

# Green signal countdown timers for bicycle traffic – Results from a field study

Heather Kath<sup>1</sup>, Georgios Grigoropoulos, Klaus Krämer

Technical University of Munich, Arcisstraße 21, 80333 Munich, Germany

<sup>1</sup> Email: heather.kaths@tum.de, Tel: +49 89 289 22436

Supported by:



Federal Ministry  
of Transport and  
Digital Infrastructure

on the basis of a decision  
by the German Bundestag

## 1. Introduction

Signal phase changes are critical in terms of traffic safety and efficiency at signalised intersections. Green signal countdown display (GSCD) and red signal countdown display (RSCD) both provide road users with information concerning the upcoming signal phase change. This information can be used by road users to avoid preventable stops and execute smooth and efficient acceleration and deceleration manoeuvres if a stop is necessary. The goal of both types of signal control display is to increase the overall traffic safety and efficiency as well as increase road user comfort at signalised intersections. GSCD allow road users approaching a 'stale' green signal to better anticipate the phase change to red. This theoretically reduces the length of the dilemma zone, the space in which a driver must decide to stop or continue when a signal changes to red (or yellow). In addition, road users can, if safe and possible, increase their speed based on the GSCD information to avoid stopping at the signal. Road users can also foresee the signal phase change and, in theory, are less likely to run a red signal.

Despite potential benefits, studies have found the effects of GSCD to be inconsistent and unintended negative effects have been observed. A significant amount of research has been carried out to investigate the effects of GSCD on the speed and traffic efficiency of motor vehicle traffic as well as red light violations of drivers. The results from these studies are extremely contradictory. Researchers observed either an increase in red light violations upon installation of a GSCD or more red light violations at intersections with a GSCD in comparison with similar intersections with no GSCD (Long, Han and Yang, 2011). Others found a positive effect of GSCD on red light violations (Papaioannou and Politis, 2014; Devalla, Biswas and Ghosh, 2015). Few researchers have investigated the effect of countdown timers on the behaviour of bicyclists. Guo et al. (2014) studied the red light violations of bicyclists, e-bicyclists and e-scooter users in China and found that countdown timers (GSCD and RSCD) increase the likelihood of red light violations by 3.6 times. No studies were identified that examined the effect of GSCD on bicycle traffic specifically.

In this paper, GSCD designed for bicycle traffic are assessed using data from a field study in Munich, Germany. GSCD are installed at three study intersections with different types of bicycle infrastructure and signal prioritisation. Video data are collected before and after the introduction of a GSCD. Trajectories extracted from the video data are used to analyse the proportion of bicyclists crossing while the signal is green, traffic signal violations and the speed of bicyclists upon crossing the stop line.

## 2. Method

Three study intersections in Munich, Germany were selected to investigate the effects of GSCD on bicycle traffic. Video data were collected at the study intersections in the morning peak and in the afternoon off-peak hours, both before and after the GSCD were installed at the intersections. The type of bicycle infrastructure, the signalisation and the time frame for video data collection at each of the intersections are given in Table 1. The intersections Karlstraße and Luisenstraße as well as Theresienstraße and Ludwigstraße are located in the

city centre of Munich. The third intersection, Milbertshofener Straße and Christoph-von-Gluck-Platz lies just outside of the middle ring road. The approach with the highest volume of bicycle traffic is selected for the GSCD investigation.

Table 1: Characteristics of the study intersections

Intersection	Bicycle infrastructure	Signalisation	Observation period	
			Without GSCD	With GSCD
Karlstraße and Luisenstraße	Bicycle lane	Actuated	8:30 - 14:30	7:40 – 9:10 12:30 – 16:50
Theresienstraße and Ludwigstraße	Bicycle lane	Actuated	7:00 - 10:00 16:10 - 19:10	8:10 - 9:40 14:20 - 18:50
Milbertshofener Straße and Christoph-von-Gluck-Platz	Bicycle highway	Actuated for bicycle highway	7:40 - 9:10 14:40 - 19:10	7:00 - 9:00 12:50 - 17:00

Video data were processed to extract trajectories from all observed road users (passenger vehicles, trucks, bicyclists and pedestrians). Trajectory data are a sequence of position vectors, one vector for each video frame in which a road user is observed. Velocity and acceleration at each point can be derived from the trajectory. Time stamps are used to link the trajectories extracted from the video data to traffic signal timing logs provided by the City of Munich. These logs contain the signal phase (green or red) of each signal head at the intersections during the observation period. Geometric information describing the intersection is used in conjunction with the trajectory data to identify the approach and manoeuvre of each road user (Figure 1, left) and further investigate the stopping behaviour (Figure 1, right).

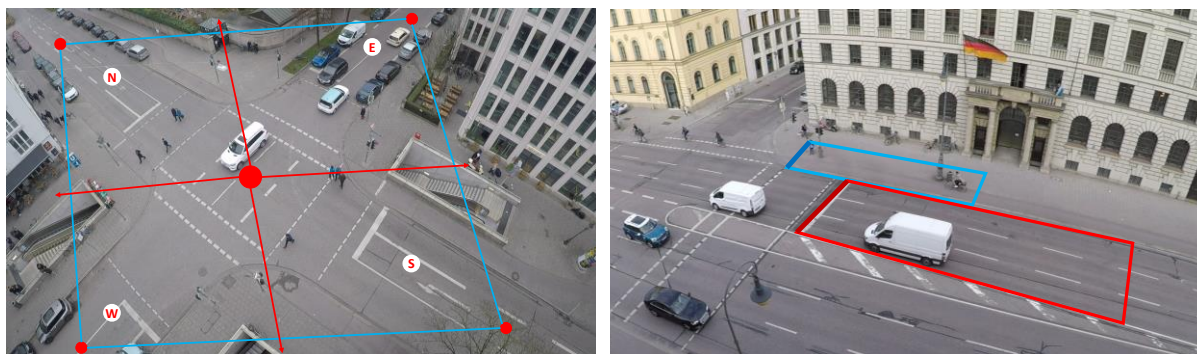


Figure 1: Example of the separation of the intersection into approaches (left, Karlstraße and Luisenstraße) and the stop polygons for data analysis (right, Theresienstraße and Ludwigstraße)

Bicyclists turning left or right are excluded from the analysis because carrying out a turning manoeuvre significantly increases the likelihood of a red light violation in comparison with riding straight across the intersection (Twaddle and Busch, 2019). The remaining road users are classified into four groups as shown in Table 2.

Table 2: Categories of road user behaviour at a traffic signal

		Signal phase upon crossing stop line	
		Red	Green
Stopping behaviour	Stop	Delayed red signal violation	Rule conform stop and cross
	No Stop	Red signal violation	Rule conform unimpeded crossing

Bicyclists in the 'Delayed red signal violation' group stopped at a red signal but proceeded to cross the intersection before the signal turned green. The proportion of road users in each of these groups is analysed before and after introducing the GSCD at the three study intersections. In addition, the crossing speed during the eight seconds before the start of the red phase is analysed to determine if road users are using the GSCD information to adjust their speed and avoid stopping.

### 3. Results

The proportions in each behaviour group at each of the study intersections are shown in Figure 2. No consistent trend between the proportion of observed bicyclists in each behaviour group with and without a GSCD at the three study intersections could be identified.

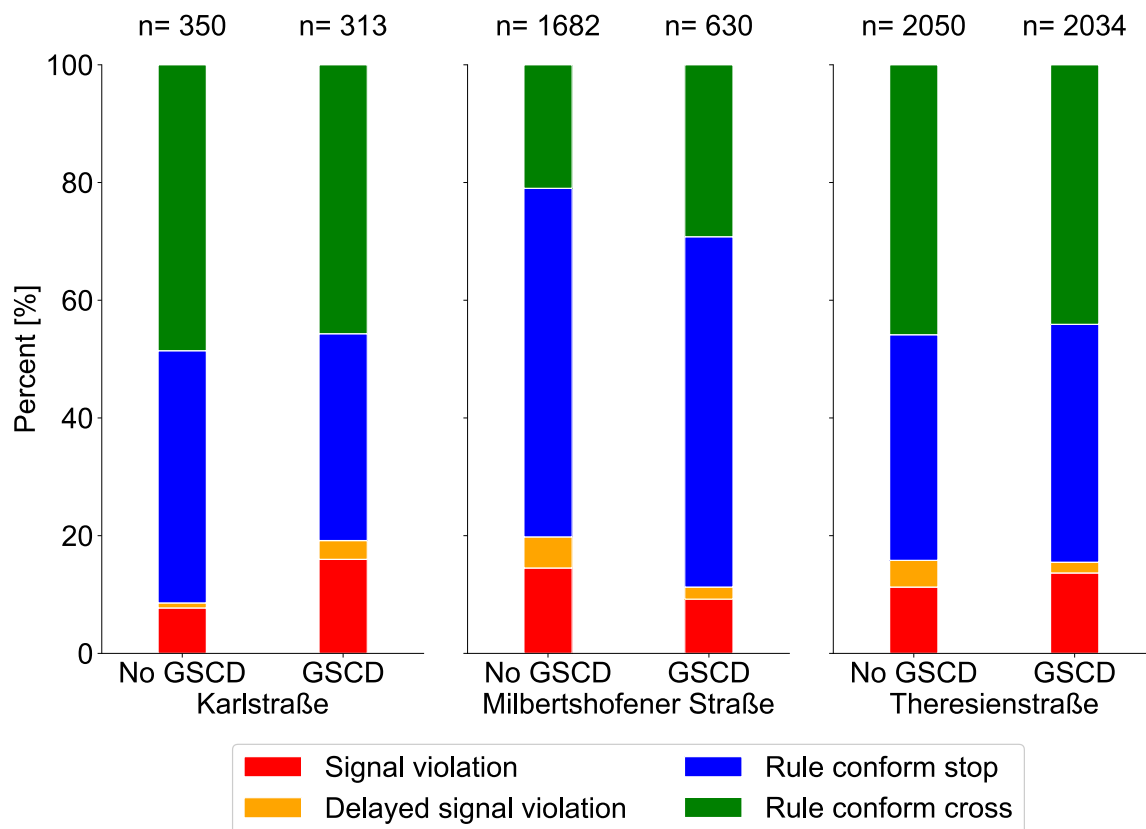


Figure 2: Bicyclist behaviour at the study traffic signals before and after introduction of a GSCD

The findings at each intersection are described below. The green share at each approach varied slightly in some cases due to the actuated nature of the signals.

- Karlstraße and Luisenstraße: This is a small intersection with low to moderate volumes of bicycle and motor vehicle traffic. The green share at the study approach is 38% before and 40% after introduction of the GSCD. Here the GSCD was found to have a significant negative influence on the occurrence of signal violations (10.6% increase) and the proportion of bicyclists able to carry out an unimpeded rule conform cross (2.9% decrease) despite the slightly higher green share in the after study ( $\chi^2(3, n = 663) = 17.111, p = 0.001$ ).
- Theresienstraße and Ludwigstraße: Ludwigstraße is a large corridor running from the north of Munich to the city centre. There are high volumes of both motor vehicle and bicycle traffic arriving on the north approach (GSCD test location). The green share at this approach is 47%, both before and after introduction of the GSCD. A very small but

significant difference in the traffic signal behaviour of the bicyclists could be discerned after the GSCD was installed ( $\chi^2(3, n = 4086) = 30.587, p = 0.000$ ).

- Milbertshofener Straße and Christoph-von-Gluck-Platz: This is a small crossing where a bicycle highway heading to the city center crosses an east-west corridor. Bicyclists are detected 20 m upstream of the intersection and are given a ten second green phase to cross the intersection. Bicyclists travelling south on the bicycle highway had 19% green share before and 18% green share after the introduction of the GSCD. Significant improvements are achieved at this intersection, with an 8.7% reduction in total red signal violations and an 8.3% increase in the proportion of bicyclists crossing unimpeded at a green signal ( $\chi^2(3, n = 2316) = 34.818, p = 0.000$ ).

Bicyclists who arrive at the intersection during the red phase are analysed further to investigate the role of distance to the stop line at the start of the red phase. Bicyclists at the intersection Theresienstraße and Ludwigstraße are selected for investigation because of the advantageous view frame of the videos. The traffic signal behaviour of bicyclists at this intersection who approach the intersection during the red phase before and after introduction of a GSCD is shown in Figure 3.

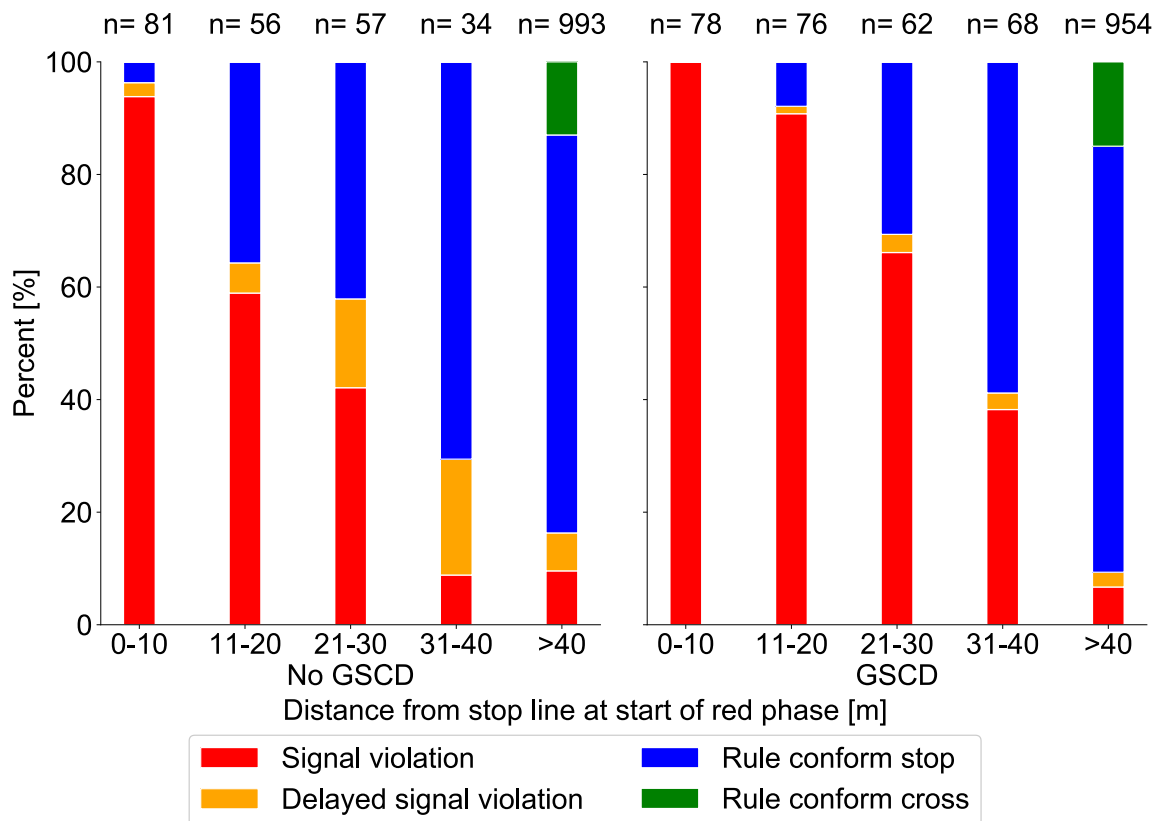


Figure 3: Bicyclist traffic signal behavior at the intersection Theresienstraße and Ludwigstraße by distance to the stop line at the point of phase change to red

Here, a negative influence of the GSCD on the red light violations of bicyclists arriving at the intersection shortly before the start of the red phase can be seen. There is a significant increase in the signal violations of all groups of bicyclists who are less than 40 m away from the stop line when the signal changes from green to red ( $\chi^2(3, n = 2459) = 33.579, p = 0.000$ ). A decrease in the proportion of bicyclists in the 'Delayed red signal violation' group is observed, particularly for bicyclists who are between 21 m and 40 m from the stop line at the

start of the red phase. For bicyclists more than 40 m from the stop line at the phase change to red there is a slight decrease in overall signal violations.

The speed of bicyclists crossing the stop line is investigated during the eight seconds before the signal phase change to red at the three intersections. A relationship between the time until phase change and the average speed of bicyclists crossing the stop line was found at the intersection Milbertshofener Straße and Christoph-von-Gluck-Platz, where bicyclists cross at a higher speed in the two seconds before the signal change. This trend was not observed at the other two research intersections.

## 4. Conclusion

The introduction of GSCD at the study intersections in Munich, Germany lead to different results at all three intersections. Results at a small intersection where a bicycle highway crosses a two lane corridor indicate that GSCD reduced the proportion of signal violations by 8.7% and increases the proportion of bicyclists crossing during the green phase by 8.3%. However, these positive results were not found at the other two study intersections. At a small intersection with low to moderate volumes of bicycle and motor vehicle traffic a 10.6% increase in total signal violations and a 2.9% decrease in bicyclists crossing the intersection unimpeded by the traffic signal was observed. A closer look at the behaviour of bicyclists who approached the stop line while the signal phase changed from green to red at the third study intersections showed a significant increase in red signal violations for bicyclists less than 40 m from the stop line when the signal phase changes from green to red.

The findings from this study do not enable a conclusion concerning the overarching effects of GSCD on the behaviour of bicyclists at traffic signals. Given these findings and the contradictory results of previous studies, it may be the case that the effect of GSCD differs depending on the geometry, traffic flow and other characteristics of the intersection, as well as the traffic culture in a given city (or community). If a GSCD for bicycle traffic is introduced, the effects should be monitored in order to ensure positive effects concerning the traffic safety and efficiency at the given intersection.

## Acknowledgement

The project is funded by the German Federal Ministry of Transport and Digital Infrastructure within the National Cycling Plan 2020 (NRVP).

## 5. References

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