5	0	26	1	0
20	19	2	0	21	1	2
21	20	2	0	22	0	0
22	27	7	0	34	1	0
23	26	1	0	27	1	1
24	19	0	0	19	0	0
25	40	2	0	42	0	0
26	28	3	1	32	0	0
27	21	6	0	27	1	0
28	37	8	0	45	2	0
29	37	4	0	41	0	1
30	24	2	0	26	1	0
31	27	6	0	33	1	1
32	28	1	0	29	0	0
33	20	3	0	23	1	0
34	21	4	0	25	0	0
35	36	6	1	43	1	0
36	41	3	0	44	1	0
37	16	2	0	18	0	0
38	20	2	0	22	2	0
39	20	4	0	24	0	0
40	21	3	0	24	3	1
41	39	8	0	47	2	0
42	24	6	0	30	2	0
43	11	4	0	15	0	0
44	28	2	1	31	2	0
Total	1057	157	6	1221	38	11

Table A-8: Traffic Volume Count for Intersection at Jelutong Expressway

Cycle	Car	Lorry	Bus	Total	Amber	Red
1	76	3	0	79	1	0
2	75	9	0	84	1	1
3	67	1	0	68	0	1
4	79	10	0	89	1	0
5	71	3	0	74	1	0
6	82	6	1	89	1	0
7	90	6	1	97	0	3
8	90	3	1	94	1	1
9	93	9	0	102	0	2
10	70	5	1	76	1	0
11	89	7	0	96	1	0
12	86	5	0	91	1	2
13	72	8	0	80	1	1
14	66	5	0	71	1	0
15	94	2	0	96	0	0
16	94	7	1	102	3	3
17	84	6	0	90	1	1
18	72	6	0	78	2	2
19	84	6	0	90	1	1
20	82	5	0	87	0	2
21	83	6	1	90	0	1
22	82	8	1	91	1	1
23	71	6	1	78	3	2
24	81	6	0	87	2	1
25	76	11	0	87	0	1
26	56	4	0	60	1	1
27	60	3	1	64	2	2
28	71	4	0	75	1	1
29	91	1	0	92	1	2
30	70	3	1	74	1	2
Total	2357	164	10	2531	30	34

APPENDIX B

TRAFFIC VOLUME IN PCU

Table B-1: Traffic Volume in PCU for Intersection at Jalan Masjid Negeri

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	1230	104	1230 + (104*1.75)	1412
Cross during amber	16	1	16 + (1*1.75)	17.75
Violates red light	2	0	2 + (0*1.75)	2
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	1234	116	1234 + (116*1.75)	1437
Cross during amber	15	1	15 + (1*1.75)	16.75
Violates red light	1	0	1 + (0*1.75)	1
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	1099	135	1099 + (135*1.75)	1335.25
Cross during amber	15	1	15 + (1*1.75)	16.75
Violates red light	2	0	2 + (0*1.75)	2

Table B-2: Traffic Volume in PCU for Intersection at Jalan Scotland

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	1237	76	(1237)+(76*1.75)	1370
Cross during amber	14	1	(14)+(1*1.75)	15.75
Violates red light	0	0	(0)+(0*1.75)	0
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	1208	68	(1208)+(68*1.75)	1327
Cross during amber	8	1	(8)+(1*1.75)	9.75
Violates red light	0	0	(0)+(0*1.75)	0
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	1156	67	(1156)+(67*1.75)	1273.25
Cross during amber	6	1	(6)+(1*1.75)	7.75
Violates red light	0	0	(0)+(0*1.75)	0

Table B-3: Traffic Volume in PCU for Intersection at Jalan Baru

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	629	74	(629)+(74*1.75)	758.5
Cross during amber	6	0	(6)+(0*1.75)	6
Violates red light	1	0	(1)+(0*1.75)	1
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	673	101	(673)+(101*1.75)	849.75
Cross during amber	12	2	(12)+(2*1.75)	15.5
Violates red light	9	2	(9)+(2*1.75)	12.5
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent Pcu	Total pcu
Comply with red light	662	114	(662)+(114*1.75)	861.5
Cross during amber	2	0	(2)+(0*1.75)	2
Violates red light	8	0	(8)+(0*1.75)	8

Table B-4: Traffic Volume in PCU for Intersection at Jalan Macalister

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	454	12	(454)+(12*1.75)	475
Cross during amber	11	0	(11)+(0*1.75)	11
Violates red light	0	0	(0)+(0*1.75)	0
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	457	15	(457)+(15*1.75)	483.25
Cross during amber	9	1	(9)+(1*1.75)	10.75
Violates red light	3	0	(3)+(0*1.75)	3
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	436	16	(436)+(16*1.75)	464
Cross during amber	11	1	(11)+(1*1.75)	12.75
Violates red light	2	0	(2)+(0*1.75)	2

Table B-5: Traffic Volume in PCU for Intersection at Jalan Tanjung Tokong

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	487	18	(487)+(18*1.75)	518.5
Cross during amber	21	0	(21)+(0*1.75)	21
Violates red light	6	0	(6)+(0*1.75)	6
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	532	17	(532)+(17*1.75)	561.75
Cross during amber	14	1	(14)+(1*1.75)	15.75
Violates red light	9	0	(9)+(0*1.75)	9
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	581	8	(581)+(8*1.75)	595
Cross during amber	10	0	(10)+(0*1.75)	10
Violates red light	6	0	(6)+(0*1.75)	6

Table B-6: Traffic Volume in PCU for Intersection at Jalan Sultan Azlan Shah (Gelugor)

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	390	57	(390)+(57*1.75)	489.75
Cross during amber	3	2	(3)+(2*1.75)	6.5
Violates red light	1	0	(1)+(0*1.75)	1
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	398	30	(398)+(30*1.75)	450.5
Cross during amber	0	1	(0)+(1*1.75)	1.75
Violates red light	0	0	(0)+(0*1.75)	0
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	391	38	(391)+(38*1.75)	457.5
Cross during amber	5	0	(5)+(0*1.75)	5
Violates red light	3	0	(3)+(0*1.75)	3

Table B-7: Traffic Volume in PCU for Intersection at Jalan Sultan Azlan Shah (Bayan Lepas)

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	296	49	(296)+(49*1.75)	381.75
Cross during amber	9	3	(9)+(3*1.75)	14.25
Violates red light	3	0	(3)+(0*1.75)	3
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	383	52	(383)+(52*1.75)	474
Cross during amber	9	3	(9)+(3*1.75)	14.25
Violates red light	5	1	(5)+(1*1.75)	6.75
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	337	54	(337)+(54*1.75)	431.5
Cross during amber	13	2	(13)+(2*1.75)	16.5
Violates red light	2	0	(2)+(0*1.75)	2

Table B-8: Traffic Volume in PCU for Intersection at Jelutong Expressway

9.30 a.m to 10.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	779	58	(779)+(58*1.75)	880.5
Cross during amber	7	1	(7)+(1*1.75)	8.75
Violates red light	7	1	(7)+(1*1.75)	8.75
10.00 a.m to 10.30 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	878	66	(878)+(66*1.75)	993.5
Cross during amber	15	0	(15)+(0*1.75)	15
Violates red light	13	1	(13)+(1*1.75)	14.75
10.30 a.m to 11.00 a.m	Total passenger car	Total lorry and busses	Equivalent pcu	Total pcu
Comply with red light	703	64	(703)+(64*1.75)	815
Cross during amber	12	1	(12)+(1*1.75)	13.75
Violates red light	13	1	(13)+(1*1.75)	14.75

APPENDIX C

MAPS OF INTERSECTION LOCATIONS

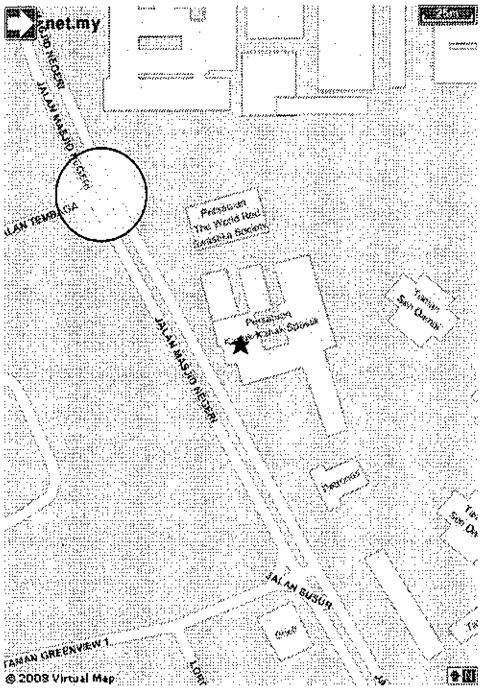

Figure C-1: Map of Jalan Masjid Negeri [16]

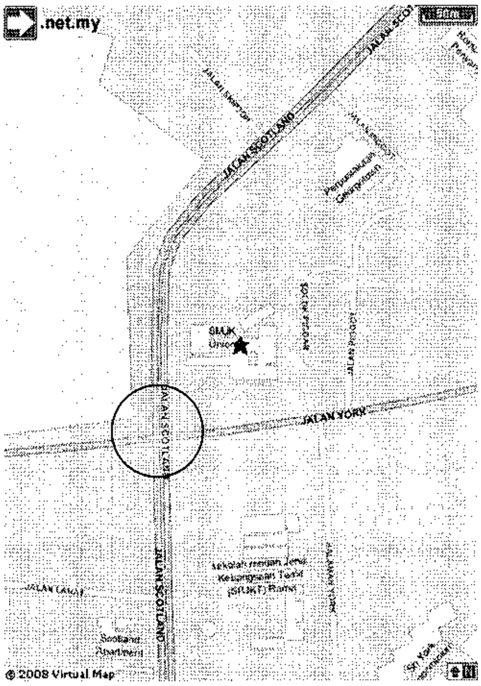

Figure C-2: Map of Jalan Scotland [16]

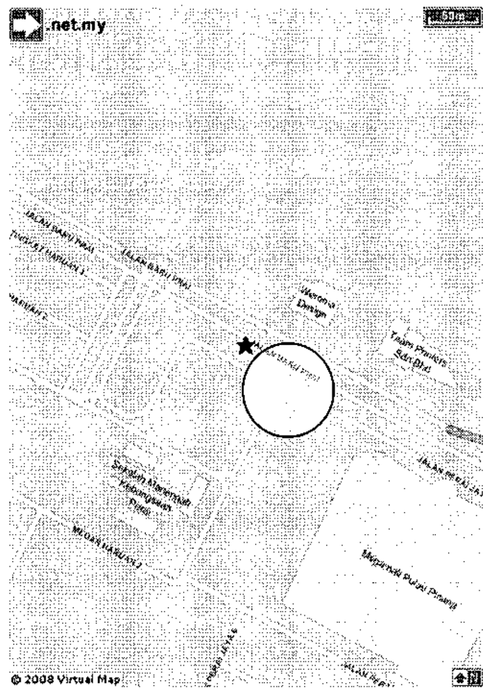

Figure C-3: Map of Jalan Baru [16]

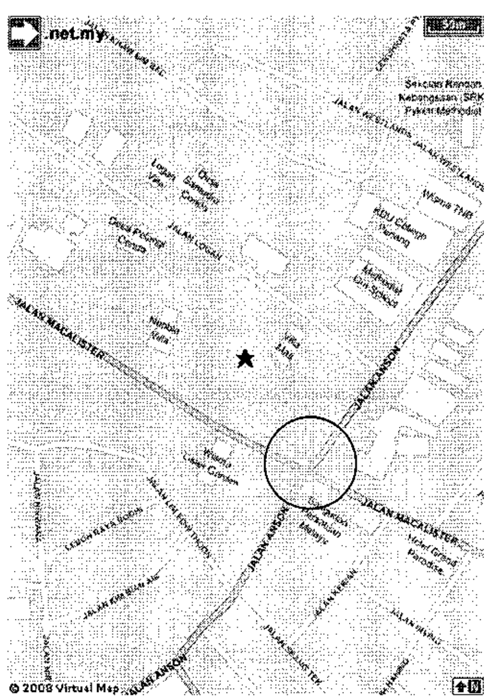

Figure C-4: Map of Jalan Macalister [16]

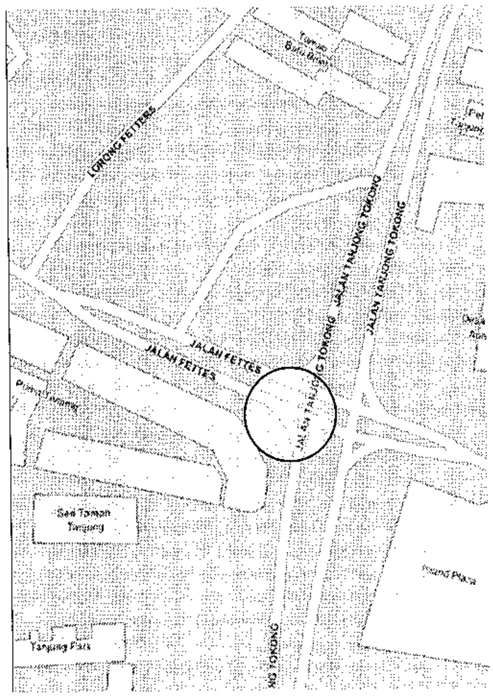

Figure C-5: Map of Jalan Tanjung Tokong [16]

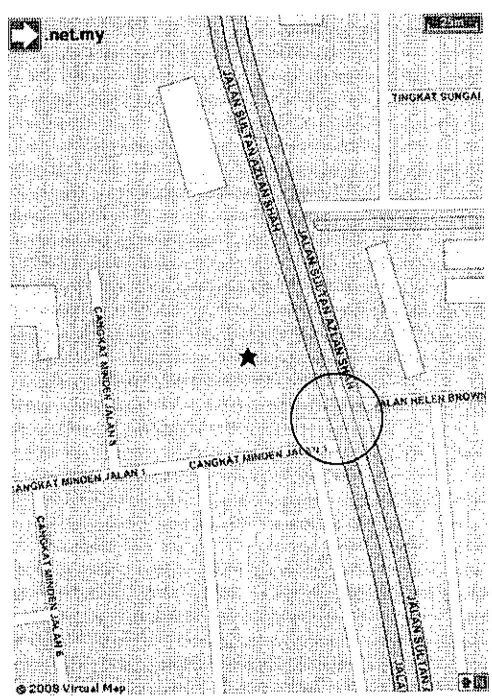

Figure C-6: Map of Jalan Sultan Azlan Shah (Gelugor) [16]

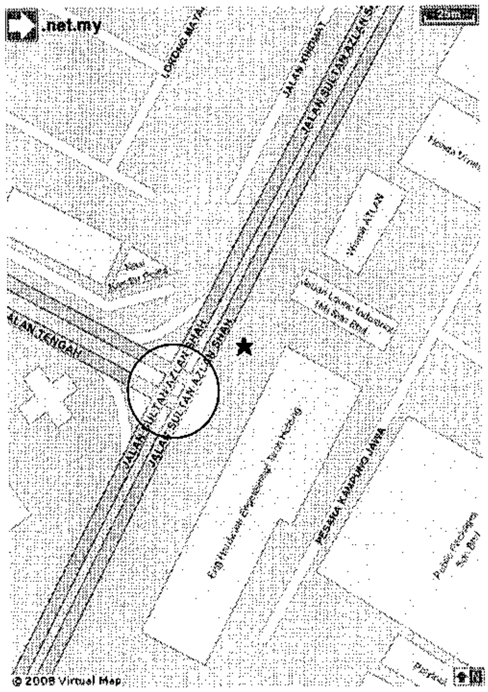

Figure C-7: Map of Jalan Sultan Azlan Shah (Bayan Lepas) [16]

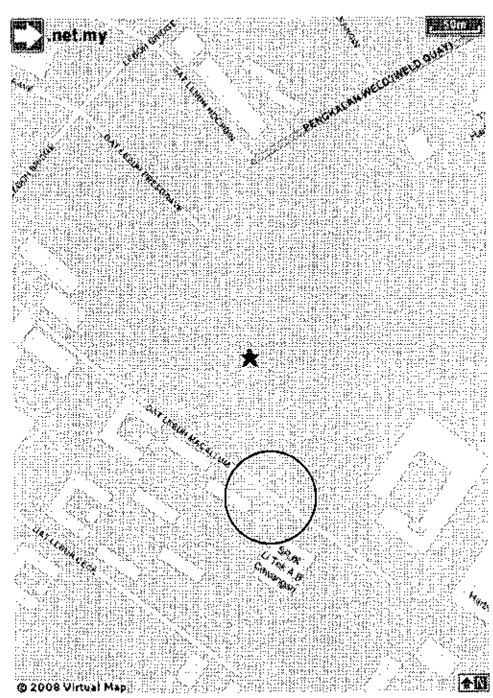

Figure C-8: Map of Jelutong Expressway [16]