THE INFLUENCE OF AN ADVANCED AMBER WARNING SYSTEM ON DRIVER BEHAVIOUR IN BRUNEI DARUSSALAM

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Abstract

In Brunei Darussalam, an advanced amber warning system, known as the 'Prepare to Stop' (PTS) signals, are typically placed between 50 and 100 m from the stop-line along the junction's approach. The purpose is to reduce dilemma zone problems, instances of abrupt braking at red-light and reduce red-light running (RLR). This paper investigates the effectiveness of the PTS signals implemented on approaches of signalised junctions in Brunei Darussalam. Traffic data were collected on each approach for 2 hours per day over 10 working days using digital video recorders which were then analysed using Microsoft Excel, descriptive statistical cross-tabulation and regression tests in SPSS. The results comprised the rate of RLR at each of the studied approaches, average vehicles' travelling speed and the likelihood of vehicles decelerating and stopping at the onset of amber light in correspondence to the PTS signals. The outcomes showed that dilemma zone is extended by up to 275m along the approach and that most vehicles eventually stop at the stop line along the approaches with PTS signals installed. Most RLR cases observed for both junctions were not accidental but were deliberated by the drivers.

1. Introduction

In Brunei Darussalam, automated traffic signal lights are installed at junctions, intersections and roundabouts to provide safe control of traffic. It is indicated that (i) the red signal prohibits traffic to proceed beyond the stop line on the carriageway until the green signal appears; (ii) the green signal allows the traffic to proceed straight on or to the left or to the right; and (iii) the amber signal shall be taken as prohibiting traffic to proceed beyond the stop line except in the case of any vehicle which when the signal first appears is so close to the said line that it cannot safely stopped before passing the line [1].

There are currently 94 signalised junctions in Brunei Darussalam, out of which 34 have been converted to Sydney Coordinated Adaptive Traffic System (SCATS) and the rest are on fixed time system. Moreover, several signalised junctions have also been installed with the 'Prepare To Stop' (PTS) advanced amber warning light [2]. A typical PTS signal layout is illustrated in Fig. 1.

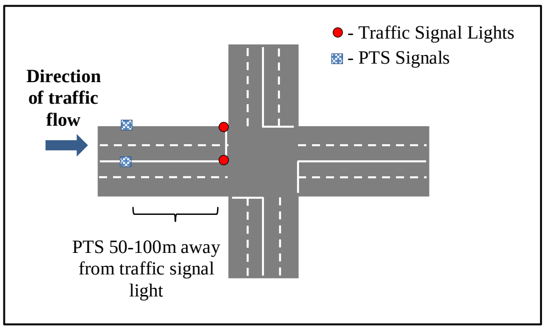


Fig. 1 Typical PTS signal set up in Brunei

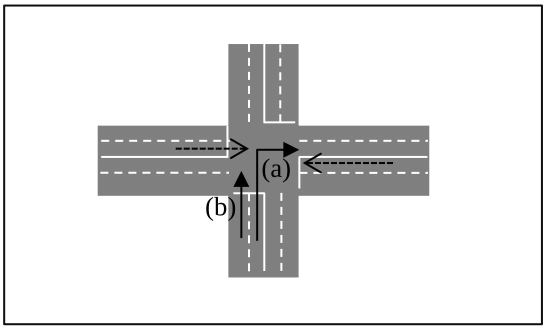


Fig. 2 (a) right-turn collision (b) right-angle collision. Solid line arrow shows vehicle running a red light. Dashed line open arrows are vehicles passing through the junction at green time.

The advance amber warning light system were first introduced to signalised junctions in Brunei Darussalam in 2003 at J70, Jalan Gadong. This was initially installed at the specified approach because it has insufficient safe stopping sight distance to drivers due to the road geometry. As of 2015, the PTS signals were installed to 54 signalised junctions in Brunei Darussalam, some of the approaches to these junctions do not have issue with sight distances; instead, the PTS signals are expected to warn drivers to slow down and prepare to stop on approach to a signalised junction in anticipation of traffic signal changes from green to amber and then red phase. The purpose of the PTS is thus to prevent abrupt braking at red-light causing rear end collision, and red-light running possibly causing a right-angle or a right turn collision as illustrated in Fig. 2.

Red light running (RLR) occurs when a vehicle deliberately or unintentionally failed to slow down and stop before a stop line on a particular signalised junction causing it to enter the junction at the on-set of red signal light. There are two common factors contributes to RLR namely substandard practice and substandard design.

Substandard practice focuses more on the human factor and individual behaviour towards driving approaching a signalised junction. It relates to deliberate RLR which could be reduced by law enforcement. A deliberate RLR is frequently due to aggressive driving or driver's frustration [3] during peak hours leading to travelling faster than the desired speed limit approaching a junction or an intersection. A driver may then decide to run the red light mainly because he or she: (i) is at a position where they do not have sufficient time to decelerate and stop; or (ii) may have thought that the signal can be beaten as they pass through or enter a junction at green time, and hence did not notice the light changes to amber subsequently to red. A driver may also have decided to enter a junction when the right turn signal has not appeared while failing to see an oncoming vehicle from the opposite direction.

Substandard design refers to where the infrastructure contributes to unintentional RLR. For example, when the geometry of the junction or intersection approach is curved or downhill, it may reduce the sight distance where drivers do not have sufficient time to confirm the colour of the oncoming signals.

Some of the above examples could be associated with dilemma zone, where the driver is unable to predict the end of green time and the onset of amber light. He or she is therefore caught in the zone of no clear cut decision of either to pass or stop at the stop line. Depending on the speed and distance from the junction, the decision can be marginal [4]. If the driver is close to the stop line, then a decision to enter the junction would be safe and possible. On the other hand, if the driver is further away from the junction, it would be necessary to slow down and stop. The dilemma zone is the area between these two distances, where the decision of the driver becomes conflicting. The dilemma zone concept is illustrated in Fig. 3. The decision process at this zone often leads to RLR and this situation can be improved by several traffic engineering measures.

Brunei Darussalam, as with many other countries around the world, also experiences this problem. It has been found that there is an increase in the number of road accident cases from 117 in 2011 to 172 in 2013 within signalised junction vicinity based on the analysis of accidents record data obtained from the Traffic Control and Investigation Department (JSKLL) under the Royal Brunei Police Force.

The aim of this paper is to determine how the implementation of PTS influenced the drivers' behaviour at the onset of amber in Brunei Darussalam. This was achieved by measuring and analysing driver's operating speed along the approach of two study junctions, and distinguishing whether the drivers' are in dilemma or not as well as their reactions at the amber onset.

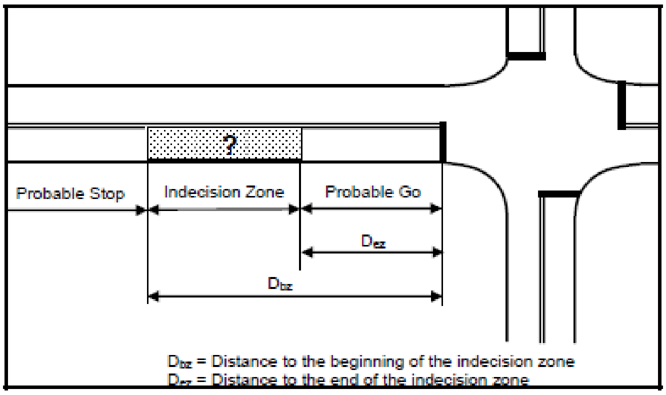


Fig. 3 Distances of dilemma or indecision zone from an intersection (Federal Highway Administration (FHWA) [5])

2. Methodology

During site selection, the following data were obtained and examined: (i) road traffic accident data at signalised junctions obtained from the Royal Brunei Police Force (RBPF); (ii) traffic signal design obtained from the Public Works Department (PWD). The sites eventually selected for this research were based on the similarities in junction and approach geometry for example width of road, approach speed limit and traffic light system. They are also considered to be safe, have clear visibility with the access to record aerial view of the signalised junctions' approaches on a pedestrian footbridge. From the traffic information and data provided by the PWD, the authors have chosen Jalan Jame 'Asr for having all the aforementioned criteria. It is a dual carriageway that leads to the Kiulap commercial area with a speed limit of 65 km/h. It has two separate and suitable approaches to signalised junctions such that the authors were able to examine the behaviour of drivers travelling towards the signalised junctions with and without PTS installed (J33 and J32 respectively).

After site selection, the field data collection were carried out which included measuring the geometry of signalised junctions, recording the traffic count on site, and video recording to interpret the operating speed of drivers and position of vehicles from stop during each 2-hour period of data collection. The geometry data of the studied area were also evaluated using the equations from Gazis et al [6] in order to identify the Type I dilemma zones for each selected location based on the posted speed limit along the road, i.e. the maximum distance, x_o and critical distance, x_c as illustrated in Fig. 4. These zones were subsequently identified on the site and in the video clips. To equate both distances, Gazis et al [6] had made assumptions such that the acceleration and deceleration were both constants. Both will begin at a time δ_1 or δ_2 (2.5s is used based on AASHTO) [7] after the onset of amber light respectively with an absolute maximum deceleration under ideal conditions of $3.4 m/s^2$.

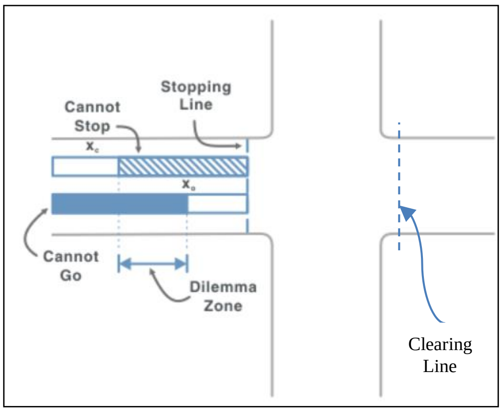


Fig. 4 Schematic diagram showing Type I 'dilemma zone' extracted from Gazis et al [6]

All data acquired were subsequently tabulated and analysed using the equations from Gazis et al [6], and mathematical modelling were run using Microsoft Excel and IBM SPSS software. Comparisons were made on the observed behaviour of drivers between the two study locations, i.e. junctions with or without the amber warning light system, in terms of decision making within the dilemma zone especially during the onset of amber traffic signal.

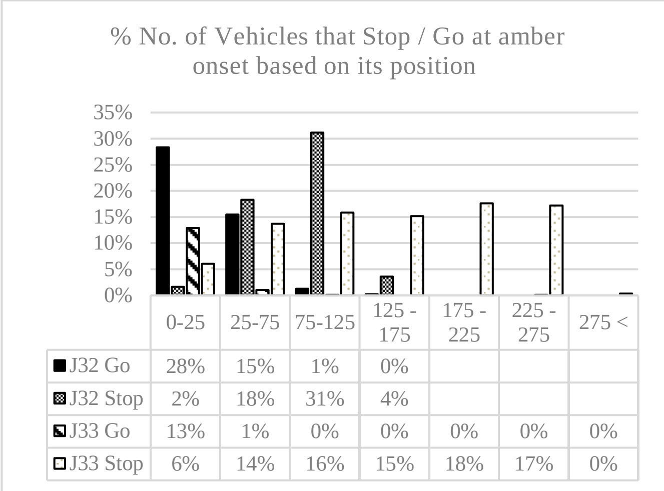
3. Results and Discussion

All vehicles were observed according to their positions along the respective junctions approached at the amber onset. Results from the data extraction were tabulated in Microsoft Excel and then tested using SPSS. The variables determined from the data extraction were the vehicles' travelling speed, 'dilemma' situation, the stop and go decisions and the red-light running cases.

Test for normality was carried out and it was found that the variables collected were not normally distributed. The relationships between the vehicles' 'Stop and Go' decisions as well as red-light running instances were then tested against their travelling speed and positions at the amber onset. This were determined using SPSS regression non-parametric tests. Statistical values observed and extracted from the field data collection were plotted as Fig. 5 to 8. Note that the values of "0-25", "25-75" and so on in the plots represent the respective distances of the drivers away from the stopline expressed in metres.

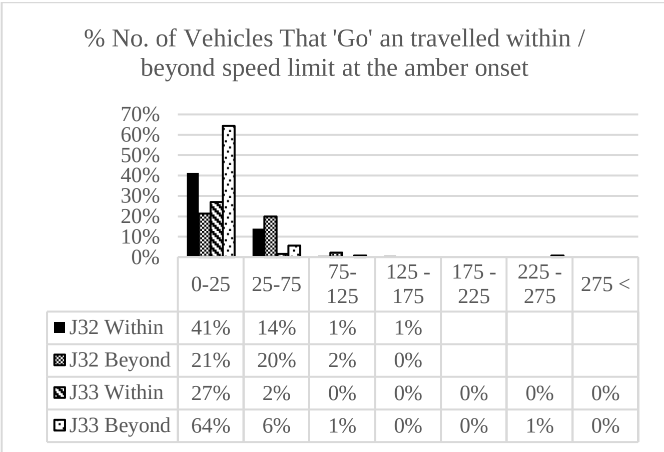
Fig. 5 and 6 showed that the drivers that decided to go were mostly closer (0-75m) to the stopline. They travelled within the speed limit at J32 but mostly beyond at J33. Vehicles at 0-25m passed the stopline at the amber onset but no RLR were observed. From Fig. 7, RLR were only observed from vehicles in the dilemma zone, calculated as between 23m and 93m [6]. Whilst the dilemma zone remained within the calculated value, it has extended further up to approximately 275m before the stopline in J33 (Fig. 8).

Irrespective of this extension, no RLR was observed throughout the recorded observation at J33. Most vehicles positioned at 25m onwards, though initially in dilemma, would stop at stopline. This showed that the existence of PTS at J33 has managed to forewarn drivers (though in 'dilemma') with regards to the amber onset and then effectively made them to decide to stop at stopline.



	0-25	25-75	75-125	125 - 175	175 - 225	225 - 275	275 <
J32 Go	28%	15%	1%	0%			
J32 Stop	2%	18%	31%	4%			
J33 Go	13%	1%	0%	0%	0%	0%	0%
J33 Stop	6%	14%	16%	15%	18%	17%	0%

Fig. 5 Percentage difference between no. of vehicles that stop or go at J32 and J33

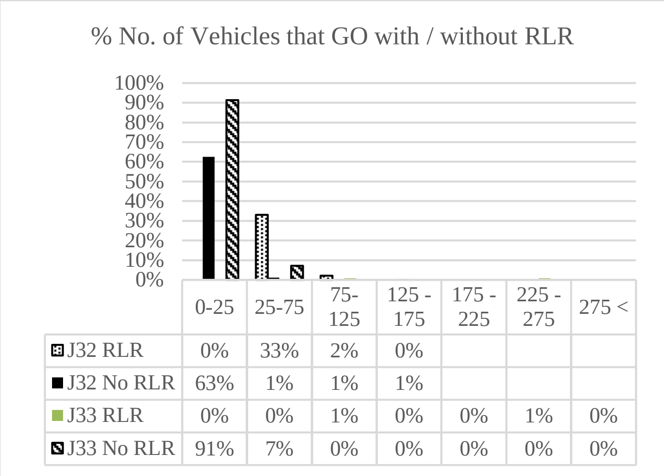


	0-25	25-75	75-125	125 - 175	175 - 225	225 - 275	275 <
J32 Within	41%	14%	1%	1%			
J32 Beyond	21%	20%	2%	0%			
J33 Within	27%	2%	0%	0%	0%	0%	0%
J33 Beyond	64%	6%	1%	0%	0%	1%	0%

Fig. 6 Percentage of vehicles at J32 and J33 that 'go' and travelled within and beyond speed limit

It was also expected that vehicles within the dilemma zone should be able to stop safely at the stopline of J32. However, site observations did not conform to this expectation. The decisions made by the drivers were obviously to challenge the amber light timing and consequently to run the red light.

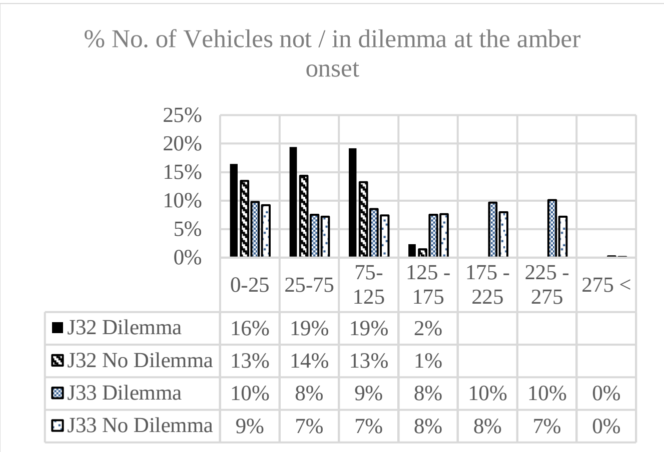
SPSS regression tests for J32 have showed that only 10.6% of the 'Stop and Go' decisions were affected by the speed of the vehicles and 51.2% affected by its positions. This clearly showed that at J32, regardless of the travelling speed, half of the decisions to go was based on the vehicles' positions. The test also showed that RLR behaviour were more deliberate because only 9.3% of these were depending on speed and most RLR instances occurs within the speed limit of the junction's approach (as shown in Fig. 6 and 7).



	0-25	25-75	75-125	125 - 175	175 - 225	225 - 275	275 <
J32 RLR	0%	33%	2%	0%			
J32 No RLR	63%	1%	1%	1%			
J33 RLR	0%	0%	1%	0%	0%	1%	0%
J33 No RLR	91%	7%	0%	0%	0%	0%	0%

Fig. 7 Percentage of vehicles with or without RLR at J32 and J33

The same test was also carried out for J33. The findings indicated that 30% of the 'Stop and Go' decisions at the amber onset were affected by the vehicles' position and only 3.6% were affected by the car speed. This clearly showed that the drivers' decisions depend more on their positions at the amber onset than their travelling speed.



	0-25	25-75	75-125	125 - 175	175 - 225	225 - 275	275 <
J32 Dilemma	16%	19%	19%	2%			
J32 No Dilemma	13%	14%	13%	1%			
J33 Dilemma	10%	8%	9%	8%	10%	10%	0%
J33 No Dilemma	9%	7%	7%	8%	8%	7%	0%

Fig. 8 Percentage of vehicles at J32 and J33 that are not / in dilemma during the amber onset

Observed results have also shown that after 75m, more vehicles travelled within the speed limit showing signs of drivers reacting to the PTS at J33 as well as the amber onset on both junctions. Drivers will most likely slow down and stop safely at stopline when they are at 25m onwards during the amber onset. Although the PTS has managed to reduce the rates of RLR for J33, the risk for rear-end collisions occurring along the junction's approach was still high especially if the drivers maintain their travelling speed to beyond the speed limit at positions 25m onwards. However, no accidents were observed during the data collecting period.

4. Conclusion

The existence of PTS and the vehicles' positions at amber onset were found to play an important role in the decision for drivers to accelerate or stop safely at the approaches' stop line. Most vehicles positioned at 0 – 25m from the junction stopline go pass the traffic light junction without RLR. Vehicles beyond the 75m mark can stop safely at the stopline with the provision that the travelling speed is within the speed limit. Even though a junction with PTS (J33) has a higher rates of vehicles stopping when compared with one that is without (J32), it was observed that more drivers at J33 travelled beyond the speed limit when compared with those at J32. This showed that drivers at J32 tend to be doubtful with the traffic light changes and preferred to slow down but will most likely attempt to go through the junction at the amber onset if they are near to the stopline, i.e. at positions 0-25m. It also showed that with the existence of PTS, drivers are understandable with their decision to stop at stopline. The results, however, has not fully verified that PTS improves drivers' safety at signalised junction. The authors believed that further research can be carried out to provide more evidence of such behaviour. It is suggested that research should also be carried out on a different neighbourhood, example residential housing areas. A possible study could be carried out for junctions that are in the plan to have PTS installed to study the behaviour of drivers before and after installation.

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