TRAFFIC FLOW ANALYSIS OF DIGITAL COUNT DOWN SIGNALIZED URBAN INTERSECTION

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Abstract: Intersections are bottleneck in the urban highway network and critical determinant of system's capacity, efficiency and safety. Recently, several countdown timers had been installed at intersections in Kuala Lumpur and some other cities in Malaysia. The function of these timers is to aid drivers to judge the amount of time left for them to get the green signal for starting their vehicles. This advance information is supposed to help drivers in reducing their initial delay especially for the first few vehicles. In the present research one intersection in a non-CBD area has been analyzed to study the effect of count down timer on driver behavior and intersection approach capacity. The data is collected at the same intersection before and after the installation of count down signal in order to exclusively study the effect of timer, keeping other factors the same. The intersection approach capacity of countdown signal is compared with normal signal and other standards. The study suggests that countdown timer has got very little effect on capacity values for both countdown and normal signal approach are very close to US Highway Capacity Manual values. For the safety level comparison of conventional and timer signalized intersections the data for red light running is analyzed and results are reported.

Key Words: Urban, Intersection, Capacity, Countdown timer, Safety.

1. INTRODUCTION

Intersections in the urban highway network have a significant effect on the operation and performance of the traffic system. There are two broad categories of intersections namely at

grade and grade separated. The traffic flow at level intersection may be uncontrolled, priority type or controlled. At the controlled intersections different directions of flow share the same road space and flow is segregated in terms of time. Due to sharing of the same space (in terms of time) by different directions of flow the traffic moves like stop and go situation. Due to this situation capacity for signalized intersection is defined and measured in a different way than uninterrupted flow. The US Highway Capacity Manual 2000 edition (HCM 2000) defined the capacity of a facility as "the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions". Basic capacity for signalised intersections is defined in terms of the saturation flow rate, i.e., the capacity of the lane or approach assuming that the signal is green at all times. The saturation flow rate at signalised intersections under ideal conditions is the 1900 passenger cars per hour of green per lane (pcphgpl). The ideal conditions at a signalised intersection approach are 12 ft lane widths, level approach grade, all passenger cars in the traffic stream, no left- or right-turning vehicles in the traffic stream, no parking adjacent to a travel lane within 250 ft of the stop line and intersection located in a non-CBD area. Prediction and knowledge of capacity are fundamental in the design, planning, operation, and layout of road sections. Capacity is greatly influenced by roadway, traffic and control conditions.

In the recent past, several countdown digital timers had been installed at intersections in Kuala Lumpur and some other cities in Malaysia. The function of these timers is to help drivers to judge the amount of time left for them to get the green signal for starting (moving) their vehicles. Apparently no in-depth study on its suitability in the local road and traffic environment has been done. In the present research one intersection in non-CBD area has been analyzed to study the effect of count down timer on driver behavior and intersection approach capacity. The data is collected at the same intersection before and after the installation of count down signal in order to exclusively study the effect of timer, keeping other factors the same. The intersection approach capacity of countdown signal is compared with normal signal and other standard values. For the safety level analysis seven signalized intersections, four with count down timer and three without timer are analyzed for red light violation by drivers. The results of red light running are compared for two types of signalized intersections.

2. REVIEW OF PAST STUDIES

Research in the area of signalized intersection capacity and design has completed about half century. First US Highway Capacity Manual published in 1965 provided a detailed guideline for signalized intersection capacity analyses and design. Maini and Khan (2000) conducted a study on clearing speeds of heterogeneous traffic at signalized intersections in two Indian cities. Findings of this study show that the intersection clearing speed is relatively constant for different vehicle types and has the potential to affect the methodology for determining the passenger car unit (pcu) values. Given the findings of this study, platoon-clearing speed may be more relevant to estimating intersection capacity. Ibrahim et. al. (2002) had carried out a study to determine the ideal saturation flow at signalised intersections under Malaysian road conditions. They adopted the method of measuring saturation flow published by the (then) Road Research Laboratory

(1963). The averaged flow values were then regressed with lane widths to obtain a linear regression model as shown below:

where, s = 1020 + 265w; $R^2 = 0.876$ s: measured saturation flow rate in pcu/hr w: lane width (m)

Leong et. al. (2003) have developed a new statistical approach for finding the pcu values of different vehicles at signalized intersections with respect to Malaysian traffic conditions. Kidwai and Tan (2004) have studied about the effect of various traffic, highway geometrics and control parameters on urban intersection capacity in Malaysia. Rehan et. al. (2004) presented a paper in MKJR meeting about preliminary findings on the performance of digital count down traffic signals in Malaysia. None of the previous studies has focussed exclusively on the effect of count down timer on intersection approach capacity and safety issues.

3. DATA ACQUISITION AND PROCESSING

For the capacity analysis data is collected at a T junction in a non-CBD area in Malaysia. The data is collected at the same intersection before and after the installation of count down signal in order to exclusively study the effect of timer, keeping other factors the same. Table 1 shows the equivalent passenger car unit (pcu) values that are used in this study. The equivalent pcu is determined based on the Table 1-2 of Arahan Teknik Jalan (13/87) JKR, Malaysia. Video recording technique is adopted in this study to carry out the field data collection. Recordings were done on weekdays during sunny weather. Data collection, which consist of determination of the phasing and signal timing for intersection, video recording process and intersection's dimension measurement.

Type of vehicles	Equivalent pcu		
Passenger car	1.00		
Motorcycle	0.33		
Light van	1.25		
Medium Lorry	1.75		
Heavy Lorry	2.25		
Bus	2.25		
Trailer	2.25		

Table 1: Equivalent Passenger Car Unit (PCU).

The cassette is run in the video cam through television to obtain the data. The clearance time of a queue of vehicles is the difference of time when the rear axle of first vehicle crosses the stop line and the rear axle of last vehicle in the queue crosses the stop line during green interval of a cycle. The clearance time can be equal to the green time of a cycle if the queue of vehicles is not fully cleared during the green time. For the safety level analysis, seven signalized intersections, four with count down timer and three without timer are selected in a non-CBD area. All these seven intersections are located close to each other and the geometric features, traffic and control conditions are similar. In this case also video recording technique is adopted to carry out the field data collection. Recordings were done on weekdays during clear weather and cassette is run in

the video cam through television to obtain the data. For the computation of RLR, only the cycles with vehicles approaching the junction during the change over phase are considered. The cycles with no vehicles approaching the junction during the change over phase are not used in analysis.

4. ANALYSES AND RESULTS

The traffic flow and driver behavior data is analyzed and compared for the two types of signalized intersections in this section. The parameters investigated in the present study are clearance of the queue of vehicles at the stop line, after light turns green and red light violation by drivers.

4.1 Comparison of Throughput

For the traffic flow analysis at signalized intersection under investigation data is collected before and after the installation of count down timer. The timer is installed at one approach only and three lanes A, B and C have the effect of timer. Lanes A (adjacent to divider) and B (middle lane) are exclusively used for through traffic whereas lane C (adjacent to curb) is used for through as well as left turning traffic. There is no exclusive left turning lane for this approach. In order to exclusively study the effect of timer on intersection approach capacity keeping other parameters uniform only lane A and B are analyzed. A recent study by Karim et. al. (2004) has shown that initial delay for first 4-5 vehicles is not very prominent at signalized intersection approach. Therefore in the computation of saturation flow all vehicles in queue behind the stop line are counted. Moreover the aim of present research is to study the effect of timer on capacity and the timer will be effective for first few vehicles only. If the flow is measured after first 4-5 vehicles, it will not show any effect of timer on capacity. Therefore the term throughput is used instead of saturation flow for the capacity measurement. The vehicles which are crossing the stop line during green time but not the part of queue are not counted for throughput.

Figure 1 (lane A) and Figure 2 (lane B) show the scatter diagram for the variation of throughput (pcu/h) with clearance time. From the scatter diagrams it seems that digital timer has no significant effect on throughput.



Figure 1: Variation between throughput (pcu/h) and clearance time for Lane A



Figure 2: Variation between throughput (pcu/h) and clearance time for Lane B

For a rigorous analysis of the effect of timer on the throughput the statistical analysis is also performed and the results are presented in Table 2 and Table 3. The comparison between timer and no-timer case for the Lane A and Lane B is presented in Table 2. The average throughput for Lane A is very close to Highway Capacity Manual saturation flow value for both timer as well as no timer case. For Lane B the value is very close for the no timer case only. The value of average throughput is more for no timer case for both the lanes. Though by intuition, approach with countdown timer should give more throughput as the drivers are informed about time left for the signal to turn green and initial delay is supposed to be less. The range of maximum and minimum throughput value is quite high; the reason may be attributed to wide variation in car sizes, and variation in driver behavior. The car length in Malaysia varies from 3.2 to 4.8m, with average length of 4.2m. The difference between average throughput for timer and no timer case for both Lane A and Lane B is tested using t-statistic. The null hypothesis is: The timer does not have a significant effect on throughput. The results show that the effect of timer on throughput for both the Lanes is not significant at 95% confidence level.

	Lane A		Lane B	
	No-timer	Timer	No-timer	Timer
Mean throughput (pcu/h)	1921	1884	1910	1838
No. of data points	29	55	28	46
Max. throughput (pcu/h)	2801	2277	2558	2110
Min. throughput (pcu/h)	1309	1627	1448	1554
Standard deviation	362.257	159.71	275.3298	146.47
t-statistic	0.651		1.493	
t(0.05)- table	1.650		1.650	

Table 2: Comparison of throughput between timer and no-timer

The comparison of average throughput between Lane A and Lane B for timer and no-timer case is presented in Table 3. The difference between average throughput for Lane A and Lane B for timer and no timer case is tested using t-statistic. The null hypothesis is: The average throughput is same for both the Lanes for timer as well as no timer situation. The difference between average throughput for Lane A and Lane B for both timer and no timer case is not significant at 95% confidence level.

	No-timer		Timer	
	Lane A	Lane B	Lane A	Lane B
Mean throughput (pcu/h)	1921	1910	1884	1838
No. of data points	29	28	55	46
Max. throughput (pcu/h)	2801	2558	2277	2110
Min. throughput (pcu/h)	1309	1448	1627	1554
Standard deviation	362.257	275.33	159.705	146.47
t-statistic	0.129		1.495	
t(0.05)- table	1.674		1.650	

Table 3: Comparison of throughput between the Lanes

4.2 Red Light Running (RLR)

One of the major safety concerns at signalized junctions is the phenomenon known as red light running (RLR). Apart from adequate amber period given after the end of green and before the commencement of red, it is also quite usual to have adequate all-red phase to further enhance the level of safety at the junction just in case a vehicle is not able to stop in time before the end of amber. It has been suggested that the digital count-down display may assist drivers to stop before the commencement of red as the driver would know the amount of green time available before it changes to amber and then red. This would help eliminate the RLR phenomenon and hence increase the level of safety at the signalized junctions.

To investigate this claim, observations were made at both the traditional non-count-down signalized junctions (NCD) and the new count-down signalized junctions (CD). For the junctions using conventional non-count-down signals there is an average of 66.2% RLR whilst that of the junctions using count-down signals the RLR is 37.1%. The RLR is computed based on the relevant cycles when there are vehicles approaching the junction during the change over phase. Based on this observation it appears that there is some merit in using the count-down facility since the RLR is reduced quite substantially. Nevertheless, there is still a relatively high occurrence of RLR at the count-down signalized junctions. One would tend to expect that if the drivers were really taking heed of the digital count-down display there should not be any RLR at all. On the contrary, the high occurrence of RLR in conventional signalized junctions may be

attributed partly to the inadequacy of amber time which does not match with the ability for a vehicle to stop safely while moving at a particular approach speed.

5. CONCLUSIONS

Following conclusions are drawn from the present research:

- The throughput in independent of effective green time.
- The difference in average throughput for timer and no-timer case is not significant at 95% confidance level using t-statistic.
- There is large variation in throughput values for different cycles for both timer and notimer case.
- The average throughput values for both timer and no-timer case are very close to US Highway capacity values.
- The incidences of red light running are about two times at no-timer case than the timer one.

6. FUTURE WORK

This study is a preliminary investigation and further research should be made to validate the results obtained in this study. This study is focussed on three-legged intersection for capacity analysis and it is recommended that a study on four-legged intersections should be conducted. There is a need to prepare warrants (guidelines) for where, when and how to employ count down timers. Cost effectiveness (installation and maintenance) of digital count down timers should be studied before recommending their use.

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