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# Driver responses to green and red vehicular signal countdown displays: Safety and efficiency aspects

Yu-Chiun Chiou*, Chien-Hua Chang

*Institute of Traffic and Transportation, National Chiao Tung University, 4F, 118, Sec. 1, Chung-Hsiao W. Rd., Taipei 100, Taiwan, ROC*

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ABSTRACT

This study investigates the effects of green signal countdown display (GSCD) and red signal countdown display (RSCD) on driver behaviours, and thus on intersection safety and efficiency. Three driver responses to GSCD, including late-stopping ratio, dilemma zone and decision to cross, and three driver responses to RSCD, including early start ratio, start-up delay, and discharge headway are observed and analyzed. Results show that although GSCD can reduce late-stopping ratio, the dilemma zone is increased by about 28 m and the decision to cross will be more inconsistent among the approaching vehicles, creating a potential risk of rear-end crashes. Additionally, following the provision of a green countdown the number of vehicles ejecting to cross the intersection reduces. On the other hand, comparisons among four observation periods examining the effects of RSCD—before-RSCD, 1.5 months after-RSCD, 3.0 months after-RSCD and 4.5 months after-RSCD, show that although RSCD significantly reduces the early start ratios of the leading vehicles in various waiting areas, the ratios soon return to their before-RSCD levels, suggesting that RSCD does not significantly improve intersection safety over the longer term. However, RSCD effectively reduces start-up delay, saturated headway, and cumulative start-up delay at 4.5 months after-RSCD installation. Thus, RSCD enhances intersection efficiency. RSCD is clearly less controversial and more beneficial than GSCD.



## 1. Introduction

To facilitate drivers' decision to cross or to stop during the critical phase-change period and to ease their waiting impatience in red phase, many countries worldwide equipped vehicular signal with green signal countdown display (GSCD) or red signal countdown display (RSCD) to provide drivers with a green or red countdown timing and help them make an informed decision. Taking Taiwan for instance, since the first introduction of GSCD in Hshinjhu City in 2000, a total of 1036 intersections of 22 counties/cities out of 25 have been installed either green, red or both countdown devices at the end of 2007. The pictorial view of two types, externally hanged and built-in, of RSCD and GSCD are depicted in Fig. 1.

Despite the popularity of countdown devices, relatively few studies have examined driver responses to countdown devices. In one of the earliest systematic studies, Lum and Halim (2006), reported a before-and-after study evaluating differences in driver response when approaching a signalized intersection with GSCD. Interestingly, they found a significant 65% reduction in red-running violations at 1.5 months following GSCD installation, but the effectiveness tended to dissipate over time with violations gradually returning to near pre-GSCD installation levels. Additionally, the number of approaching vehicles choosing to stop during the onset of amber significantly increased. Therefore, they concluded that the longer term performance of GSCD would help encourage stopping, but would not curb red-running violations. However, their study only examined red-running and red-stopping behaviours. Other behaviours, such as changes in decision to cross and changes in dilemma zone, are also crucial to intersection safety and efficiency. Additionally, a more comprehensive study should also investigate driver responses to RSCD. In Taiwan, a research report by the Institute of Transportation (Chen et al., 2007), a government-owned transportation research center, examined the effects of RSCD and GSCD on intersection safety. Specifically, this study examined the number of fatal and injury accidents during 2003–2006 at 187 signalized intersections within one year before-and-after RSCD and GSCD installation. The results showed that the number of fatal and injury accidents at intersections with GSCD increased by 100% while the number of accidents decreased by 50% for intersections with RSCD. For the intersections equipped with both devices, the number of such accidents increased by 19%. Based on these comparisons, Chen et al. (2007) postulated that drivers tend to accelerate aggressively when green countdown information is provided, so more crashes are then induced. In contrast, the accident rate can be curtailed because drivers are more likely

* Corresponding author. Tel.: +886 2 23494940; fax: +886 2 23494953.
*E-mail address:* ycchiou@mail.nctu.edu.tw (Y.-C. Chiou).

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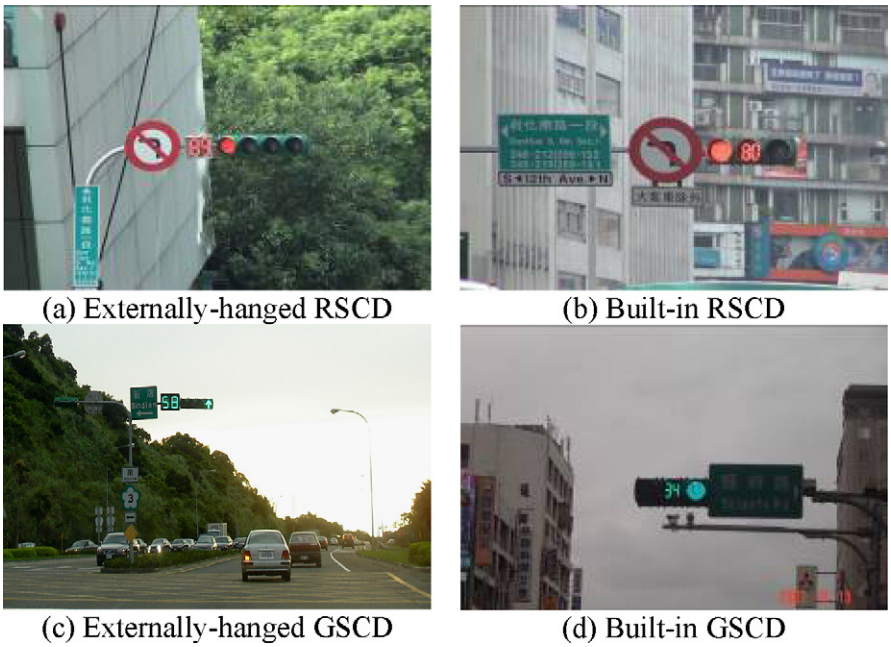


**Fig. 1.** Pictorial view of two types of RSCD and GSCD.

to obey red signal with the provision of red countdown information. Consequently, Chen et al. (2007) strongly recommended local authorities avoid installing GSCD but consider installing RSCD at intersections with long red time and/or multi-phase signal timing to relieve the impatience and confusion of waiting drivers, although no evidence on these postulated driver behaviours has been proven.

To improve on the gaps in the above researches, this study aims to investigate driver responses to GSCD and RSCD, respectively. Although both GSCD and RSCD are used to display remaining signal timing to drivers, they exert very different effects on driver behaviours. Generally, GSCD may affect driver behaviours that include late-stopping behaviours (red-running), dilemma zone and decision to cross. Meanwhile, RSCD may affect driver behaviours including early start behaviours (red-running), start-up delay of the leading vehicle, and discharge headway of following vehicles.

The rest of this paper is organized as follows. Section 2 classifies possible driver responses to GSCD and RSCD and then introduces the experimental design for observing driver responses. Section 3 then describes the effects of GSCD on three driver responses—late-stopping ratio (red-running ratio), dilemma zone, and decision to cross through a with-or-without approach. Meanwhile, Section 4 compares the effects of RSCD on three driver responses of early start ratio (red-running ratio), start-up delay, and discharge headway through a before-and-after approach. Finally, concluding remarks and suggestions for future studies are presented.

## 2. Experimental design and data collection

### 2.1. Driver responses to countdown devices

Although both GSCD and RSCD provide countdown timing to drivers, they affect driver behaviours differently. GSCD affects drivers during the transition from the motion state to the still state while RSCD affects them during the transition from the still state to the motion state. Consequently, drivers face the two devices from completely different situations, meaning their responses to the two devices can be observed and analyzed separately. To examine intersection safety and efficiency issues, three phenomena related to driver responses to GSCD are analyzed, including late-stopping ratio (*i.e.* red-running ratio), dilemma zone, and decision to cross. Late-stopping ratio is defined as the percentage of drivers who cross the stop line after the signal turns red (*i.e.* the countdown value shown on the GSCD is zero). The dilemma zone denotes the space of approach where larger than 10% and less than 90% of drivers will decide to stop. The longer dilemma zone implies the concern of intersection safety. Decision to cross is defined as the probability of drivers deciding to cross the intersection under various situations characterized by approach speeds, distances from the stop line, and stages of green countdown.

Similarly, three phenomena resulting from driver responses to RSCD are observed and compared, including early start ratio (*i.e.* red-running ratio), start-up delay and discharge headway. Early start ratio is defined as the percentage of leading vehicles crossing the stop line prior to the signal turning green during each cycle. Start-up delay is the time period from the start of the green phase (*i.e.* the countdown value shown on the RSCD is zero) until the leading vehicle crosses the stop line. Because of prevalence of motorcycles on urban streets in Taiwan, a motorcycle waiting area is installed at many intersections in front of queuing cars or buses in the right lanes to reduce potential conflicts among mixed discharge traffic at the beginning of the green phase. Additionally, at many medium to large intersections in Taiwan, another waiting area for left-turning motorcycles coming from the left hand direction on the cross street is located in front of the motorcycle waiting area and pedestrian crossing. The leading vehicles behind these waiting areas definitely suffer from larger start-up delay. Consequently, the driver behaviours for vehicles in the four different waiting areas are compared, including motorcycles in the left-turn waiting area, motorcycles in the through-traffic waiting area, cars in the waiting area immediately behind the stop line (namely in the inner lanes), and cars in the waiting area behind the motorcycle waiting area (namely in the outer lanes). To further analyze the influence of RSCD on sequential vehicles, the distributions of the discharge headway are also compared, where the discharge headway denotes the time that elapses between consecutive vehi-