Effects of Countdown Timer on Yellow Light Running: An Empirical Study

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***Abstract*—Yellow light violation is exacerbated by the deficiency in the definition of yellow light function from Chinese road traffic safety law and no penalty to such violators. Last January, the "embarrassment" of a new traffic regulation pertaining to deter drivers from running yellow light made countdown timer be the better option to prevent this risky behavior. Since then, more and more countdown timers have been installed in China cities. However, the actual influences on yellow light running of countdown timer are still unclear, though there are very few relevant studies. The current study attempts to uncover more deeply the effects on yellow light running of countdown timer. Data on the number of yellow light running occurrence, entry time, and entry speed of vehicles crossing the stop line after yellow light onset were collected at four comparable intersection approaches located in Harbin, China. Statistical analysis results show that countdown timer has limited positively impact on the reduction of yellow light running, but no significant effect on entry speed. Furthermore, countdown timer leads to increase entrance into the intersection during the earlier portions of yellow signal.**

***Index Terms*—countdown timer, yellow light running, entry time, entry speed, signalized intersection**

I. INTRODUCTION

Yellow light which is the phase transition period from green to red is employed to alert drivers of the imminent commencement of red signal. When presented with the yellow light, a vehicle that the front of the vehicle has crossed the stop line is allowed to continue to proceed through the intersection according to the Chinese road traffic safety law [1]. In other word, the vehicle must stop no matter how close to the stop line at the onset of yellow indication. It is illegal for a vehicle before the stop line to continue to cross the intersection after yellow light onset.

In fact, the function of yellow light defined by this law is unreasonable, which usually results in risky driving behaviors. On the one hand, a driver may brake abruptly so as to comply with the yellow signal if he or she finds him or herself close to the stop line at yellow light onset. One the other hand, the driver may violate the yellow signal to proceed through the intersection due to hardly stop safely before the stop line by the start of red light. What is worse, the driver even violates red light to pass through the intersection under such situation. Additionally, some drivers may deliberately disobey with the amber signal to cross the intersection before the beginning of red signal, even though they are far enough from the intersection to stop comfortably before the stop line.

As above mentioned, running yellow light, or even running red signal, often occurs, when the driver faces with the amber light. As a matter of fact, yellow light running (YLR) is much more common than red light running (RLR). The occurrence of RLR in China, like in other countries, decreases obviously because of the increased enforcement of traffic law and corresponding regulation over the years. Although there has been a traffic law coming into force against YLR in China since May 1st 2004 [1], yellow light runners were not given any penalties until January 1st 2013 [2]. A new traffic regulation took effect and stipulated that a driver who violated a yellow signal would lose 6 points from the 12 points allocated on his or her driving license [3], [4]. However, the new regulation desisted six days later because of the deficiency of the traffic law and the widespread controversies and complaints arising from this regulation [5]. Since then, yellow signal violators have not received any penalties, but education and warning instead [5]. At the same time, installing a countdown timer, that indicates the remaining time (in seconds) of the current signal phase to assist drivers in being more prepared to react to the status change [6], is deemed as the better option to deter YLR occurrence.

The configurations of countdown timer can be grouped into three categories: counting down green signal, counting down red signal, continuously counting down green, yellow, and red signals [6]. So far, to our knowledge, only a few is known about the effects of countdown timer on YLR occurrence. A before-and-after investigation of green signal countdown timer (GSCD) in Singapore, reported the number of vehicles stopping during yellow interval increasing by about 6.2 times for a short term (1.5-month after installing this device) [7]. A comparison study at two similar intersections with and without GSCD in Shanghai, China, found that GSCD might encourage drivers to cross the stop line after yellow light onset with high speeds [8]. In addition to green signal, continuous countdown timer (CCD) also displays the remaining time of yellow light. This may lead to different influences on YLR occurrence. CCD in

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Bangkok, Thailand, had no effect on the number of vehicles entering the intersection and entry time during the yellow signal [9]. However, an evaluation in Changsha, China, concluded that CCD was associated with an increase in YLRs during the latter part of yellow indication [10].

Among the aforementioned studies, the effects on YLR of GSCD or CCD have varying results across different cities due to locality driving culture, traffic law/regulation enforcement activities, traffic condition, and other factors. Hence, more field observations are needed to enrich the dataset for exploring more deeply the impacts of countdown timer on YLR. The objective of this study is to investigate the influences of CCD on the number of YLR occurrence, entry time, and entry speed of vehicles crossing the stop line after the onset of yellow light.

TABLE I. CHARACTERISTICS OF THE SELECTED INTERSECTIONS

Intersection	CCD installed	No. of through lanes/no. of total lanes	Yellow duration (s)/ cycle(s)	Distance (m) between stop line and crosswalk
Haping Rd. & Muyan Rd.	No	3/4	4/149	2
Hongqi Rd. & Huaihe Dong Rd.	Yes	3/4	4/113	1.5
Nanzhi Rd. & Huanghe Rd.	No	4/6	4/170	2
Hongqi Rd. & Xianfeng Rd.	Yes	4/6	4/156	2

II. DATA COLLECTION

A. Study Sites

Four signalized intersections were selected for field observations performed in Harbin, China. The criteria used for selecting studied intersections include: (1) in the urban settings, (2) adequate sight distance, (3) on high speed major arterials with posted speed limit of 60 km/h, (4) the minimal effects of pedestrians and non-motorized vehicles, and (5) having a pedestrian bridge over the target approach. Two of them are installed with CCDs while the other two are not. The detailed information of each study site is shown in Table I.

B. Filed Observation and Data Extraction

In this study, vehicles passing over the stop line during yellow interval were recorded using Sony camera (HDR-CX610E) installed on the pedestrian bridge located at approximately 190 to 330 m upstream of the intersection. Field observations at these identified intersections were performed from 2:00 pm to 6:00 pm (in which, 4:00 pm to 6:00 pm is the peak period) on sunny days from Apr. 17th (Thursday), Apr. 19th (Saturday), Apr. 29th (Tuesday), and May 1st (Thursday) in 2014. A total of 16 hours of video data was recorded at these four signalized intersections.

In order to extract the data, the format (MTS) of collected video was transformed into AVI through the software, Format Factory. And then, the software, Adobe Premiere Pro CS3, was utilized to play the transformed videos with a frame rate of 25 fps. The video footage of yellow interval was played frame by frame to extract the accurate time information of the rear wheel of target vehicle crossing stop line after yellow light onset and passing over the edge of crosswalk (the edge close to stop line), respectively. Time information was recorded in the format of hh:mm:ss:ff where hh stands for hour; mm stands for minute; ss stands for second; ff stands for the number of frame (from 00 to 24). The entry speed is measured by dividing the distance from stop line to crosswalk by the time interval between the rear wheel of target vehicle successively passing over stop line and the edge of crosswalk. The moment of yellow light onset was also recorded to determine the entry time which is defined as the seconds after the beginning of yellow indication.

Since the focus of this study was on YLR, the cycle without any vehicles violating yellow signal was excluded. Finally, there were 400 samples for further analysis. Table II presents a part of the final dataset derived from the video processing.

TABLE II. A PART OF THE FINAL DATASET

Cycle no.	Time of target vehicle crossing stop line	Time of target vehicle crossing the edge of crosswalk	Time interval	Entry speed
	hh:mm:ss:ff	hh:mm:ss:ff	s	km/h
C2	00:04:05:01	00:04:05:04	0.12	60.00
C5	00:07:17:13	00:07:17:19	0.24	30.00
C5	00:07:17:14	00:07:17:21	0.28	25.71

III. ANALYSIS RESULTS AND DISCUSSION

A. Propensity and Intensity of YLR

Similar to the analysis of red light violation in the literature [11], propensity (proportion of cycles having YLR) and intensity (mean YLRs per YLR cycle) of YLR were introduced to examine the effects of CCD on YLR occurrence. Table III summarizes the propensity and intensity of YLR under the two conditions. It was found that the propensity of YLR was 44.39 % under the “with CCD” condition, and less than 59.89% under the “without CCD” condition. It was also found that the intensity of YLR was 2.17 vehicles at intersections without CCD, whereas this dropped to 1.73 vehicles at intersections with CCD. Thus, from the findings of this research, CCD has a positive impact on the reduction of YLRs.

B. Distribution of Entry Time

For CCD-equipped intersections, the observed mean entry time was 1.808 s (*SD*=0.992 s), while for intersections without CCD, it was 2.606 s (*SD*=1.002 s). The *t*-test showed that the difference in mean entry times was statistically significant at 95% confidence level (t=-7.862, p<0.0001). According to entry time of each yellow light runner, the number of vehicles committing

YLR each second of yellow time is summarized and illustrated in Fig. 1. As shown in Fig. 1, in the absence of CCD, most vehicles entered the intersections during the latter 3 s of yellow interval. This was significantly different ($\chi^2(3,400) = 33.815$, p<0.0001) from the situation that, in the presence of CCD, majority of vehicles streamed into the intersection 1, 2, 3 s after the commencement of yellow light. Consequently, the results of this analysis indicated that CCD tended to increase entrance into the intersection during the earlier portions of yellow signal. It should be noted that this finding contradicts the result from the Long et al. research [10], which found that CCD induced vehicles to be more likely to enter the intersection near the end of yellow light. Such discrepancy may be related to the yellow duration as well as traffic demand. Based on the observation in the existed study [10], the yellow interval (3 s) was not "long enough" for all vehicles to cross the intersection which continued to occur 4 s after the beginning of red, but the frequency of crossing vehicles descended sharply since the 1st s of red light. The result from the literature [10], that the distribution of the frequency of crossing vehicles during the earlier 4 s of entry time (3 s of yellow plus 1 s of red), is similar to the observation in the current research.

TABLE III. COMPARISON OF PROPENSITY AND INTENSITY OF YLR BETWEEN WITH AND WITHOUT CCD CONDITIONS

Cases	No. of all cycles collected	No. of cycles with at least one YLR	No. of YLRs	Propensity of YLR (%)	Intensity of YLR (vehicles)
With CCD	214	95	164	44.39	1.73
Without CCD	182	109	236	59.89	2.17

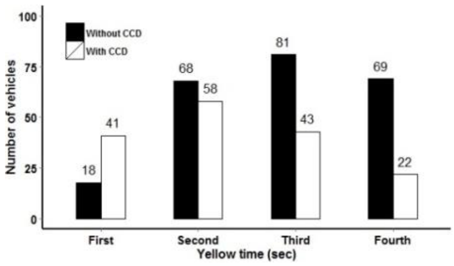

Figure 1. Number of vehicles committing YLR each second of yellow time.

C. Distribution of Entry Speed

The observed entry speeds from non-CCD and CCD-installed intersections with the distributions are shown in Fig. 1 and Fig. 2, respectively. The Shapiro-Wilk normality test validated that both groups of entry speed data followed the normal distribution with $\mu = 31.79$, $\sigma = 11.46$ and $\mu = 30.74$, $\sigma = 14.06$, respectively. Also, the estimated 85th percentile speeds were similar between the two conditions, with 45.32 km/h under the "with CCD" condition and 43.67 km/h under the "without CCD" condition. A more active speed limit of around 45 km/h may be posted at intersection approach to prevent intentionally violating yellow signal with high speed, since the 85th percentile speed is the critical (decision) speed for determining speed limit [12].

The mean entry speed of 30.74 km/h (*SD*=14.11 km/h) at the intersection with CCD did not exhibit a significant difference from the intersection without CCD (*Mean*=31.79 km/h, *SD*=11.49 km/h). This finding had been further verified by the *t*-test (*t*=-0.786, *p*=0.433). Such result is inconsistent with the finding of the Ma et al. study[8], which concluded that vehicular mean speed passing over stop line during yellow signal at the intersection with GSCD was greater than without GSCD. This difference is mainly attributed to the different function between CCD and GSCD. Unlike CCD, GSCD cannot count down yellow time. In the absence of yellow time information, the drivers usually accelerate to proceed through the intersection with GSCD after the onset of yellow.

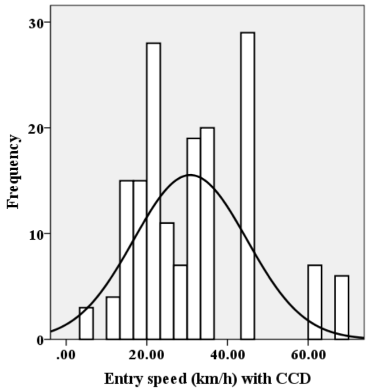

Figure 2. Distribution of entry speeds under the "with CCD" condition.

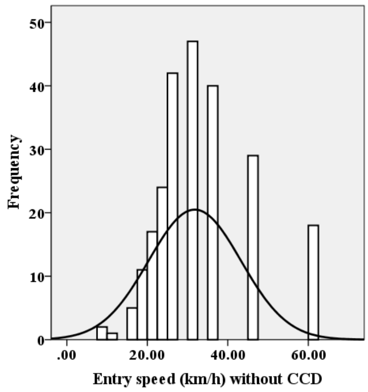

Figure 3. Distribution of entry speeds under the "without CCD" condition.

IV. CONCLUSIONS AND RECOMMENDATIONS

This study focused on investigating the effects of CCD (continuous countdown timer) on YLR (yellow light running), including the number of YLR occurrence, entry time since yellow onset, and entry speed of vehicles entering the intersection during yellow interval. The measures of effectiveness on the number of YLRs incidence included propensity of YLR (proportion of cycles having YLR) and intensity of YLR (mean YLRs per YLR cycle). In the presence of CCD, both propensity and intensity of YLR decreased to some extent. Such finding provides evidence that, as expected, CCD has a positive influence on the reduction of YLR incidence, but the impact is limited.

Statistical analysis suggested that the observed mean entry time since yellow onset under the “with CCD” condition was significantly lower than under the “without CCD” condition. Furthermore, most vehicles entered the intersection during the earlier 3 s of yellow time at the intersection with CCD, whereas the opposite result was found at the intersection without CCD. These findings come to a conclusion that CCD tends to increase entrance into the intersection during the earlier portions of yellow signal.

No matter at the intersection with or without CCD-installation, crossing vehicles’ entry speed data was found to follow the normal distribution. The estimated 85^{th} percentile entry speeds were similar under the two situations. Moreover, there was no significant difference between the observed mean entry speeds across with and without CCD conditions. These results imply that CCD has no effect on entry speed.

When compared to GSCD (green signal countdown timer), CCD can provide the full time information of yellow signal as well as green signal, which may be much better to reduce YLR occurrence, or even red light violations. Viewed from this angle, CCD has priority over GSCD to be installed at the intersection for deterring YLR.

In order to prevent vehicles intentionally accelerating to violate yellow light, in addition to countdown timer, reasonable speed limit enforcement is needed at intersection approach. Based on the analysis result of the current study, a speed limit of around 45 km/h may be posted, however, which needs to be further validated and adjusted with some other factors, such as driver attribute, roadway geometry, and crash history.

It should be mentioned that all findings in the present study remain to be extended with richer data. For instance, exploring more insights into yellow light violation under different yellow intervals will be the promising research direction.

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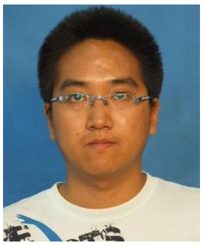

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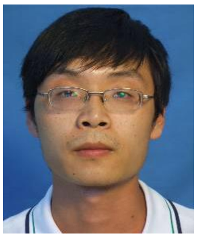

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