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The Effect of Countdown Timer with Running Text at Signalized Intersection: An Empirical Study

RIZKA DIMAS FITRIAN, AGUS DARMAWAN

Department of Mechanical and Industrial Engineering, Universitas Gadjah Mada, Yogyakarta, 55281 Indonesia

ABSTRACT: This study aims to analyze driving behaviour at signalized intersections due to the countdown timer. In the scenario, we also test the countdown timer with running text that lacks attention in the literature. We collect data on lost time, early start, number of vehicles passing per cycle, number of violations and vehicle's speed. In determining the signalized intersection for scenario implementation, we consider the volume of vehicles, the number of phases, and the geometric of the intersection in the city of Yogyakarta, Indonesia. The results show that the use of a countdown timer in traffic lights, whether with running text or not, is able to increase the efficiency of vehicle movement. The lost time decreases, and the number of vehicles that pass each cycle increases. However, the number of early starts at the signalized intersection increases. Meanwhile, the average speed of vehicles at the end of a green light signal does not show a statistical difference between traffic lights without and with a countdown timer, whether with running text or not. The use of running text in the last few seconds of the red-light signal tends to give a smaller early start than an unmodified countdown timer. In addition, the number of vehicles violating the rules when entering a red light tends to decrease for the traffic light with a countdown timer. The number of violations when using an unmodified countdown timer tends to be less than the countdown timer with running text.

KEYWORDS: Traffic light; countdown timer; driving behaviour; running text; early start

1. INTRODUCTION

In urban areas with high mobility, traffic is one of the activities carried out almost every day that requires ethics in driving. As users of motorized vehicles, we must adhere to traffic signs to ensure safety and maintain smooth traffic flow. One of the most common traffic control signs is a traffic light. Almost at every intersection, we can find traffic lights, especially at intersections that have the potential to cause traffic jams or accidents. Violations at signalized intersections are still one of the most dominant violations in Indonesia. These violations often lead to traffic accidents (Fitrian, 2014; Agus, 2021; Arnani, 2021; Saputra, 2021).

According to Ma (2008), the interaction between a driver and other road users or objects at a signalized intersection generates information that enables the driver to make informed decisions. This decision-making process is influenced not only by traffic signals but also by road conditions, environmental factors, and the driver's own condition. Consequently, several factors, including the characteristics of the driver, the vehicle, the environment, and other vehicles, play a role in shaping the driver's behaviour at intersections.

Traffic lights that exist today generally consist of red, yellow, and green. However, since 2008, the Department of Transportation of Yogyakarta has added a countdown timer to traffic lights at signalized intersections. The installation of a countdown timer is expected to reduce driver ignorance, enabling them to decide when to accelerate, slow down, or stop at the appropriate time. For example, at the green light, the driver can know the crucial time before changing to the red signal, and at the red light, the driver can get ready before the green light (Lu & Yuan, 2007). In addition, the countdown timer can also reduce driver boredom while waiting (Zhang et al., 2009).

This study aims to analyse driving behaviour at signalized intersections due to the countdown timer. We conduct scenarios related to the countdown timer, unmodified and countdown timer with running text. In the latter, we modify the countdown timer to display running text with a warning/exhortation during the last 10 seconds. In this study, we discuss behavioural analysis using more traffic efficiency metrics than previous studies. This approach enables a more comprehensive evaluation of the impact of countdown timers, which we believe is an important contribution to the field of traffic engineering.

This paper is organized as follows: The first section provides the background and motivation for studying the effect of countdown timers in traffic engineering. The next section outlines and discusses the key findings from previous studies on countdown timers. The third section presents the methodology of this study, detailing how we conducted scenarios at two signalized intersections with high vehicle volumes. In the fourth section, we present the results of the study, including observations on lost time, the number of passing vehicles, early starts, red light violations, and vehicle speed. Finally, the last section offers conclusions and suggests directions for further research.

2. LITERATURE REVIEW

Several previous studies have investigated the effectiveness and impact of the countdown timer on the traffic light. Wang and Yang (2006) reveal that 50% of motorized vehicle users felt that the countdown timer decreased start-up lost time. Furthermore, they show that start-up lost time decreased by 17.8%, and the number of vehicles passing every hour increased by 10%. Kim and Kim (2020) analyse the impact of a countdown timer at a signalized intersection. They state that apart from functioning to improve traffic efficiency and safety, countdown timers can also encourage drivers to voluntarily control vehicle idling, reducing emissions at signalized intersections by more than 50%. Yuan et al. (2009) present that installing a countdown timer at a traffic light can reduce delays or reduce start-up lost time, the time lost between the start of the green light and the first vehicle that passes. In addition, the number of vehicles that pass in one traffic light cycle can increase. However, there are also adverse effects. The number of violations at the beginning of the red light increases and as well as the speed of vehicles carried out by motorists in the last 5 seconds of the green light signal.

Islam et al. (2017) use a driving simulator to study the driver's response to the countdown timer. By involving 55 participants, they present that a green signal countdown timer could increase intersection safety. Drivers become more orderly and start preparing to stop when the remaining time is running out. Lum and Harun (2006), Paul and Ghosh (2020), Jatoth et al. (2021) also show that the countdown timer can reduce violations that occur at an intersection and lost time. Malecki and Iwan (2019) develop a two-lane road model with a traffic countdown timer. Using a computer simulation, they show that the countdown timer increases the number of vehicles passing. They argue that drivers become more focused on the countdown timer than their surroundings and will be ready to go when the time is right.

Pathivada and Perumal (2019) analyse the driver's dilemma at signalized intersections in India. They state that the essential factors in determining whether a driver will stop/go are the distance from the stop line, the vehicle's speed and the type of intersection. For example, at the 4-arm signalized intersection, drivers tend to be more impatient and aggressive than at a 3-arm signalized intersection. In addition, the type of vehicle also influences the decision to stop or not at the onset of yellow, where two-wheeled drivers have less probability of stopping than cars. In their study, Manan et al. (2020) also state that two-wheeled drivers have a large portion in contributing to violations of the necessity to stop when there is a red light.

Sun et al. (2013) present effects at a signalized intersection with a countdown timer. Installing a countdown timer allows us to know the drivers' behaviour. The vehicle speed at the end of the green light is higher than without a countdown timer. At the first 10 seconds of the green light, the vehicle's speed is very different and varies. They suggest that the installation of a countdown timer should take into account the traffic flow at signalized intersections. For example, in a traffic light with a large enough volume of passing vehicles and long red light in one cycle, it is advisable to install a countdown timer. However, if the volume of passing vehicles is not too large, the countdown timer does not need to be installed. Elekwachi (2010) shows that countdown pedestrian signal (CPS) reduces start-up lost time in each cycle of 1.1 - 1.8 and increases the number of passing vehicles per hour.

Zhang et al.(2012) highlight that when the countdown timer shows less than 3 seconds remaining at the end of the green signal, drivers should exercise caution and reduce their speed. However, some drivers accelerated the vehicle. Even when the green light has turned off and the red signal has just begun, some drivers may still proceed through the intersection. This behaviour can be attributed to varying perceptions of the countdown timer and the influence of driving habits. Additionally, drivers may experience frustration if they have to wait too long for the red light to change. Vice versa, if the green light is fast, the driver will hurry to cross. Such an incident can result in a near miss that can endanger the driver and others. Therefore, it is necessary to improve the existing countdown timer or traffic light system and evaluate driving behaviour.

Several previous studies have discussed the countdown timer at signalized intersections and used two or three indicators. This study uses five indicators to measure the countdown timer's effectiveness: lost time, early start, number of passing vehicles, number of violations, and vehicle's speed. We also conduct an experiment to adjust the countdown timer to have running text containing a warning/exhortation in the last 10 seconds. To the best of our knowledge, this is the first study that discusses the implementation of a countdown timer with running text. In addition, we obtain data from the scenarios that we implement directly to the signalized intersections, which has previously received approval from the Department of Transportation. Furthermore, this study will add literature on driving behaviour due to countdown timers in developing countries, particularly Indonesia, which still lack attention.

3. METHODOLOGY

This study takes data directly from the field on two signalized intersections in Yogyakarta; Senopati and Wirobrajan intersection. We determine the above location based on a high volume of vehicles, the number of phases, and the geometry of the signalized intersection. During peak hours (i.e. 06.30-08.30 and 15.30-17.30), the volume of vehicles at the Senopati and Wirobrajan intersections reaches 8879 - 11702 units/hour. Both intersections have 4 phases and are geometrically symmetrical. Figure 1 illustrates the phase shift at the two signalized intersections.

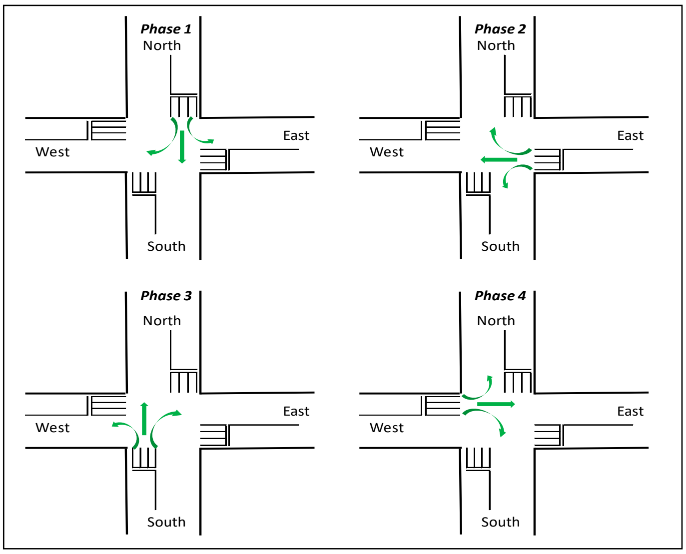

Figure 1. An example of phase change at a signalized intersection

We get approval from the Yogyakarta transportation department for implementing scenarios (i.e. without and with countdown timer) directly on the signalized intersections. In the initial stage, the countdown timer is off, and then in the second stage, the countdown timer is on. We use digital cameras to record traffic and driver's behaviour at signalized intersections. In addition, we place cameras at intersection corners to get a clear view of drivers' behaviour. In both stages, we collect data on lost time, early start, the number of vehicles, violations (red light violations) and vehicle's speed.

We run the scenarios at peak hours at 06.30-08.30 and 15.30-17.30 for eight days according to the permission obtained from the Yogyakarta transportation department. The traffic light cycle lasts 152 and 156 seconds, respectively, resulting in 184 and 188 data cycles over a 2-hour period at the signalized intersection. Because a signalized intersection is only allowed to do a maximum of two scenarios, at the Senopati intersection, we run the scenario without a countdown timer and with a modified countdown timer (e.g. running text in the last few secs of red/green light signal). Meanwhile, at the Wirobrajan intersection, we test signalized intersection without and with an unmodified countdown timer. We hypothesized that implementing countdown timers with running text at signalized intersections would lead to a measurable improvement in traffic efficiency and safety. We also hypothesized that the presence of these timers would positively influence driver behaviour, reducing instances of abrupt stopping and accelerating.

4. RESULTS AND DISCUSSIONS

4.1 Lost time

We measure the time lost between the start of the green light and the vehicle in the first line passing through the stop line. Figure 2 shows the average lost time per cycle for the south arm at the Senopati intersection. For example, at 6:30 (first cycle), the lost time for traffic lights without and with a countdown timer is 2.56 and 1.45 sec, respectively.

Table 1 compares the average lost time between without and with a countdown timer for the Senopati and Wirobrajan intersections. For the north arm of Senopati, there was no statistically significant difference in the lost time between without and with countdown timer (p-value=0.878 > 0.05). In general, Table 1 shows a significant difference (p-value = 0.000) for the two scenarios, where the lost time value decreases for signalized intersections with a countdown timer.

4.2 The number of passing vehicles

The different scenarios of countdown timers can affect the number of passing vehicles. Therefore, we count the vehicles that pass each cycle during peak hours and then calculate the average. Figure 3 and Figure 4 show the number of passing vehicles before and after countdown timer installation.

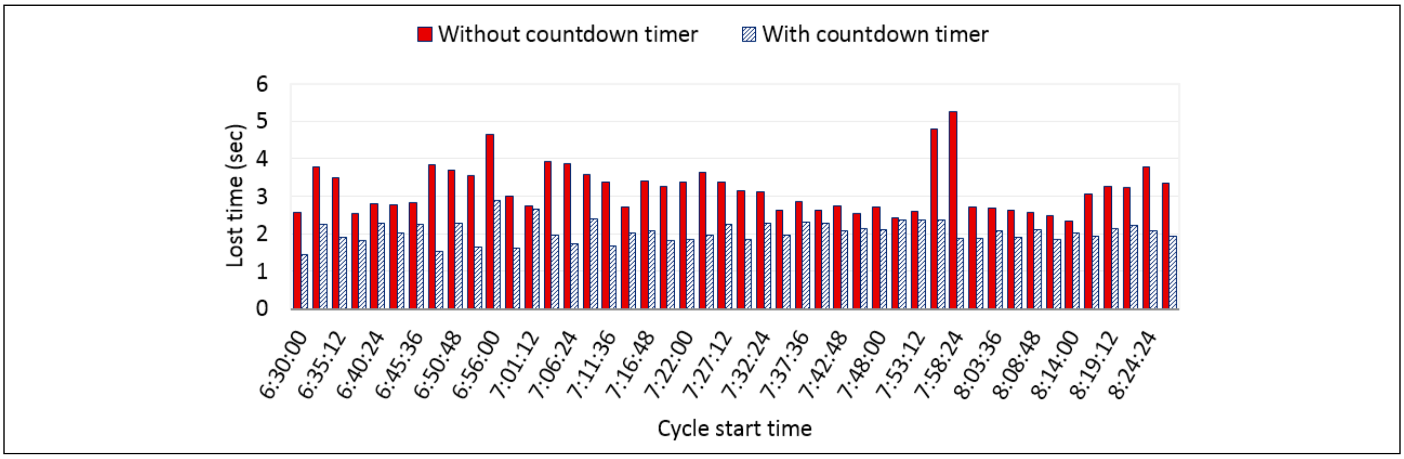

Figure 2. Average lost time per cycle at south-arm of Senopati intersection

Intersection	Arm	Average lost time (and std.deviation)		P-value
		Without countdown timer	With countdown timer	
Senopati (*with running text)	North	2.32 (0.57)	2.41 (0.86)	0.878
	East	2.31 (0.74)	1.66 (0.45)	0.000
	South	3.18 (0.67)	2.05 (0.3)	0.000
	West	2.72 (0.8)	1.6 (0.38)	0.000
	Total average	**2.63 (0.76)**	**1.93 (0.62)**	
Wirobrajan	North	3.62 (0.94)	1.31 (0.43)	0.000
	East	2.87 (0.72)	1.4 (0.48)	0.000
	South	3.02 (0.48)	0.96 (0.19)	0.000
	West	3.39 (0.79)	1.73 (0.61)	0.000
	Total average	**3.22 (0.77)**	**1.35 (0.52)**	

Table 1. The average lost time at Senopati and Wirobrajan intersection

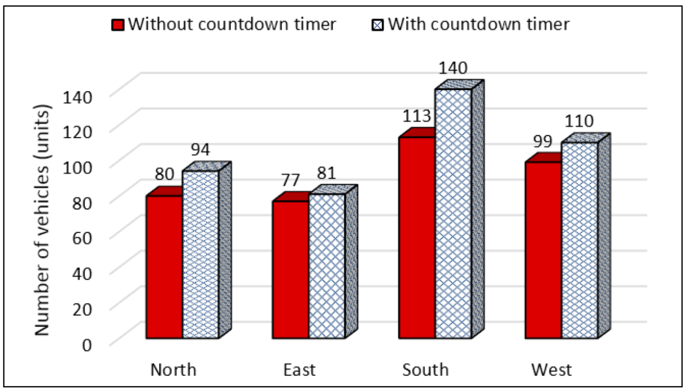

Figure 3. The average number of passing vehicles per cycle at Senopati intersection

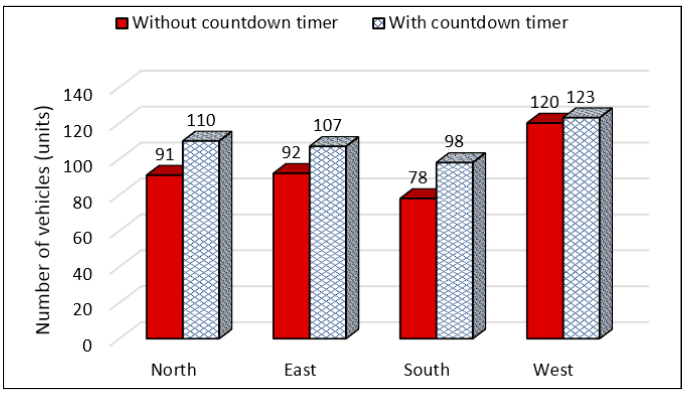

Figure 4. The average number of passing vehicles per cycle at Wirobrajan intersection

In general, the number of passing vehicles per cycle is higher for the case with a countdown timer. The information about the remaining time allows the driver to focus more on preparing to move, which leads to an increase in the vehicle's movement. Based on observations, when there is no countdown timer, some front-line drivers prepare when the green light is on, which result in a longer delay.

4.3 Early start

In the early start, we count the number of vehicles that pass the stop line before the green light turns on. Drivers start running when they are still in the last few seconds of red signal. Figure 5 shows an illustration of when drivers make an early start. Table 2 shows the average number of early starts at the Senopati and Wirobrajan intersections in the case without and with countdown timers.

Figure 5. An example of early start in the red-light signal

Based on Table 2, the number of early starts before and after the countdown timer installation was not significantly different (P-value > 0.05) for the north and south arms at the Senopati intersection. However, in general, the countdown timer increases the number of early starts significantly (P-value = 0.000). This result aligns with the findings of Zhang et al.(2012), who suggest that drivers should prepare to stop as the signal approaches the last 3 seconds. However, it is often observed that many drivers at the front of the line start moving prematurely, even when the light is still red. The result contradicts Yuan (2009), who shows that the number of early start decreases after countdown timer installation.

The overall ratio of early start between without and with countdown timer are 1:2.7 and 1:11 for Senopati and Wirobrajan intersections, respectively. The early start ratio at Senopati is much smaller than Wirobrajan intersection. We replaced the display of the remaining 10 seconds with running text containing warnings and exhortations at the Senopati intersection. It seems that running text can cause drivers to wait a few seconds before having confidence that it will soon turn into green light. In the case with an unmodified countdown timer (Wirobrajan intersection), from interviews with several drivers, the remaining time information allows the drivers to have more control over when they run. Besides, they have presumptions and experiences that in the last few seconds of red signal, the other three arms usually have red lights, so they decide to run first before the green light is on. Therefore, the countdown timer with running text in red signal is better than the common countdown timer in terms of the early start.

In addition, we also measure the average time of early start at the end of the red signal until the green light turns on. Figures 6 and 7 show the average early start time on the 4-arm signalized intersection.

Intersection	Arm	Average early start (and std.deviation)		P-value
		Without countdown timer	With countdown timer	
Senopati (*with running text)	North	0.05 (0.22)	0.05 (0.22)	0.650
	East	1.00 (1.22)	3.25 (3.30)	0.000
	South	0.30 (0.69)	0.38 (0.67)	0.510
	West	1.28 (1.88)	3.50 (3.40)	0.000
	Total average	**0.66 (1.23)**	1.79 (2.78)	
Wirobrajan	North	0.25 (0.87)	6.93 (3.13)	0.000
	East	1.28 (2.12)	4.40 (2.06)	0.000
	South	0.23 (0.83)	8.13 (3.05)	0.000
	West	0.33 (0.73)	3.63 (2.13)	0.000
	Total average	**0.52 (1.27)**	**5.77 (3.16)**	

Table 2. Average early start for Senopati and Wirobrajan intersections

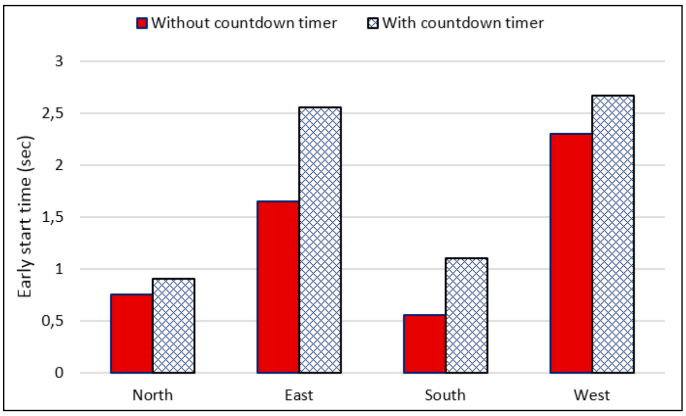

Figure 6. The average time of early start at Senopati intersection

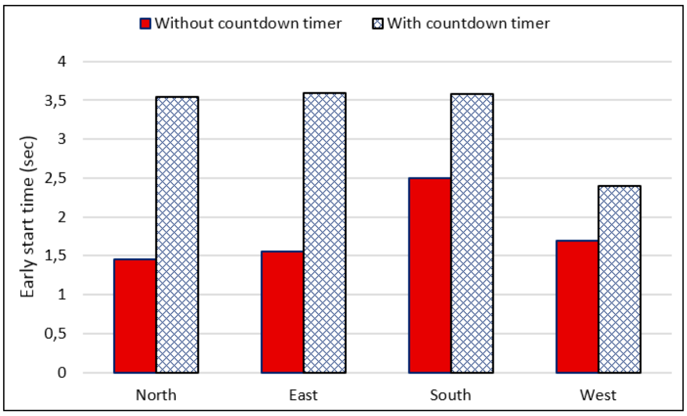

Figure 7. The average time of early start at Wirobrajan intersection

The average early start time at the south arm of the Wirobrajan intersection is 2.5 seconds for the case without a countdown timer. It means that the drivers have started running 2.5 seconds before the green light on average. Meanwhile, in the case of the traffic light with a countdown timer, the average early start time is 3.58.

4.4 Red light violation

The red-light violation is the number of vehicles that pass at the red light after the green signal. Figure 8 illustrates the violation at the signalized intersection.

Figure 8. An example of red-light violation

This section compares the number of violations for different scenarios, without and with a countdown timer. Table 3 shows that in almost all arms at the Senopati intersection except for the east arm, there was no statistical difference in the number of violations after the countdown timer installation (P-value >0.05). Based on interviews with several drivers, the running text at the end of the green light signal eliminates the remaining time information. It makes the drivers assume that running without slowing down their vehicle is still safe. The number of violations in the north and east arms tends to be less than the south and west arms because few vehicles pass at the green light's end. Thus, the probability of a violation in the north and east arms is small. Meanwhile, vehicles passing on the south and west arms tend to be more congested, so the probability of a violation is greater.

An interesting result is at the Wirobrajan intersection, where the countdown timer does not have running text. In contrast to the Senopati intersection, there was a significant difference (p-value < 0.05) between traffic lights without and with countdown timers for all arms at the Wirobrajan intersection. A countdown timer can reduce the number of drivers passing by when the red light starts. It indicates that the remaining time information at the end of the green signal can give the impression that drivers do not have to force themselves to pass and immediately get ready to stop. However, this contradicts Yuan et al. (2009), who state that violations increase if a countdown timer is installed.

4.5 Vehicle's speed

We identify the vehicle's speed for the vehicle passes at the end of green light. Figure 9 shows the average vehicle's speed at the south arm of the Senopati intersection for the case without and with a countdown timer.

Intersection	Arm	Average violation (and std.deviation)		P-value
		Without countdown timer	With countdown timer	
Senopati (*CT with running text)	North	2.25 (3.52)	2.93 (4.63)	0.680
	East	2.53 (2.37)	1.55 (1.85)	0.020
	South	4.95 (4.12)	5.65 (6.59)	0.830
	West	3.60 (3.97)	3.88 (3.80)	0.560
	Total average	**3.33 (3.57)**	**3.50 (4.51)**	
Wirobrajan	North	4.68 (4.30)	1.88 (1.98)	0.001
	East	3.90 (4.55)	2.13 (2.07)	0.002
	South	4.65 (4.75)	1.25 (1.86)	0.000
	West	10.40 (5.07)	4.38 (3.48)	0.000
	Total average	**5.91 (5.11)**	**2.41 (3.36)**	

Table 3. The average number of violations at the Senopati and Wirobrajan Intersections

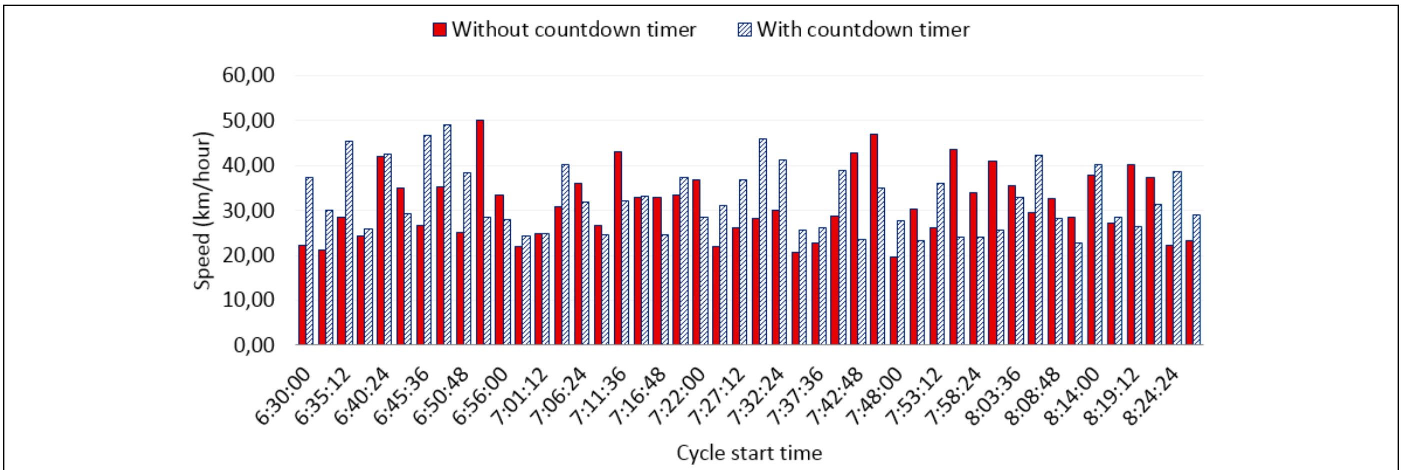

Figure 9. The vehicle's speed at the south-arm Senopati intersection

Intersection	Arm	Average speed (and std.deviation)		P-value
		Non countdown timer	Countdown timer	
Senopati (*CT with running text)	North	30.12 (7.47)	30.93 (8.84)	0.620
	East	45.26 (11.44)	41.15 (16.15)	0.120
	South	31.30 (7.65)	32.36 (7.60)	0.450
	West	38.69 (8.98)	34.82 (12.85)	0.060
	Total average	**36.34 (10.62)**	**34.81 (11.92)**	
Wirobrajan	North	28.09 (8.54)	25.34 (9.59)	0.060
	East	29.44 (9.34)	30.50 (10.42)	0.130
	South	28.21 (9.93)	30.21 (10.91)	0.590
	West	29.59 (8.39)	30.88 (9.44)	0.162
	Total average	**28.83 (8.66)**	**29.23 (10.21)**	

Table 4. The average vehicle's speed for Senopati and Wirobrajan intersections

Table 4 shows the average speed on all arms at the Senopati and Wirobrajan intersections. Again, we use statistical tests to determine whether the use of the countdown timer has a significant difference. From Table 4, the p-value > 0.05 for all sides, so we can conclude that there is no difference in the speed of passing vehicles without and with a countdown timer statistically. This result is different from Zhang et al.(2012), where they state that the vehicle's speed decreases after a countdown timer installation.

5. CONCLUSIONS

The use of a countdown timer in traffic lights, whether with running text or not, increases the efficiency of vehicle movement. For example, from the scenarios that we implement directly to the signalized intersection, the average lost time at the Senopati intersection decreases from 2.63 secs to 1.93 secs, while the Wirobrajan intersection decreases from 3.22 secs to 1.35 secs. In addition, the number of passing vehicles per cycle is higher for the traffic light with a countdown timer. Nevertheless, a countdown timer causes an increase in the number of vehicles that run before the green light (early start), especially at the Wirobrajan intersection. It is the shortcoming of the countdown timer. Early start behaviour will endanger the drivers because it can cause near misses, especially with the drivers from other arms. Therefore, the use of running text in the last few seconds of the red-light signal is better than the use of an unmodified countdown timer.

The red-light violations tend to decrease for the traffic light with a countdown timer, especially at the Wirobrajan intersection. This is because the drivers can estimate the time to stop before the red light. However, the number of violations at the Senopati intersection was not significantly different before and after installing the countdown timer with running text. The use of an unmodified countdown timer is better than a countdown timer with running text, especially for the green light signal. Meanwhile, the vehicle's speed at the end of the green light signal does not significantly differ between the traffic light without and with a countdown timer, either with running text or not.

The results of our study provide insights into the effectiveness of countdown timers with running text at signalized intersections. Specifically, our findings suggest that these timers can significantly improve traffic efficiency and safety by reducing driver anxiety and enhancing compliance with traffic signals. These results can guide urban planners and traffic engineers to design more effective traffic management systems, potentially reducing accidents and improving traffic flow in urban areas. Additionally, the data can support policymakers in making informed decisions about investing in traffic signal infrastructure.

We acknowledge the limitations of this study and suggest several topics for further research. Firstly, this study test different scenarios during peak hours. Thus, a possible extension is to conduct an experiment during off-peak hours to know whether there are differences in results. Secondly, this study could only perform two scenarios for each signalized intersection due to the experimental permit obtained. Therefore, testing more than two scenarios at each signalized intersection may make the comparison more fairly (i.e. without and with a countdown timer and a countdown timer with running text). Finally, further empirical studies are necessary to validate the results of this study.

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