DO PROFESSIONAL DRIVERS SUFFER FROM DILEMMA ZONE PROBLEM WHILE FACING AMBER LIGHT?

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ABSTRACT

Signal controlled junction, which is a good measure to cater for conflicting traffic in heavily trafficked intersections, has been widely adopted in urban road networks. Traffic flow distributions, delay on road users, and more importantly road safety are the major considerations when designing junctions. Numerous studies have been conducted attempting to strike a balance between these three aspects by extending the green or yellow time in case of vehicles fall within dilemma zone (DZ) to avoid conflicts. In this study, a new proposed parameter termed "perception" was adopted to quantify the favorability of recorded vehicles in making STOP/GO decisions and to assess drivers' performance in making stop/go decisions while facing amber light. Paired t-test was used to check the proposition that (1) whether the situations of approaching vehicles at the amber onset at the studied signalized junction is generally favorable to GO; (2) whether professional drivers including Public Bus, Public Light Bus, Taxi and Goods Vehicle drivers suffer from DZ problem in making STOP/GO decision while facing amber; and (3) attempt to figure out the worst decision making performance area of observed drivers at the junction considered in this study. The results of this study indicate that the situations of drivers that were observed in the studied junction were generally favorable to GO and virtually all the observed drivers aware of their favorable choices while facing amber light. In other words, drivers that were observed in this study do not suffer from DZ problem. The results also indicate that Taxi drivers are comparatively worse in making STOP decision while facing amber light compared to Public Bus, Public Light Bus, Goods Vehicle and Private Car drivers, but this is subject to speeding problem that should be prohibited. In addition, the worst decision making performance area was found at approximately 44 to 48m from stop line (i.e. 3.2 to 3.5 seconds travel time from stop bar) that is slightly larger than travel distance covered by 3 seconds amber time. Further comprehensive analyses on whether or not drivers suffer from DZ problem at signalized junctions with difference geometry layouts and traffic conditions in Hong Kong are required to evaluate if there is a need to provide DZ avoidance measures and thus to improve junction design in safety respect.

KEYWORDS

Dilemma Zone, signalized junction, professional drivers

INTRODUCTION

Comparatively high accidents records at signalized junctions are commonly reported in cities with extensively developed road networks such as British, Japan and Sweden where the traffic risk in urban area is reported similar to that in Hong Kong. This high accidents record is indeed a world-wide problem that great attentions to improve traffic safety conditions at signalized junctions have been drawn from traffic engineers. In the past, violations of traffic regulations including speeding and red-light running were commonly believed as factors contributing to the high accidents records. Therefore, corresponding actions to combat speeding and red-light running were undertaken. The reviews of counter measures combating red light running at signalized junctions have been conducted indicating that the numbers of red-light running has been reduced, but the noticeably high accidents records at signalized junctions have yet been solved (Retting et al., 2008; Bonneson and Zimmerman, 2007). Meanwhile, scholars have started to question the high accidents records problem might be due to drivers' inability in making STOP/GO decision at the time when traffic signal turns to amber from green (Zegeer and Deen, 1978; Retting and Greene, 1997). This inability has later been named as dilemma zone (DZ) problem which previously suggested attributing to insufficient amber time duration and high approaching speed (Gazis et al., 1960). Presence of DZ problem would lead to traffic accidents if (1) a vehicle approaching a signalized junction in which driver mistakenly opts to proceed the junction without sufficient amber time; and (2) two or more vehicles approaching a signalized junction in the form of platoon at the same traffic lane in which two drivers make contradictory decisions in response to amber light, i.e. leading driver opt to STOP while the following driver opt to GO. These two cases might explain why comparatively high accident records were reported at the vicinity of signalized junctions. Referring to the statistics from Transport Department HKSAR regarding traffic accidents happened at non-signalized and signalized junctions in Hog Kong, comparatively high number of traffic accidents was reported at signalized junctions, particular at cross-roads and T-junctions as shown in Figure 1. This is somewhat supporting the assumed situation described above; and it seems that there is a pressing need to investigate if drivers in Hong Kong suffer from DZ problem, leading to such noticeably high accidents happened at signalized junctions.

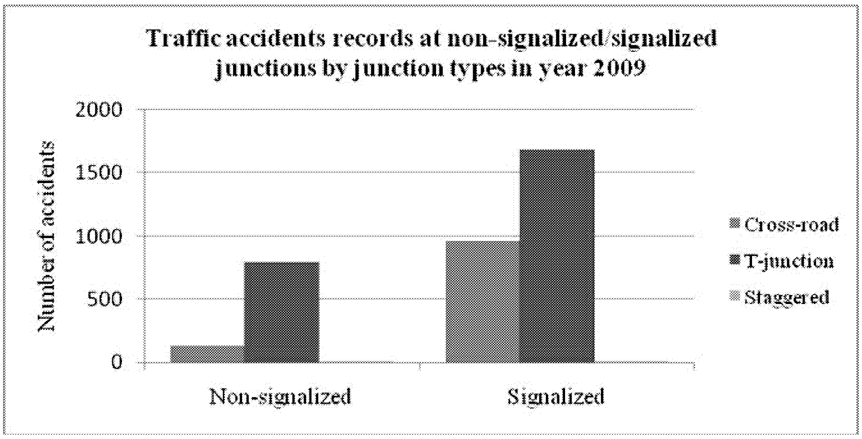

Figure 1 Traffic accidents records at non-signalized/signalized junctions in Hong Kong in year 2009

Since the 1960s, a study concerning the drivers' inability while approaching junction at the onset of amber has been initiated by Gazis et al. (1960) with the conclusions that the problem could be solved by providing sufficient amber time that obtained by using deterministic average value of drivers' reaction time, acceleration and deceleration rates. This formulation which has been commonly known as GHM model adopted in design handbook for practical use. Theoretically, GHM model can provide guidelines to determine amber time in safety respect as to relieve DZ problem at signalized junctions, but, in reality, road users may not be as capable of as expected and thus drivers whose abilities are out of expectation might be prone to traffic accidents. For instance, if driver's reaction time is longer than the assumed value adopted in the GHM model, it would probably require harder acceleration and deceleration to clear the junction and stop at the stop line, respectively. This abrupt change of speed might consequently lead to traffic accidents. The relation between longer reaction time and traffic accidents occurrence is somewhat supported by previous studies that older and inexperienced drivers are less reactive to repaid changing traffic conditions and thus they are more likely to have accidents compared to middle-aged and experienced drivers (Lourens et al., 1999; Massie et al., 1994; Factor et al., 2008). It thus leaves an imperative issue that DZ problem could not be solved by using deterministic approach because diversified driving behaviour is anticipated to be prevailing among junctions and cities. Therefore, Zegeer (1978) proposed a probabilistic approach to cope with diversified driving behaviour. This approach based on observing drivers' STOP/GO decisions while facing amber under naturalistic driving environment states that DZ boundary is the area where 10% of drivers choose to GO and 90% of drivers choose to STOP. This probabilistic approach has later been named as Type II DZ and the deterministic approach (i.e. GHM model) proposed by Gazis et al. (1960) has been named as Type I DZ. Nevertheless, both approaches are valid and widely adopted for different purposes.

For years, numerous studies attempt to figure out DZ boundary have been undertaken (e.g. Heng et al., 2009; Gates et al., 2007 and 2010; Sharma et al., 2010). Foci have also been paid onto implementations of avoidance measures to relieve DZ problem and thus the noticeably high accidents records at signalized junctions (e.g. Archer and Young, 2009; Li and Abbas, 2009; Hamaoka et al., 2010). To prevent drivers from facing dilemma at the amber onset, traffic engineers attempt to provide green or amber time extension so that drivers do not need to face dilemma when approaching signalized junctions. Under low traffic flow situations, the avoidance measure is effective to relieve DZ problem, but in heavily trafficked situations, this measure may be problematic due to indefinite signal time extension as vehicles from upstream direction would continue to get into DZ boundary, i.e. the area where drivers face dilemma in making STOP/GO decision if traffic signal turn to amber from green. This indefinite signal time extension would thus significantly worsen junction efficiency, even though, in the later stage, max-out signal time extension measure, i.e. a maximum threshold of signal time extension has been used. Other than DZ avoidance measures, studies attempting to predict drivers' stop/go decision by modeling observed drivers' decision making behaviour on sites have been undertaken. With the use of the calibrated prediction models, road operators could able to predict drivers' STOP/GO decision in accordance with their situations (i.e. approaching speed, distance from stop line and other variables such as vehicle types and lane positions) at the onset of amber so that signal time extension is set to provide for vehicles that are predicted to GO but without sufficient amber time to safely clear the junctions. These studies have significant contributions in protecting drivers from facing DZ problem while approaching signalized junctions, it however leaves a question that whether or not drivers actually face dilemma in making STOP/GO decision at the onset of amber while approaching signalized junctions. Without assessing whether or not drivers suffer from the DZ problem, it may not be worthwhile to implement protective measures if drivers indeed do not face dilemma in making STOP/GO decision. This is because protective measures in the form of signal time extension might impose another dilemma to drivers as they may feel hesitate that why green and amber time changes randomly. For drivers who routinely drive across the same junction, fully activated signal time configuration could influence their decision making abilities because of unfamiliarity and thus contribute to traffic accidents at signalized junctions. Studies investigating drivers' ability in response to rapid changing traffic conditions have been widely conducted with an overall conclusion that old, young and inexperienced drivers are less reactive to the risk prone traffic conditions compared to middle-aged and experienced drivers (e.g. El-Shawarby et al., 2010; Lourens et al., 1999; Massie et al., 1994; Factor et al., 2008). These studies give an insight that the problem of whether drivers having dilemma while approaching signalized junction might be due to their capabilities and explain why the less reactive drivers group is commonly reported as more likely to have accidents. Therefore, drivers who are of comparatively driving skills might be more prone to traffic accidents while approaching signalized junctions if assumed design parameters adopted in the GHM model do not cover the need of this driver group. Albeit the studies discussing interaction between drivers' abilities and traffic accidents occurrence were conducted on expressways and urban trunk roads, studies focus on signalized junctions have also been conducted with similar conclusions (e.g. El-Shawarby et al., 2010; Liu, 2006; Papaioannou, 2007). To have an in-depth investigation on drivers' driving behaviour, Papaioannou (2007) is probably the first one who attempt to assess drivers' performances in making STOP/GO decision at the onset of amber. Drivers that were observed in the study were classified as "aggressive", "normal" and "aggressive" according to their speed choice and STOP/GO decision in response to their situations at the onset of amber. The results suggest that driver's "aggressiveness" which is the prevailing classification of drivers in the studied junction would be the imperative factor contributing to the high accidents records. In addition, this study gives an insight to forthcoming safety assessment studies that road user behaviour should first be assessed to get a better understanding of why accident records at that locations are noticeably high. Because of these arguments on road safety issue, it leads to a pressing need to know if drivers in Hong Kong suffer from DZ problem and if the noticeably high accident records are the consequences of the DZ problem. This study aims to contribute to these aspects by quantifying drivers' decision making performances using a new proposed measure termed "perception". In particular, professional drivers including Public Bus, Public Light Bus, Taxi and Goods Vehicle drivers which are expected to have better driving skills are the focus of this study.

METHODOLOGY

Studied junction

Video records of drivers' approaching and STOP/GO decision making behaviour were undertaken in a signalized T-junction. This junction has three through lanes, two straight lanes and one right turning lane with speed limit 50kph. The studied junction is situated at the point of intersecting traffic between Lei Yue Mun Road and Ko Chiu Road that is in a highly populated residential urban area in Hong Kong. This junction serves both vehicular traffic and pedestrian traffic by means of signal control in which amber time is 3 seconds that is the standard widely adopted in Hong Kong. As a signalized junction and roundabout is 400m and 600m, respectively, apart at the upstream direction, the probability that the approaching vehicles facing onset of amber are related to signal coordination between the two junctions. For the junction considered in this study, approximately 19 vehicles were observed to face the amber onset in 10 signal cycles. According to the Transport Department HKSAR, the studied junction was labelled as Blacksite in quarter 3 of year 2010 (i.e. the time before the observation period) meaning that 2 or more fatal accidents happened in the past 5 years or 9 or more injury accidents happened in the past 12 months. No speeding camera or red-light running camera has been installed in the studied junction.

Data Collection

A video camera was used to record drivers' driving behaviour at the onset of amber while facing amber light. To avoid interferences on drivers' approaching and decision making behaviour, equipment used for video recording was mounted on the podium of a residential building alongside the studied approach at approximately 65m from the stop line at upstream direction. In addition, this elevated platform provides a clear viewing angle for data extraction. As vehicles' approaching speed and distance from stop line at the amber onset were obtained via replaying video thereafter, benchmarks in every 5m interval along the pedestrian footpath next to the observed approach were placed. Figure 2 shows the view of studied junction from camera with 5m interval lines overlaid on it. In this study, 15 hours video was filmed in the studied junction during weekdays in which 381 drivers were recorded providing data for this study. Parameters describing subject vehicles at the instance of amber onset including approaching speed, vehicle distance from stop bar at the instance of amber onset, vehicle type and drivers' STOP/GO decision were recorded providing the focus data of this study. Of the 381 drivers observed in this junction, 210 drivers opt to GO and 171 drivers opt to STOP with average approaching speed at 45kph. It is important to highlight that 60 percentile of approaching speed is at 49kph, that's mean approximately 40% of drivers manoeuvre over speed limit (50kph) in the studied junction.

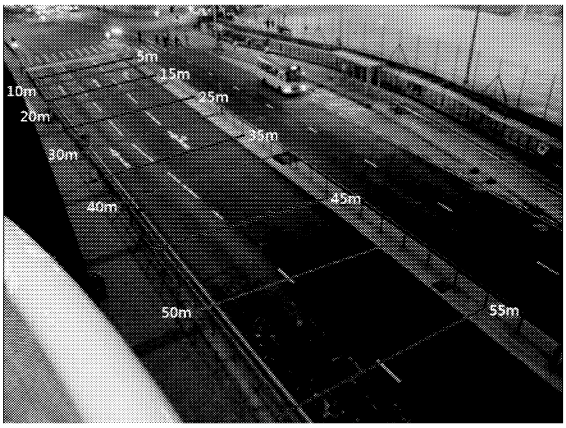

Figure 2 Evaluated view of studied signalized junction from camera

Formulation of the new proposed measure

As aforementioned, the new proposed measure "perception" that is used to quantify driver decision making performance at signalized junctions is formulated based on the GHM model (Gazis et al., 1960), i.e. the deterministic Type I DZ approach. For drivers opt to STOP, per_{stop} which is used to quantify driver's STOP decision performance defines as the difference between vehicle distance from stop line and the minimum safe stopping distance at the amber onset; for drivers opt to GO, per_{go} which is used to quantify driver's GO decision performance defines as the difference between vehicle distance from stop line and the maximum safe passing distance at the amber onset. Detail formulation of these two parameters are shown as follows,

$$per_{stop} = D - x_c = D - \left(v_o \delta_{stop} + v_o^2 / 2a_{stop} \right) \tag{0}$$

and

$$per_{go} = x_o - D = \left[v_o \tau + 0.5 a_{go} (\tau - \delta_{go})^2 \right] - D \tag{0}$$

where

τ is the amber time of studied signalized junction, i.e. 3 seconds.

v_o is the vehicle approaching speed in m/s.

x_o, x_c, D are safe passing distance, safe stopping distance and vehicle distance from stop line at the amber onset.

$\delta_{stop}, \delta_{go}$ are driver's reaction time to make STOP/GO decision while facing amber, 1 second reaction time was adopted.

a_{stop}, a_{go} are deceleration rate to make comfortably stop at the stop line and acceleration rate to proceed the junction within amber, in which 5m/s^2 acceleration rate and the equation 5-0.213v_o to obtain deceleration rate were adopted.

Those assumed values adopted in the calculation of this study are referred to the literature (e.g. Bonsall et al., 2005; Papaioannou, 2007; Heng et al., 2009; El-Shawarby et al., 2010). Following is a numerical example showing how per_{stop} and per_{go} apply to quantify driver's decision making performance at signalized junctions assuming a vehicle approaching the junction with speed 50kph at 35m apart at the onset of amber. Driver's per_{stop} and per_{go} are determined as follows:

$$per_{stop} = 35 - \left[(50*1000/3600)*1 + (50*1000/3600)^2 / 2/5 \right] = 1.8m$$

and

$$per_{go} = \left[(50*1000/3600)*3 + 0.5*[5 - 0.213*(50*1000/3600)]*(3-1)^2 \right] - 35 = 10.8m$$

In this example, the appropriateness of the driver opts to "GO" is 10.8 m; and the appropriateness of driver opts to "STOP" is 1.8 m. That's mean it is more preferable for this driver opt to "GO" under its situation. In addition, the positive values of both per_{stop} and per_{go} indicate that this driver is situated in the option zone (OZ) at the onset of amber, meaning that it can choose both comfortably STOP at the stop line and GO with gentle deceleration and acceleration, respectively.

Statistical model

To check the hypothesis that whether or not professional drivers in Hong Kong suffer from DZ problem at signalized junctions, paired t-test was adopted to compare mean difference of per_{stop} and per_{go} with respect to zero by the categories of drivers' STOP/GO decisions. The null hypotheses that if professional drivers do not suffer from DZ problem, grand mean of per_{stop} and per_{go} are significantly larger than zero as follows:

$$\begin{aligned} H_o &: \overline{per}_{go} > 0 \quad AND \quad \overline{per}_{stop} > 0 \\ H_1 &: \overline{per}_{go} \le 0 \quad AND \quad \overline{per}_{stop} \le 0 \end{aligned} \tag{0}$$

If this hypothesis not rejected, it can then be concluded that professional drivers that were observed in the signalized junction considered in this study did not suffer from DZ problem during the observation period.

RESULTS AND DISCUSSIONS

Table 1 shows the mean average value of per_{go} and per_{stop} of all recorded drivers with respect to their situations while facing amber. With the exception of Public Bus, all other vehicle types were found to have negative mean average values of per_{stop}, meaning that their situations at the instance of amber onset were not favourable for them to STOP. In case of choosing STOP, hard deceleration is required to make a complete stop at the stop line and thus they might prone to rear-end collision if the following driver do not keep sufficient following headway distance or not quickly respond to the STOP decision made by the leading vehicle's driver. On the contrary, the mean average values of per_{go} of all vehicles that were recorded in this study were found to be positive with respect to their situations at the instance of amber onset. The results obtained in the junction considered in this study appear to show that making GO decision is generally a better choice for drivers approaching the junction at the instance of amber onset, as the grand mean value of per_{go} is significantly larger than per_{stop} by 16m ($p<0.001$), regardless of vehicle types. It then leaves a question that whether or not this favourable situation applies to all individual vehicle types that were observed during the observation period. By further examine average mean differences between per_{go} and per_{stop} by vehicle types, analogous results were obtained revealing that statistically all the vehicle types that were observed during the study period were favorable to GO with respect to their situations at the amber onset.

Table 1 Mean average value of perception to GO and perception to STOP by vehicle types

Vehicle type		per go	per STOP	N
Public bus	Mean SD	12.3 14.7	3.0 15.2	42
Public light bus	Mean SD	18.1 16.1	-5.8 17.8	73
Taxi	Mean SD	20.9 16.2	-10.6 19.8	47
Private car	Mean SD	17.5 15.3	-6.4 18.5	84
Goods vehicle	Mean SD	13.8 15.8	-1.0 17.8	135
Overall	Mean SD	16.2 15.9	-3.9 18.3	381

Apart from the favorability for drivers opt to GO while facing amber, an interesting finding that the mean average value of per_{stop} obtained in the group of Public Buses reveals that the situations at the instance of amber onset are statistically favorable for Public Bus drivers to choose both GO and STOP. This comparatively more balanced situation between STOP and GO decisions might be because Public Bus drivers maneuver in a relative slow operating speed compared to other vehicles. Average mean operating speed of Public Bus is about 36kph compared to Goods Vehicle at 42kph, Private Car and Public Light Bus at 47kph and Taxi at 52kph. This further supports the proposition of the GHM model that slower operating speed is the most effective measure to avoid DZ problem; and the study conducted in Greece with the conclusions that the noticeably high accidents records and the DZ problem is due to drivers' "aggressiveness", i.e. high speed choice and aggressive decision making behvaior with respect to their situations while approaching signalized junctions (Papaioannou, 2007). From the first part of the analytical results, an insight to tackle DZ problem was given that controlling drivers' approaching speed at approximately 40 to 45kph might relieve drivers' proneness to face dilemma at the amber onset without significantly influence junction efficiency as design speed limit is set at 50kph.

Table 2 Driver's decision performance by STOP/GO decision and by vehicle types

Vehicle type		Mean	SD	95% CI lower	95% CI upper
Public bus	STOP GO	14.2 24.5	2.8 2.9	8.797 18.845	19.646 30.223
Public light bus	STOP GO	9.7 26.0	2.6 1.9	4.573 22.335	14.749 29.679
Taxi	STOP GO	3.1 27.8	3.2 2.3	-3.306 23.192	9.415 32.331
Private car	STOP GO	5.9 26.3	2.1 1.9	1.746 22.546	10.111 29.968
Goods vehicle	STOP GO	9.0 24.7	1.5 1.6	5.951 21.555	11.990 27.915

In regards to signal coordination and road network efficiency, the results as shown in Table 1 seem to indicate that signal coordination in area traffic control respect has been achieved, providing smooth traffic flow for road users and thus maximize system efficiency. The well signal coordination design that promotes smooth traffic flow among closely packed junctions may however have negative impacts on road safety if drivers do not aware that GO is generally a better choice or drivers often being conservative (i.e. bias to STOP) while facing amber light. Therefore, further assessments on whether or not drivers aware of their favorable choices with respect to their situations while facing amber were undertaken. This assessment aims to check the hypothesis that drivers in Hong Kong do not suffer from DZ problem as stated in the previous section. If this is proved to be true, it can be concluded that drivers that were observed in the junction considered in this study did not suffer from DZ problem during the observation period. Table 2 shows the results of mean average values of driver's decision making performance by categories of STOP and GO. In this part, paired t-test was adopted to compare mean difference of decision making performance by STOP/GO decision and by vehicle type. With the exception of Taxi, all other vehicles were found to perform statistically appropriate (i.e. mean value and 95% confident intervals are greater than zero) in both STOP and GO decisions while facing amber light, even though the traffic conditions are generally favorable for drivers opt to GO as reported above. In addition, the best and the worst decision making performance were reported under the category of Taxi among the vehicle types considered in this study. The paradoxical performances of Taxi drivers are somewhat in line with the reported favorability of STOP and GO in the previous section. In particular, the unsatisfactory performance in making STOP decision was suggested attributing to the relatively high operating speed that is about 52kph. It is indeed over the design speed limit of the studied junction (50kph) and is significantly larger than all other vehicles that were found to have satisfactory STOP performance. The unsatisfactory performance of Taxi due to high operating speed further supports the proposition that relatively slow operating speed would be a good measure to avoid DZ problem at signalized junctions (Gazis et la., 1960; Papaioannou, 2007). Apart from looking at the worst decision making performance obtained by Taxi, positive effects of lower operating speed on decision making were reflected by Public Buses' records. Table 2 shows that the mean performance value of Public Bus in making STOP decision is significantly larger than all other vehicles providing Public Buses mean average operating speed is significantly lower, which is about 36kph. The performance mean difference results of Taxi and Public Bus appear to reflect that lower operating speed might help making better STOP/GO decision while facing amber. Choosing the low operating speed level as Public Buses may however significantly worsen productivity of signalized junctions. Therefore, with reference to the results of Public Light Buses and Goods

Vehicles, taking operating speed at around 40km/h to 45km/h would sufficiently good to help with decision making as these two vehicles groups also show statistically satisfactory performances in both STOP and GO decisions, and more importantly, this suggested speed level which is slightly lower than that of speed limit is expected to have insignificant impact on system productivity. To conclude, an overall message given by the 381 drivers is that their decision performances in the studied junction appear to reflect that professional drivers do not suffer from DZ problem at the amber onset while approaching the junction, as only Taxi drivers were found to have unsatisfactory STOP performance in which the problem would be attributed to speeding that should be prohibited. Consequence to assessing drivers' decision making performance at the amber onset, linear regression method was adopted to establish the relationship between mean performance difference of STOP/GO decision and vehicle distance at upstream direction from stop line, attempting to figure out the worst decision making performance area as shown in Figure 3. By equating the regression line equal to zero, i.e. zero mean difference between STOP and GO decisions performances, the worst performance area is at approximately 44 to 48m (i.e. 3.2 to 3.5 seconds travel time with operating speed at speed limit 50kph) from stop line. This area is slightly larger than travelled distance with operating speed at speed limit covered by amber time (i.e. 3sec) of the studied junction. The slight deviance between amber time and the time obtained by the worst performance area appears to show that drivers are capable of maximizing the use of designated amber time duration, as they appear to have difficulties in determining whether they should STOP or GO just outside the boundary. This phenomenon gives a good feedback to traffic engineers for signalized junctions design in safety respect because at the area that outside the 3 seconds boundary, drivers should indeed choose to STOP as regulated. Therefore, measures to tackle the worst performance area problem could be tackled by providing road signs to notify drivers that they should opt to STOP from the point onward where road sign is installed. It would be unnecessary to provide avoidance measures to prevent drivers from falling into DZ or signal time extensions for drivers who would opt to GO without sufficient amber time to safety clear the junction. In case of vehicles are detected to prone to running red-light, extend all-red interval to avoid head-on/angled collision might be a more suitable measure as this is expected not significantly influence system efficiency.

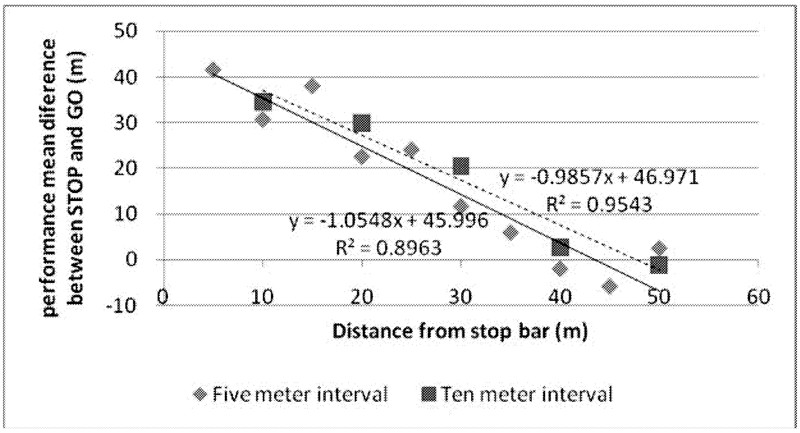

Figure 3 Performance mean difference between STOP/GO against Distance from stop bar

CONCLUSIONS

The study presented in this paper attempt to answer the research question that whether or not professional drivers in Hong Kong suffer from DZ problem. With the use of drivers' approaching and STOP/GO decision making behaviour observed in the signalized junction considered in this study and the new proposed measure that used to quantify drivers' decision making performance, an overall message is given that professional drivers in Hong Kong do not suffer from DZ problem. In fact, manual errors in making STOP/GO decision at amber onset do exist, but it exists outside the boundary of 3 seconds travel time with operating speed at design speed limit (i.e. 50kph). The boundary is about 44 to 48m (3.2 to 3.5 seconds travel time at 50kph) from stop line at the upstream direction. It is therefore suggested to install road signs to notify drivers that from the location with installed road signs onward is out of amber time duration, helping drivers opt to STOP to avoid having traffic accidents due to red-light running. Regarding drivers' STOP/GO decision performance assessed by the new proposed measure, Public Bus and Goods vehicle drivers demonstrate that manoeuvre with a relatively low operating speed could help to maintain a more balanced favourability between STOP and GO decisions at the amber onset, so that whether drivers choosing STOP/GO is likely to be appropriate and thus it is less likely to have red-light running or even rear-end/angled/head-on collision due to erroneous decision derived from DZ problem.

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