Re-arrangement of traffic signal timings by cyclic vehicle queue profile

Yetiş Şazi Murat[1], Sabit Kutluhan[1], Ziya Çakıcı[1]

[1]*Department of Civil Engineering, Pamukkale University, Denizli, Turkey*

ABSTRACT

Traffic signal timing is one of the interesting subjects that have been considered by transportation engineers and researchers. In spite of many technological and innovative solutions, fixed time controlling approach is still applying widely in the world. Signal timings are pre-defined in fixed time control and many programs can be applied for time of day. But in some cases, these programs can be insufficient for the demands occurred by variations in traffic flows.

Assigned signal timings can be more or less than that of the timings required. Thus, vehicle delays can increase because of these irregular assignments. In this study, cyclic vehicle queue profile is considered for re-arrangement of signal timings at isolated intersections. Observations were made at sample intersections in Denizli, Turkey. 5 isolated intersections were considered and cyclic based observations were made for peak and off-peak periods. Traffic compositions were taken into account in the observations, cyclic traffic flow profile and remaining number of vehicles for each cycle was determined. Based on these observations, average remaining queue, average discharging time of queue, remaining phase time were measured. Present cycle times were modified depending on remaining phase times and new cycle times were calculated. The average delay times of the traffic flows for new cycle times were calculated with Akcelik delay formula. In addition, they were compared to that of existing cycle time. The results showed that at least 30% improvements can be obtained by re-arrangement of signal timings considering cyclic vehicle queue profile.

INTRODUCTION

Traffic engineers are struggling on developing different and efficient strategies for traffic flow management. Isolated signal control is one of the strategies used in common. On the control of isolated intersections, to determine traffic volumes correctly on the approach legs and their variation in time are important the most. If the observations are inadequate or variations of traffic volumes can not be determined, vehicle queuing will be observed at intersection approaches, level of service for intersection will decrease and average delay will increase. Thus, road users can be encountered with unfavorable results in points of economy and environment.

In this study, the traffic flows for each cycle time were investigated at the signalized intersections in Denizli. The number of vehicles waiting in queue at each cycle, passing and remaining at green signal, and green time remained were observed. Due to vehicle queuing, signal phase time and cycle time were re-arranged and as a result of this, the intersection performance was evaluated. The average delay time was considered as intersection performance parameter. Delay times were calculated using Akcelik formula.

In the second part of this study, literature relating to delay and queue length relation was reviewed and the relation used in the study was introduced. Because of being used most widely equation, Akcelik equation was also used in the scope of this study. In the third part, field studies were explained and the informations about collected data were presented. Analyses were presented and the results of these analyses were expressed in the fourth part. The fifth part includes the results obtained and recommendations.

Delay and Queue Length at Traffic Signalization

Delay is an important performance parameter in the traffic signalization. Delay parameter includes random and uniform components [1-3]. The red time at signal cycle can be evaluated as uniform component, however vehicle arrivals and the formation of queue can also be evaluated as random components. Because trying to determine the delay with the observations was very difficult, for the purpose of easy calculation and prediction by the researchers, analytical approaches and formulas were improved [4-9]. Akcelik delay equation is also one of these formulas and this equation is used widely by transportation researchers [4].

AKCELIK DELAY FORMULA

According to this method, the queue length must be calculated primarily to determine the average delay of vehicles in a traffic flow. The queue length value is calculated by the following equation [4].

$$N_0 = \frac{QT_f}{4}\left(z + \sqrt{z^2 + \frac{12(x + x_0)}{QT_f}}\right) \tag{1}$$

If $x_0 > x$, $N_0 = 0$

Where;

N_0: Average queue length (The vehicle numbers on all lanes)

Q: Capacity (vehicle/hour)

Tf: The flow period

QTf= The maximum number of vehicles which can be discharged during the flow period
x=q/Q : (degree of saturation)
Z=x-1,
x_0 = Maksimum value of degree of saturation (the average overflow queue is approximately zero)

x_0 is calculated by equation 2.

$$x_0 = 0.67 + sg / 600 \qquad (2)$$

where ;
s= saturation flow (vehicle/second)
g= effective gren time (second)

Total delay (value) is calculated by the following formula

$$D = \frac{qc(1-u)^2}{2(1-y)} + N_0 x \qquad (3)$$

where;
D: Total delay (second)
q: Flow (vehicle/second)
c: Cycle time (second)
u: Green time ratio (g/c)
y: Flow ratio (q/s)

In addition, the average delay time per vehicle can be expressed as;

$$d=D/q \qquad (4)$$

where;

D: Total delay (second)
q: Flow (vehicle/second)

The queue length is considered as a significant component in Akcelik delay equation.

FIELD STUDIES

In the scope of this work, the traffic flows for each cycle time were investigated with observations at the signalized intersections in Denizli. The number of vehicles waiting in queue at each cycle, passing and remaining at green signal, and green time remained were observed. As a result, signal phase times and cycle times were rearranged taking into account of queuing. The delay performances of intersections were determined again regarding new signal timings.

The observations were made at two signalized intersections and the countings related to parameters mentioned above were made at intersection approach legs.

Vehicle queue lengths were determined for each lane, additionally vehicle discharging headways from the queue were observed. The geometry of Lise intersection is illustrated in Figure 1.

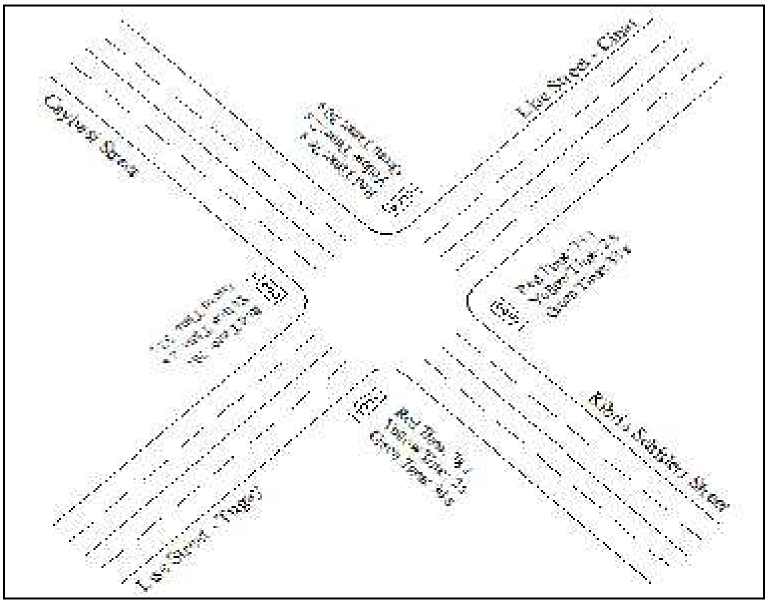


Figure 1 Geometry of Lise Intersection

The steps of observational studies are as follows;

1. After the green signal turned on, vehicle discharging headways from the queue are determined considering loss time of the first movement.
2. When the signal returned to red signal, the number of vehicles in the queue is recorded.
3. Before the green signal finished, If the vehicles in the queue discharge completely, remaining green time is recorded.
4. Based on these observations, the signal times of the intersection are re-arrenged.

Cyclic queuing profiles on the approach legs and remaining values of the green time at each cycle were observed and these values were recorded. Samples taken from the observation studies are given in Table 1.

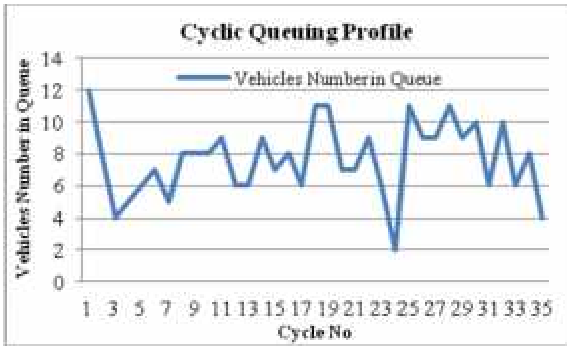
Table 1 Cyclic Vehicle Queuing for Cinar Approach (Samples)

Off-Peak Hour			Peak Hour	
Cycle No	**Vehicle in Queue**		**Cycle No**	**Vehicle in Queue**
2	8		2	19
5	6		5	16
8	8		8	25
10	8		10	16
14	9		14	18
17	6		17	26
20	7		20	20
23	6		23	21
25	11		25	13
27	9		27	27

As can be seen in Table 1, the vehicle queuing generally occurs at the peak hours and it's not at off-peak hours. In addition, because of fixed-time signalization, after the vehicle queue is discharged at each cycle, an extra green time remains still. It's resulted from the dynamic form of traffic flow and insufficiency of existing signalization systems.

On a sample approach leg, Cyclic queuing profiles and remaining time profiles are shown in Figure 2 and Figure 3 respectively.

Off-Peak Hour **Peak Hour**



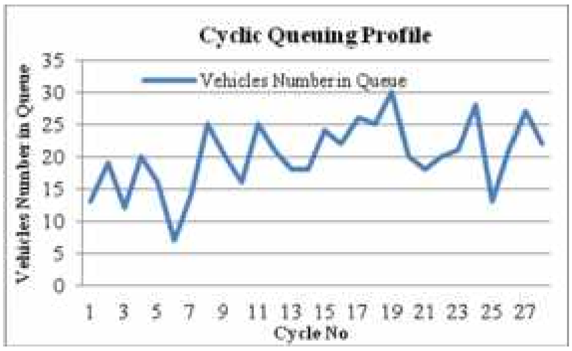


Figure 2 Cyclic Queuing Profiles for Cinar Approach

Off-Peak Hour **Peak Hour**

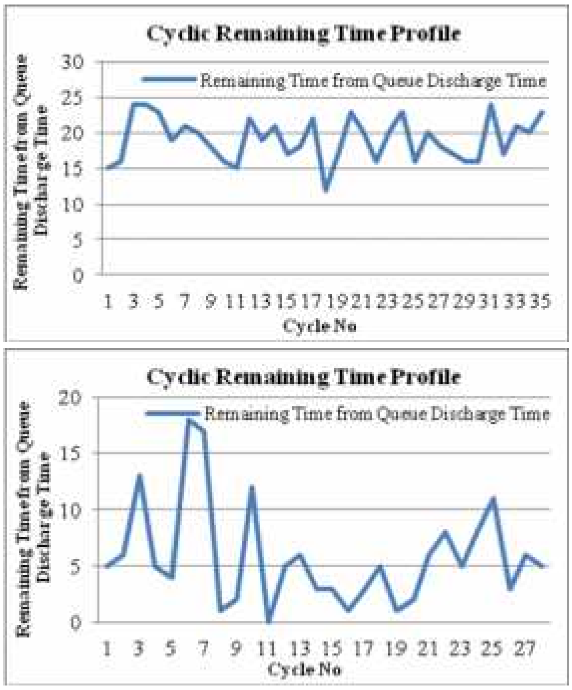


Figure 3 Cyclic Remaining Time Profiles for Cinar Approach

RE-CALCULATION OF THE CYCLE TIME

In the scope of this study, the cycle times were re-arranged taking into account remaining time at each cycle. The average delay times of the traffic flows for new cycle time were calculated with Akcelik delay formula. In addition, they were compared to that of existing cycle time. These cycle times are shown in Table 2.

Table 2 Existing and re-arranged cycle times

Lise Intersection	Existing Cycle Time (sec.)	Re-arranged Cycle Time (sec.)
Off-Peak Hour	110	53
Peak Hour	110	75

If the values in Table 2 are investigated, it is understood that existing cycle times are inadequate for peak and off-peak hours. In order to evaluate the performance of re-arranged cycle time, new delay times were calculated.

For existing and re-arranged cycle times, the delay times which are calculated with Akcelik delay formula are given in Table 3.

Table 3 Average Delay Times

Lise Intersection Off-Peak Hour	Lane	Average Delay (second/vehicle)	
		Akcelik Delay Formula results (Existing Cycle Time)	Akcelik Delay Formula results (Re-arranged Cycle Time)
Cinar Approach	Right	60	35
	Left	216	126
Caybasi Approach	Right	52	35
	Left	44	30
Tugay Approach	Right	58	17
	Left	114	56
Lise Intersection Peak Hour	Lane	Average Delay (second/vehicle)	
		Akcelik Delay Formula results (Existing Cycle Time)	Akcelik Delay Formula results (Re-arranged Cycle Time)
Cinar Approach	Right	101	62
	Left	551	328
Caybasi Approach	Right	59	48
	Left	53	43
Tugay Approach	Right	32	37
	Left	181	150

As seen on Table 3, average delay values for the intersection are decreased about at least 25% comparing to existing case by Akcelik delay formula.

CONCLUSIONS

As a result of this work, it was understood that the intersection signal times must primarily be determined with appropriate and sufficient observations. It was determined that the cycle time assignment without observations in peak and off-peak hours causes excessive and undesirable delay. It was analyzed that only fifteen minutes of observations for the cycle time assignment is sufficient and in this way, it was concluded that significant gains can be obtained.

According to calculations, it was understood that phase time is too long unnecessarily for off-peak hours. However, the average delay time can be reduced by 25% or 45% with the new arrangements.

It was determined that existing situation is sufficient for peak hours and according to calculations, new arrangement can reduce average delay only 5%.

It was concluded that dynamical evaluation of traffic flows and accordingly determination of signal timing are the most appropriate approach for efficient and sustainable control.

For future works, statistical distribution of the vehicle discharging headway can be evaluated and relations with vehicle delay can be inspired. Additionally, statistical distributions of the number of vehicles remained in the queue and remaining green times can be investigated.

REFERENCES

[1] Murat Y. S., Gedizlioğlu E. A Fuzzy Logic Multi-phased Signal Control Model for Isolated Junctions. Transportation Research Part C-Emerging Technologies, Vol 13/1 pp 19-36., Pergamaon Press, 2005.

[2] Murat Y.S., Comparison of Fuzzy Logic and Artificial Neural Networks Approaches in Vehicle Delay Modeling. Transportation Research Part C-Emerging Technologies, Vol 14/1 pp 316-334., Pergamon Press, 2006.

[3] Murat Y.S., Modelling Vehicle Delays with Fuzzy Logic at Signalized Intersections. Chamber of Civil Engineers Technical Journal, pp 3903-3916, 2006. (in Turkish)

[4] Akcelik R., The Highway Capacity Manual Delay Formula for Signalized Intersections, ITE Journal, pp 23-27, 1988.

[5] TRB, Special Report 209: Highway Capacity Manual, Trasportation Research Board, National Research Council, Washington D.C., USA, 2000.

[6] Akcelik R., Traffic Signals: Capacity and Timing Analysis Research Report 123. Australian Road Research Board, Melbourne, Australia, 1981.

[7] Akcelik R., The Highway Capacity Manual Delay Formula for Signalized Intersection. ITE Journal 6, 23-27, 1988.

[8] Burrow I., A Note on Traffic Delay Formulas. ITE Journal, 29-32, 1989.

[9] Baskan O., Modelling Average Vehicle Delays at Isolated Signalized Intersections using Artificial Neural Networks. M. Sc. Dissertation, Institute of Natural and Applied Sciences, Pamukkale University, Denizli, Turkey, 108 p (in Turkish)