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ACCEPTABILITY OF COUNTDOWN SIGNALS AT AN URBAN SIGNALIZED INTERSECTION AND THEIR INFLUENCE ON DRIVERS BEHAVIOUR

ABSTRACT

There are different factors that affect driver's behaviour at an urban signalized intersection. Complementary countdown signal heads can be used to inform the driver about the traffic light phase status. In the research presented in this paper, we explored how a countdown signal affects the driver's reaction. We focused on the analysis of red/amber, red and amber running violations. We also observed and measured traffic flow start-up lost time and headway per cycle. Measurements took place in Ljubljana at a four-way intersection where two countdown signal heads are installed that face different directions. We used the "on-off-on" approach, using video surveillance and detection technology. According to the results of the investigative questionnaire, more than 84% of the surveyed drivers expressed positive opinion about the device. Analyses of field-test results have shown that the red and/or amber running violation rate is higher when the device is turned off. The results of the paper suggest that the countdown device had very little effect on the capacity of an urban signalized intersection.

KEYWORDS

signalized intersection, countdown signal, start-up lost time, headway

1. INTRODUCTION

Intersections have a significant influence on traffic flow efficiency and traffic management in urban road networks. Traffic Light devices are one of the most efficient ways of regulating traffic at urban road intersections. A piece of complementary equipment is a countdown device for motor vehicles and pedestrians. The main purpose was to provide better safety and to inform drivers about the duration of each light phase.

Countdown devices have been increasingly applied in practice, but their influence on driver reaction and traffic flow rate at signalized intersections has hardly been investigated. The main purpose of countdown devices is to draw the driver's attention to the quantity of time still available for a given light phase. This information allows them to better prepare for the start-up and stopping phases. The quality information is the success to better performance of traffic system [1].

The first studies were made in Texas and in Florida, at the end of the 1970s, different methods of warning drivers about the nearing end of each light phase using numerical countdown devices were used. They were eventually abandoned because no essential contribution to the safety of the intersections could be detected [2]. Lum and Halim performed a study of a monochrome, green vehicular countdown signal head in Singapore [3]. They noticed that on the average, the number of red light running violations decreased by as much as 65% only 1.5 months after the green countdown signal head had been installed. Later observations showed that after 7.5 months, the number of violations rose almost back to the same level as before the installation of the green countdown signal head as drivers got used to it. Yu-Chiun and Chien-Hua compared green and red countdown signals [4]. According to their findings, the green countdown signal extends the dilemma zone by approximately 28m, and the drivers find it more difficult to decide between proceeding through the intersection and stopping, which increases the accident risk. The red countdown signal reduces considerably the number of early start-ups, but eventually, this value returns to the initial value. In the long run, the red countdown signal does not improve the safety, but it does reduce start-up lost time. The final conclusion was that the red countdown signal is more useful than the green one [4, 5]. Li, Dong, Sun and Yu wrote that the green countdown signals increase the number of accidents in intersections, thus decreasing the safety for drivers [5]. However, they also improve the traffic flow capacity at the end of the green light phase. The red countdown signals can increase the traffic flow capacity by increasing the effective green light time (drivers start earlier), but this decreases safety in intersection [5]. Limanond, Prabjabok and Tippayawong investigated countdown devices in Bangkok [6]. Because of countdown devices, the start-up lost times decreased from 8.32s to as low as 6.53s (22%). The reduction of start-up lost times contributes to the crossing of an additional vehicle per cycle per lane. In addition, the total number of violations decreased the red light violations by 50%. They conducted a questionnaire survey, which showed that more than half of local drivers believed that the countdown signals reduced stress and the nervousness of drivers while waiting at the red light. Almost all of them believed that countdown signals should be installed throughout the traffic network.

In Ljubljana and in other Slovenian towns, there are at present only a few countdown devices designed for vehicles (driver countdown signals). The countdown devices were installed for the purpose of informing drivers about the duration of the green and red light phases of the traffic lights, either at full signalized intersections or at signalized pedestrian crossings. Some were also installed with the main purpose of informing bus drivers at larger bus stops ahead of signalized intersections. Thus, bus drivers know how much time they have left to the end of the green or red light phases. This information helps them to estimate the remaining time to wait for the passengers at bus stops.

2. ISSUES AND BASIC HYPOTHESES

Driver's reactions at signalized intersections are influenced by several factors that directly affect the level of service and traffic safety [13, 14]. In addition, countdown signals affect driver's behaviour and decisions. Questionnaire surveys [6], also ours (see chapter 4.3), conducted thus far give evidence of their positive reception. Respondents find countdown signals a positive complement, and they are favourably disposed to them. If a decision about the installation of a countdown device was based on public opinion, it would certainly be considered an "easy" decision. However, such installation should be scientifically evaluated and justified. We can assume that countdown devices influence the capacity of signalized intersections. This capacity is normally dealt with according to the HCM definition [8], which is, under certain conditions, acceptable in Slovenia and Croatia [11, 15]. In addition to increasing intersection capacity, the devices have found application also because they are thought to improve traffic safety. Considering the fact that different authors report different results about the efficiency of the analyzed devices, in our research we set several of our own hypotheses regarding the influence of countdown signals on driver's behaviour (for example [2, 3, 12]):

- H1: Because of vehicular countdown signals, the start-up lost times at urban signalized intersection will decrease.
- H2: Because of vehicular countdown signals, the number of amber light running violations at urban signalized intersections will be lower.
- H3: Because of vehicular countdown signals, the number of red light running violations at urban signalized intersections will be lower.

3. EXPERIMENT

We performed field measurements of violations: red light, amber light and red/amber light running violations. We also measured headways at start-up and conducted a short questionnaire survey, asking the respondents about their opinion of countdown signals.

Because of technical constraints, the research was limited to only one signalized intersection in Ljubljana, between Tržaška and Langusova streets. In the direction A-C toward the town center and in the opposite direction C-A, two complementary countdown signal heads for motor vehicles were installed (see *Figure 2*).

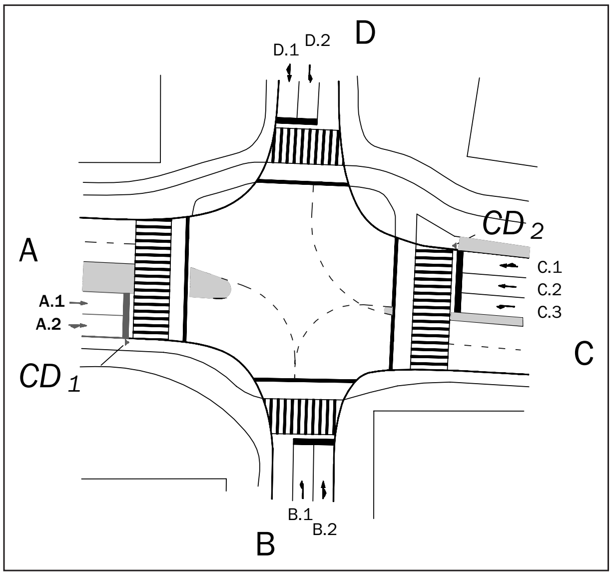

Figure 1 - Intersection sketch with presented monitored access lanes

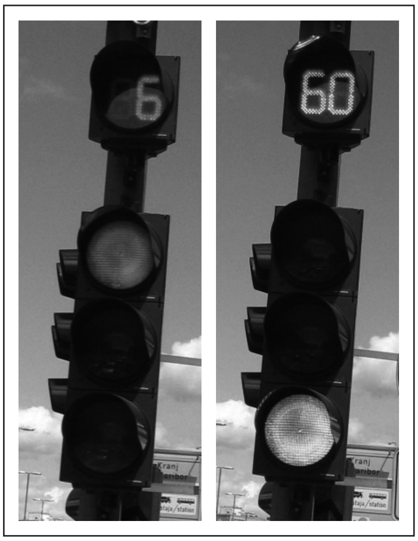

Figure 2 -Two-colour vehicular countdown signal Sipronika SD 300–type heads

Their location is shown in *Figure 1* as CD_1 and CD_2. Both were installed in January 2007, and both are capable of showing the duration of the red light and green light phases. We only analyzed access lanes *A.1* and *A.2*, i.e., countdown signal CD_1, marked bold in *Figure 2*. *A.1* offers the possibility to proceed only straight to access road C, while *A.2* leads straight to leg C and to the right to leg B. The intersection traffic control runs as part of a fixed-time arterial control scheme. Thus, all intersections included in the coordinated control have the same cycle lengths and switch on at individual intersections one after another, allowing a vehicle travelling at a certain speed to follow the "green wave" [7].

We observed the reactions of drivers at signalized intersection with and without a vehicular countdown signal head, which required us to provide such conditions. We decided to analyze a specific period when the countdown signal was off, as well as the time before and after turning it off. Such conditions were created by turning off the countdown signal for a certain period for seven days. In the off period, we observed the first and the last two days it was off. *Table 1* shows the measurement periods, the number of observed periods and their names. All of the measurements were carried out in the afternoon hours when the control program with a 100s cycle was used.

3.1 Start-up lost times

The test was carried out with the aid of a video surveillance camera that allowed us to observe and record the activities at the intersection. The camera was mounted on a rack near the roadway, out of sight of the drivers. The angle of view included the traffic lights with the countdown signal heads as well as all of the vehicles waiting in the queue at the red light.

All video recordings were processed in a laboratory using the video detection system AutoScope 2004. The data processing was semiautomatic, which allowed us to observe the video recordings with the aid of software equipment. Among other options, the software also records the time of each vehicle passing the stop line, either automatically by placing virtual detectors, or manually by pressing a certain key on the computer keyboard. Because of the unfavourable position of the camera, we used the keyboard to record the following events: the start and the end of the red light phase, the presence of passenger car in stopped arrival queue at stop line in the lane *A.p* ($p = \{1,2\}$), the presence of passenger car at the stop line *A.p* under the non-saturated traffic flow condition during the green phase *A.p*, and the presence of a truck or bus in the driving lane *A.p* (see *Figure 1*).

Start-up lost time was calculated according to the HCM 2000 method. Because the mentioned method does not specifically describe or show how the share of other than non-passengers' cars influences the start-up lost times, they were excluded from the data. We took under consideration only passenger cars. All

Table 1 - Presentation of measurement periods

Observed Period			Observed Cycles
ON_6-7: Countdown signal ON, before turning off			
Thursday	12.8.2010		29
Monday	16.8.2010		29
Tuesday	17.8.2010		40
OFF_1-2: Countdown signal OFF, 1st and 2nd day after turning off			
Wednesday	18.8.2010		86
Thursday	19.8.2010		68
OFF_6-7: Countdown signal OFF, 6th and 7th day after turning off			
Monday	23.8.2010		74
Tuesday	24.8.2010		73
ON_1-2: Countdown signal ON, after turning on			
Thursday	26.8.2010		91

other vehicles were excluded with the help of the information about the vehicle position in the driving line, in the output ASCII file according to the pressed key. We also eliminated all passenger cars that followed non-passenger cars. The latter were eliminated because we assumed that the drivers waiting with their cars in the queue behind a large vehicle have more problems seeing the traffic lights or cannot see them at all. In addition, their headway is much larger only because of the presence of a large vehicle in the queue. All right turning vehicles and all vehicles following them were also eliminated from the experiment. The reason is that all right turning vehicles obstruct the through traffic. The traffic flow also included motorcycles. Motorcyclists have the ability to move to the head of the queue when the traffic lights are red. Such motorists were neglected because they normally wait on the stop line or even in front of it, which constitutes a violation. All other motorcyclists who waited for the green light phase in the queue, like all other vehicles, were treated as passenger cars.

All the measurements obtained in this way were statistically processed. The reason is that the results are quite scattered, making the processing more difficult. It was possible for individual measurements to stand out substantially from the average and need to be eliminated as not representative. We used the Box-plot technique that allows graphic presentation of a group of numerical data. In the sequence, the numerical headways for the vehicles starting up in a queue in the signalized intersection are presented. The presentation includes the maximum and minimum value in the observed area, the lower first quartile q_1, the upper third quartile q_3, and the median. IQR represents inter-quartile headway between q_1 and q_3 [8]. The technique was used for the statistical processing and elimination of outstanding results.

According to the HCM 2000 method, the headway between vehicles is larger for the first vehicle, slightly smaller for the second one, and so on. After the fourth vehicle waiting in the queue at the red traffic light, the headway should come close to the headway value of vehicles in unsaturated traffic flow. This is calculated according to Eq. (1) as the average of headways h_i of the i^{th} cycles from the fourth to the last vehicles in the queue:

$$h_i = \frac{t_{N,i} - t_{4,i}}{N - 4} \tag{1}$$

where $t_{j,i}$ is the time at which the j^{th} vehicle of the queue crosses the stop line and N is the last vehicle of the queue at the i^{th} cycle. The average value of the saturation headway is estimated as the mean of all cycles.

Based on the specific case of measuring headways in Edmonton (Canada), it can be noticed that the first vehicle has a smaller headway than the second one; then, the headway starts to decrease again with the crossing of each additional vehicle [10]. Similar results were observed in our research. For this reason, we decided to process our data mathematically with the best-fitting function $f(x)$. Previously, we filtered the data using the multiple Box-plot concept. In our case, the result was a third-level polynomial and not an exponential function, as could be concluded from the past research [10]. This function adapts to the mean values or medians. Such a polynomial was chosen specifically because we noticed that the first vehicle in the queue had a smaller headway than the second one. The headway of the second vehicle appears smaller than that of the third one, and only with the fourth vehicle was a lower value of the headway between vehicles observed. With all additional vehicles after the fourth one, it was noticed that headways decreased, but they approached a certain limit value or the value of headways between vehicles in saturated traffic flow.

We took into account the measurements for up to ten vehicles in the queue because only rarely were there more than ten vehicles in the queue. All vehicles after the tenth were eliminated from processing because there were not enough measurements available for them.

For an individual cycle, the start-up lost time is defined with Eqs. (2) and (3):

$$l_i = \sum_{j=1}^{4} t_{j,i} \tag{2}$$

$$t_{j,i} = t_{h\,j,i} - h_i, \tag{3}$$

where l_i is the total start-up lost time, $t_{j,i}$ is the start-up lost time for the j^{th} vehicle of the queue, $t_{h\,j,i}$ is the j^{th} vehicle's headway and h_i is the saturation headway at the i^{th} cycle. The average value of the total start-up lost time was estimated as the mean of all cycles.

3.2 Running violations at intersection

In Slovenia, signals on the vehicular traffic lights turn on in the following sequel: red, red and amber together, green, amber and once again red. Driving through a red light is forbidden for all traffic participants. Driving through amber light is generally forbidden in Slovenia but is sanctioned in the case when the driver, driving at an allowed speed, cannot safely stop at the amber light because at the moment the light turns on the vehicle is too close to the traffic lights. Similar laws apply for the red/amber combination.

We observed all video material in the laboratory, recording the number of violations in a form prepared especially for conducting measurements. We recorded the number of amber light, red light and red and amber light running violations, as well as the flow of vehicles per individual cycle. All video recordings were observed twice with the help of an enlarged video image, a feature of the video player. The measurements were carried out for each cycle separately and for a better presentation, the results were evaluated for the entire interval of observations. The level of violations is given in Section 4.2.

3.3 Public opinion survey

Within the research study, we also conducted a short questionnaire survey. The aim of the survey was to seek general opinion of the wider public about vehicular countdown devices in Slovenia. We decided to conduct quantitative research and designed out a web-based survey in the form of a structured questionnaire. Several answers were prepared in advance, and the respondents also had the possibility to add their own answer.

We received 411 replies. Twenty-six of them were not useful because the respondents had the possibility to express their opinion and the contents of these 26 answers did not agree with the questionnaire. For this reason, they were eliminated from further analysis.

4. RESULTS

4.1 Headways between vehicles and start-up lost times

Statistical data processing and evaluation of "before/after" were done using Mathematica 8 and OriginPro 8.1 software.

Graph in *Figure 3* shows the status before the countdown signal was turned off (ON_6-7). Box-plots were plotted according to the positions of individual vehicles in the queue at the time of start-up. For a better presentation of the change of the average headways according to the position of a vehicle in the queue at the time of start-up, we present the best-fit regression curve, which is a third-order polynomial. The hatched line also presents the average value of headways from the fourth vehicle onwards.

It can be noticed that the average headway of the first vehicle is smaller than that for the second vehicle. The headway of the third vehicle is larger than that for the second and fourth vehicles waiting in the queue ahead of the red light. After the third vehicle, the trend of decreasing headways between vehicles can be noticed and it approaches a constant value (headway in saturated traffic flow).

From the graph in *Figure 4* for the period of the 1st and 2nd day after the countdown signal was turned off, similar behaviour to that shown in *Figure 3* for the period before the turn-off can be noted. The largest headways between vehicles can be noted for the third vehicle waiting in the queue at the red light.

Figure 5 is different than the previous graphs. It can be clearly determined that the largest headway between vehicles is for the first vehicle, then this value decreases and starts to approach the average value of the headway between vehicles in saturated traffic flow.

In the graph in *Figure 6* for the period after the countdown signal is turned on again, similar trends to those shown in Figures 3 and 4 can be observed. Once again, the maximum value of the headway between vehicles is for the third vehicle waiting in the queue at the red light.

Based on the measurements, we calculated the average headway of all vehicles waiting as the j^{th} vehicles in the queue before start-up (*Table 2*).

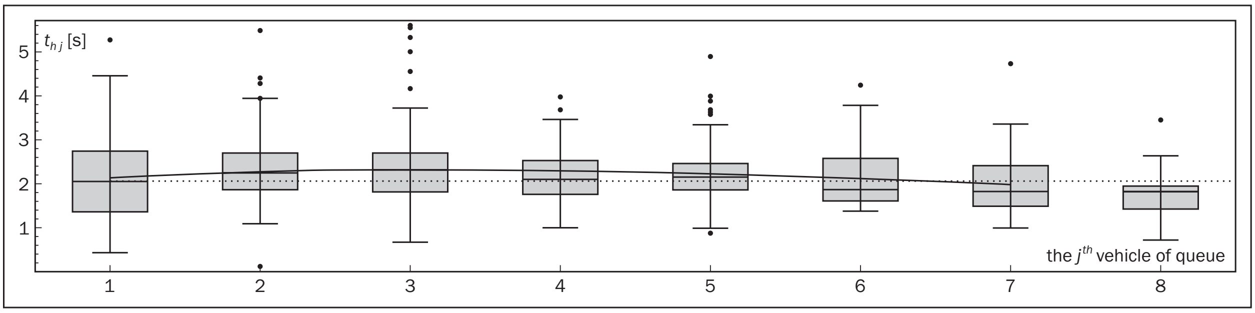

Figure 3 - Box-plot presentation of headway and the fit median curve for the time period ON_6-7 according to the position of a vehicle in the queue before start-up

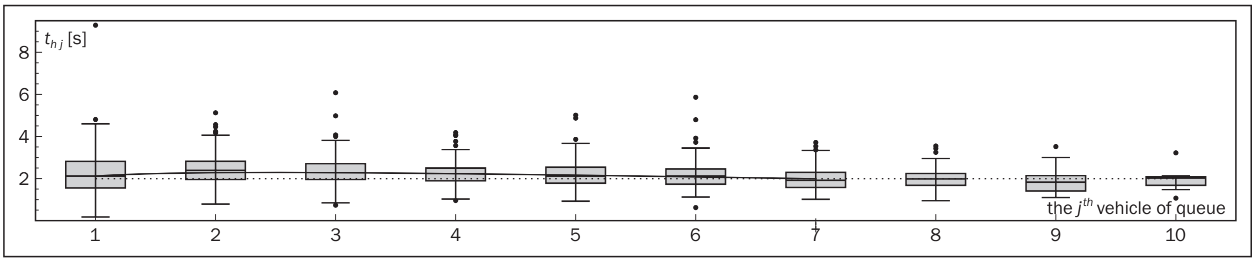

Figure 4 - Box-plot presentation of headway and the fit median curve for the time period OFF_1-2

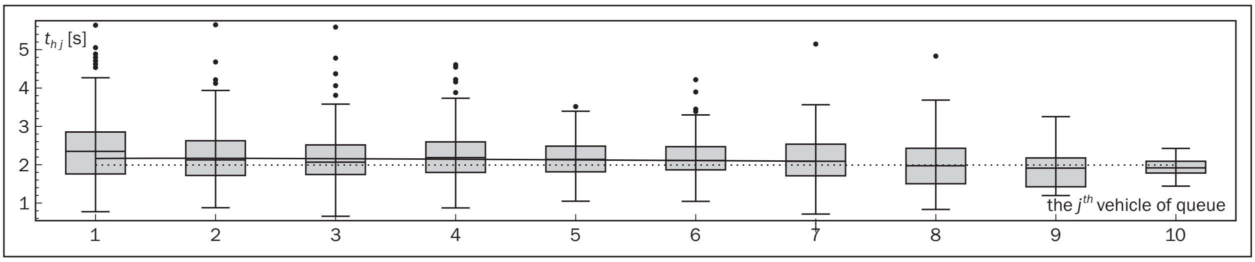

Figure 5 - Box-plot presentation of headway and the fit median curve for the time period OFF_6-7

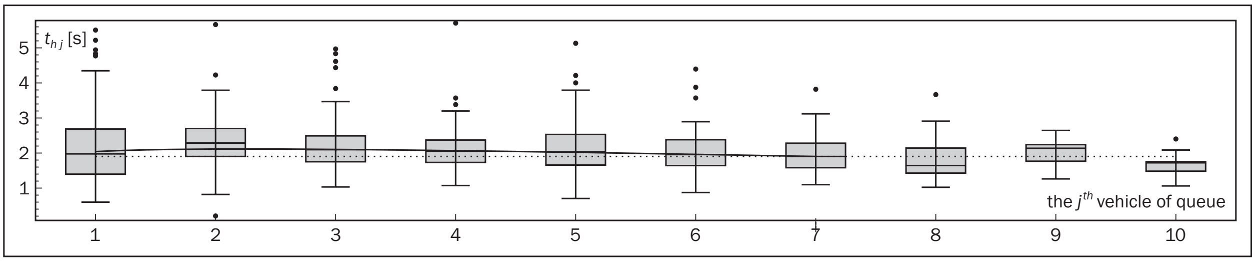

Figure 6 - Box-plot presentation of headway and the fit median curve for the time period ON_1-2

We elaborated a comparison of headways between vehicles in saturated traffic flow for both changes of the countdown signal status using the »before/after« analysis. The results are presented in *Table 3*.

The average headway between vehicles in saturated traffic flow is approximately the same in all periods: 2.0s. The value before turning off and after subsequent turning on is smaller by 0.1s, but this is negligible. According to experience and based on the hypothetic test, it can be assumed that there are no »before/after« differences. The results of start-up lost times per cycle using the comparison for both »before/after« changes are shown in *Table 4*.

When compared with the period in which the countdown signals were off (OFF_1-2 and OFF_6-7), the average start-up lost times with the countdown signal on were slightly increased (ON_6-7 and ON_1-2), i.e., on the average by 0.25s. The average headways below the value of 1.0s are minimal, especially when compared with others (Transport Research Board, 2000).

Table 2 - Presentation of average headways between vehicles waiting in the queue for different countdown signal operating periods

Observed Period	Mean headway of the j^{th} vehicle for all cycles [s]									
	1	2	3	4	5	6	7	8	9	10
ON_6-7	2.08	2.28	2.25	2.12	2.14	2.09	1.90	1.81		
OFF_1-2	2.22	2.40	2.30	2.20	2.21	2.08	1.96	1.97	1.85	1.89
OFF_6-7	2.31	2.18	2.06	2.17	2.11	2.13	2.12	2.03	1.96	1.90
ON_1-2	2.05	2.27	2.13	2.05	2.06	1.96	1.92	1.80	2.17	1.70

Table 3 - Results of headway comparison in saturated traffic flows for both »before/after« changes

Saturation headway *h* [s]				
Period	ON_6-7	OFF_1-2	OFF_6-7	ON_1-2
Observed cycles [N]	46	70	69	48
Mean μ	2.07	2.10	2.16	1.97
Standard Deviation	0.335	0.403	0.440	0.410
Variance	0.112	0.162	0.193	0.168

Two sample t Test: Null Hypothesis: $\mu_{before} - \mu_{after}$ = 0; Alternative Hypothesis: $\mu_{before} - \mu_{after}$ <> 0						
	t Statistic	dF	Prob>|t|	t Statistic	dF	Prob>|t|
Equal Variance Assumed	-0.449	114	0.653	2.404	115	0.017
Equal Variance NOT Assumed	-0.467	107.788	0.641	2.434	105.572	0.016
At the 0.05 level, the difference of the headway means	is NOT significantly different than the test difference(0)			is NOT significantly different than the test difference(0)		

Table 4 - Results of comparisons of start-up lost times for both »before/after« changes

Total start-up lost l [s]						
Period	ON_6-7	OFF_1-2		OFF_6-7	ON_1-2	
Observed cycles [N]	44	66		61	43	
Mean μ	0.83	0.78		0.66	0.86	
Standard Deviation	1.736	1.591		1.747	1.652	
Variance	3.014	2.531		3.054	2.730	
Two sample t Test: Null Hypothesis: $\mu_{before} - \mu_{after} = 0$; Alternative Hypothesis: $\mu_{before} - \mu_{after}$ <> 0						
	t Statistic	dF	Prob>|t|	t Statistic	dF	Prob>|t|
Equal Variance Assumed	0.181	108	0.856	-0.591	102	0.555
Equal Variance NOT Assumed	0.178	86.650	0.859	-0.597	93.607	0.552
At the 0.05 level, the difference of the headway means	is NOT significantly different than the test difference(0)			is NOT significantly different than the test difference(0)		

Considering the hypothetic test, it can be concluded that the »before/after« differences are minimal compared with the confidence level of α = 5%.

4.2 Results of violations

Table 5 shows the number and the level of violations for individual phases (*t-light*). Note that the rate of running violations before turn-off was 14.5%, and it increased immediately after turn-off by approximately 12% (OFF_1-2). This value increased by an additional 8% on the 6th and 7th day after turn-off (OFF_6-7), thus adding up to 17.6%. When the countdown device was turned on again, this value decreased to the rate approximately the same as before the turn-off, i.e., changing by as much as 21%.

For this case, we also concluded that the number of such violations increased in the period when the countdown device was off (*Table 5*). Before it was turned off and immediately afterwards, the violation rate was approximately the same, 0.29% before the turn-off and 0.25% after the subsequent turn-on. In the period when the countdown device was off, this value increased on the 1st and 2nd day of the turn-off status, increasing by further 6.5% on the 6th and 7th day after turn-off. Once the countdown device was turned on again, the violations decreased by more than a half.

During the period when the countdown device was off (OFF_1-2, OFF_6-7) red/amber light running violations were not recorded. Before turn-off, the violation rate was 1.59%, and after subsequent turn-on, it was slightly lower at 1.01%.

Table 5 - Results of violations for individual phase or light

Period	Index	*t-light*, lanes *A.1* and *A.2*		
		Amber	Red	Red/Amber
ON_6-7	Total *t-light* violations [veh.]	100	2	11
	Observed cycles [N]	98		
	Observed volume [veh.]	690		
	t-light violation rate [%]	14.49%	0.29%	1.59%
OFF_1-2	Total *t-light* violations [veh.]	213	6	0
	Observed cycles [N]	154		
	Observed volume [veh.]	1310		
	t-light violation rate [%]	16.26%	0.46%	0.00%
OFF_6-7	Total *t-light* violations [veh.]	214	6	0
	Observed cycles [N]	98		
	Observed volume [veh.]	1215		
	t-light violation rate [%]	17.61%	0.49%	0.00%
ON_1-2	Total *t-light* violations [veh.]	115	2	8
	Observed cycles [N]	98		
	Observed volume [veh.]	796		
	t-light violation rate [%]	14.45%	0.25%	1.01%

4.3 Survey results

Vehicular countdown devices have been present in Ljubljana for almost 5 years. The drivers are used to them and are familiar with how they operate.

Of all the received answers, 385 were useful; 98% of the respondents had driving licenses of category B (passenger cars), 84% of the respondents considered the countdown devices a positive complement to the traffic signal, 10% considered them a negative complement, and 6% of the respondents believed that countdown devices were simultaneously a positive and a negative complement.

Most of them (55%) believe that they are a positive complement because the driver is able to prepare in advance to start up and stop. Some (25%) believe that they are useful because they inform the driver about the duration of an individual phase. Only 8% are convinced that they reduce the number of accidents in intersections, and 9% feel that they increase safety in an intersection. Because they had the opportunity to write their own opinion, 3% of the respondents chose other options.

Of those who consider countdown timers a negative complement, 32% believe they are negative because they disturb the driver and distract their attention. In addition, 32% believe that the presence of a countdown device increases the number of violations in intersections, 7% say that countdown signal disturbs them and 16% are of the opinion that it reduces safety in intersection. Other options in the survey were chosen by 13% of the respondents.

5. DISCUSSION

During the research, a lot of questions were asked whether the countdown signals have a positive or negative effect on the driver's behaviour at the signalized intersections. Unfortunately, there is no short "yes or no" answer to this question.

When the countdown signal was on, fewer red or amber light running violations were detected. Thus, it can be concluded that the presence of the countdown device decreases the occurrence of red or amber light running violations. When the countdown signal was off, no red/amber light running violations were detected (in our opinion a coincidence). In this way, hypotheses H2 and H3 can be confirmed, but we could say that there is no essential contribution to the safety because of the two-colour countdown signal. The same results were reported by Craig et al. [2] and Chen et al. [12]. On the other hand we could deny the conclusions of Lum and Halim [3] in the case of Ljubljana. In our case, we could say that the red-time countdown device has a more positive influence on safety than the green one.

When speaking about start-up lost times, it has been established that with the presence of vehicular countdown devices, they are the same or even higher than in the case when the countdown device is not present. Based on this, hypothesis H1 is rejected. The reason for this is that drivers are attentive while waiting for their green light. They mainly observe how the traffic flow in other directions is running and are attentive of the pedestrian traffic. Accordingly, they get prepared to start up at the moment when other participants in cross directions prepare to stop. When the countdown signal is on, this attention decreases because the drivers focus on the countdown signal. We assume that this explanation applies particularly for the use of a countdown signal at urban intersections, where congestion is more frequent and drivers are familiar with (fixed-time) traffic control systems. In this case we found more positive impacts for red countdown signal than for the green countdown signal. The red countdown signal could help drivers to reduce start-up lost time, as recently reported by Chen et al. [12], but we did not prove that in our experiment.

Considering the results of the questionnaire survey, in general, drivers speak very positively about countdown signals. There were only few who found them to be a negative complement. Similar findings are described by Limanond et al. [6].

It must be noted that the countdown traffic signal heads can accurately display the time remaining for a particular phase only at intersections with fixed-time traffic signal control. It is almost impossible to introduce the two-colour countdown traffic signal in the case of traffic-actuated or traffic-responsive control. In that case we do not recommend the use of green countdown traffic signal and only the red countdown traffic signal has no dangerous and ambiguous information about real end of red phase. The future research will be necessary to determine under which condition the countdown devices would be possible with traffic responsive control systems. In our case we did not research the impact on human behaviour in case of pedestrian countdown traffic signal. In our opinion they are very well received by pedestrians, more so than by vehicle drivers.

Thus, in order to get a clear answer to the question of whether countdown devices are a positive or a negative complement, we believe that the additional research should be conducted. Countdown devices should also be investigated with regard to their impact on the decision and dilemma zone, which are of key importance for the rear-end and lateral crash risks. We also believe that results vary because of the human factor impact. We are convinced that the results would differ for different cities or/and countries. The results of drivers' reactions observed at locations with higher volume of transit traffic or at suburban or rural intersections would also be interesting. These drivers are not used to such traffic arrangements and may for this reason be more attentive to countdown signals.

6. CONCLUSION

The answer to the question whether countdown signals are a positive complement in terms of reducing traffic violations (reduction of the number of red and amber light running violations), would be that they are very helpful in the case of urban fixed-time arterial control scheme, but they have no significant impact on drivers' behaviour.

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POVZETEK

REAKCIJE VOZNIKOV NA SEMAFORIZIRANEM KRIŽIŠČU Z IN BREZ ODŠTEVALNIKA ČASA V NASELJU

Na voznikove reakcije na semaforiziranih križiščih vplivajo različni faktorji; na obnašanje in odločitve voznika pa vplivajo tudi časovni odštevalniki za vozila. V raziskavi smo skušali raziskati, kako časovni odštevalnik za vozila vpliva na reakcije voznikov. Osredotočili smo se na analizo prekrškov vožnje v rdečo/rumeno luč, rdečo luč in rumeno luč. Opazovali in merili smo tudi časovne izgube pri speljevanju, izvedli pa smo tudi anketo, kjer so anketiranci lahko izrazili svoje mišljenje o odštevalnikih časa za vozila.

Meritve so potekale v Ljubljani na izbranem križišču, kjer sta nameščena dva časovna odštevalnika za motorna vozila v glavni smeri. Rezultati ankete so pokazali, da so ljudje odštevalnikom po večini naklonjeni; dobrih 84% anketirancev je do njih izrazilo pozitivno mišljenje. Analize terenskih meritev so pokazale, da se število prekrškov, vožnje v rdečo luč in rumeno luč ob prisotnosti odštevalnika zmanjšajo. Glede na opazovanja pa lahko trdimo, da odštevalniki ne pripomorejo k povečanju pretočnosti mestnih semaforiziranih križišč.

KLJUČNE BESEDE

semaforizacija, odštevalnik časa posamezne faze, prometna varnost, vožnja v rdečo, rumeno in rdečo/rumeno luč, časovni razmak med vozili, izguba na startu

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