An Investigation of Observation Periods on Vehicle Delay Measurement

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***Abstract*— Vehicle delay is one of the important performance parameters for signalized intersections. Because the vehicles are observed individually so the measurement of the delay takes a long time and this situation causes both the waste of time and needs more labor. The aim of this study is to get reliable analysis approach related to the measurement of the vehicle delay in less time. Different time durations are taken into considered in the analysis. To investigate effect of observation time periods on the results of delay, statistical tests are applied. Kolmogorov-Smirnov and Wilcoxon Signed Rank Test are used for the evaluation of the approaches. As a result of the statistical analyses, though thirty-minute delay observation results are the most closed to hourly (peak hour) delay observation results, fifteen-minute delay observation results are not closed to hourly (peak hour) delay observation results. It is concluded that use of thirty-minute delay observation instead of hourly delay observation may save time and labor cost.**

Keywords—signalized intersection, traffic, vehicle delay, observation period, kolmogorov-smirnov test, wilcoxon signed rank test

I. Introduction

Delay is the waste of time that approaching vehicle to intersection because of the other vehicles, the geometric properties of intersection and the control systems like traffic signs and traffic lights. Vehicle delay is important performance parameters at signalized intersection approaches. This parameter has been used for determining of the level of service and evaluating the operation of signalized intersections.

In the field, measurement of delay should also be quite sensitive to approximate the real observation values. Therefore, these measurements take a long time. For many decades, various calculation methods have been developed for exactly prediction of the vehicle delay by the transportation researchers. Webster [1], Akcelik [2] and Transportation Research Board (Highway Capacity Manual) [3] methods are the common methods used in calculation.

Delay observation study takes long times and it is a difficult process. On the other hand, it should be made precisely as much as possible to obtain closer values. These measurements can be made by both a video camera and at least two observers for an intersection approach. Observations are made at the peak hours. Generally, the observation period is one hour that the traffic volumes are the highest. In the field studies, each vehicle has been considered separately. At the end of this, the delay value has been obtained for each vehicle.

Because of the inaccurate measurements of the delay can cause assigning the wrong signal duration for each intersection approaches and improper design, these measurement should be made quite sensitive (Ban et al., [4]). These sensitive measurements can be made only using video-camera and in case of any problem it needs to be repeated. This situation causes both the waste of time and the more labor.

For the measurement of the delay takes long times as well as is difficult and tiring process, new method which is more efficient than the others, takes less time and more closer to real observation is needed.

A. *The Components of the Delay and Delay Observation*

The vehicle delay at signalized intersection consists of three part that is referred as the stopping, acceleration and deceleration delays (Dion et al., [5]). The stopping delay indicates time process that the vehicle spends because of stopping during the red or green signal period at signalized intersection. When the acceleration delay of the vehicles can be defined as required time to accelerate after the red signal turn the green signal, the deceleration delay of the vehicles can be defined as the time between that drivers start to reduce their velocity while approaching to intersection and that drivers stop in front of the signal while red signal is shown. Figure 1 illustrates trajectory diagram of a vehicle near a signalized intersection approach. Deceleration delay (A), Stopping delay (B), Acceleration delay (C) are also demonstrated in the Fig.1.

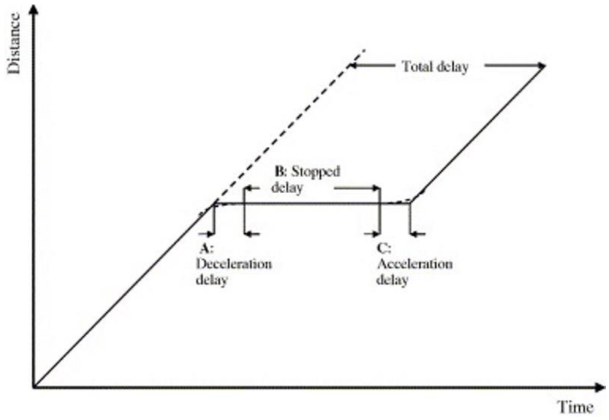

Fig. 1. Components of Vehicle Delay

For the estimation of delay at signalized intersections, many studies have been done by transportation researchers for many years. The 1985 Highway Capacity Manual delay formula was examined and a calibration process was improved by Akcelik, [6]. Akgungor, [7] focused on the new time-dependent delay calculation method considering various analysis time period. Murat, [8] studied on vehicle delay modeling using artificial neural networks and fuzzy logic optimization technique and compared the result with each other. Su et al., [9] investigated the effects on delay considering proportion and position of heavy vehicles at signalized intersection in China and produced a new estimation model for delay. Delay estimation model results and observed traffic delays were compared in that study. Murat et al., [10] produced a new delay formula depending some variables (Average Entering Time to Intersection, Red Signal Time, Number of Vehicles in Queue, Average Discharging Headway), at the end of the study, the results obtained with the formula were compared with field observations and Akcelik delay formulation results.

In this study, thirty-minute delay observation results at the peak hour were compared with hourly (peak hour) delay observation results. In the Materials and Methods part, field studies and samples for delay measurements were presented. Besides, Delay analysis, sample cases of average delays and comparisons of delay observations at Pekdemir Intersection were introduced. Some information about the statistical analysis were also given in Materials and Methods part. As the results of the statistical tests were demonstrated in the Results part, in the Discussion part, the results were evaluated considering Kolmogorov-Smirnov and Wilcoxon Signed Rank Tests and some recommendations were presented for measurement of the delay.

II. MATERIAL AND METHOD

A. *Field Studies*

In the field, delay observation studies are made as defined in the following:

1. Determining of Reference Point 1 and Reference Point 2: When Reference point 1 is selected as the middle point of intersection, Reference point 2 is selected as a point existing behind of hundred meters from traffic light.

2. Observers or Video Cameras: At least two observers or a video-camera is needed for an intersection approach when the delay observation is made. Observers must be situated between Reference Point 1 and Reference Point 2. Thus, both entry time (at Reference point 2) of the vehicle to intersection and exit time of (at Reference point 1) the vehicle from the intersection can be precisely recorded. If the video camera is used instead of observers, it is needed that video camera must be placed on location covering both reference point 1 and reference point 2. The locations of observers or video-camera and reference points at an intersection are depicted in the Figure 2.

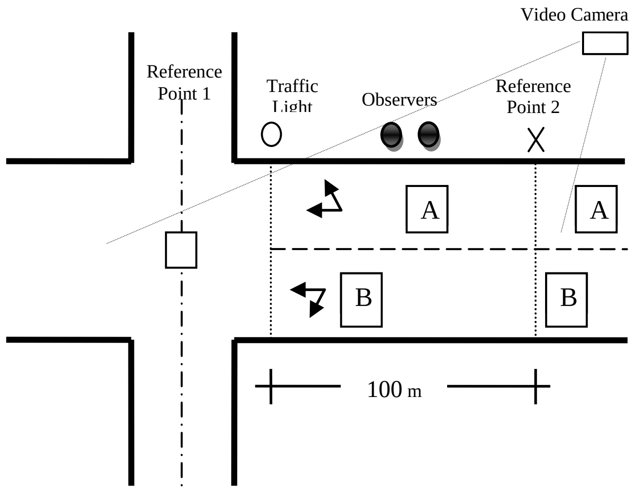

Fig.2. The Locations of Observers, Video-Camera and Reference Points at an Intersection

Vehicle delay is computed in the following Equation; (Equation 1)

$$\text{Vehicle Delay} = t_{exit} - t_{entry} \quad (1)$$

t_{exit} : Exit time of the vehicle from the intersection - Reference Point 1 (sec.)

t_{entry} : Entry time of the vehicle to intersection - Reference Point 2 (sec.)

Sample cases for delay calculation are given in Table 1.

TABLE I. SAMPLE CASES FOR DELAY CALCULATION

t_{entry} (sec.)	t_{exit} (sec.)	Vehicle Delay (sec.)
2	62	60
21	64	43
27	67	40
28	70	42
32	73	41
38	75	37
40	77	37
44	83	39
46	87	41

B. Analysis

In this study, vehicle delay observation values were obtained from the Pekdemir Intersection in Denizli, Turkey. Observations were made at between 08:00 and 09:00, between 12:00 and 13:00 and also between 17:00 and 18:00 by video-cameras as an hourly. Besides, Observations consist of two days of week including a day in the weekday and in the weekend. Each vehicle was examined individually. The average vehicle delay was calculated for each lane.

The average vehicle delay based on the lane was calculated in the following equations (Equation 2, Equation 3).

$$\text{Average Vehicle Delay for an hour} = \frac{\left|\sum_{n=1}^{k}\left(t_{exit} - t_{entry}\right)_n\right|}{k}$$

$$\text{Average Vehicle Delay for thirty minutes} = \frac{\left|\sum_{n=1}^{z}\left(t_{exit} - t_{en}\right.\right.}{z}$$

Where;

t_{exit} : Exit time of the vehicle from the intersection (sec.)

t_{entry} : Entry time of the vehicle to the intersection (sec.)

k : The total number of vehicle on the lane for an hour (veh.)

z : The total number of vehicle on the lane for thirty minutes (veh.)

This study was carried out on six different time period and on three approaches (eight lanes) at the Pekdemir intersection. The sample cases of average delays are given in Table 2. Fifteen-minute delay observation results are not given in the table because of not close to real delay values (deviations are more than 15%). Each thirty minutes delay observation results and hourly delay observation results are given in the Table 2.

TABLE II. SAMPLE CASES OF AVERAGE DELAYS AT PEKDEMIR INTERSECTION

Approach Name	Time Period	Lane	Average Delay (sec./veh.) 0 – 60 min.	Average Delay (sec./veh.) 0 – 30 min.	Average Delay (sec./veh.) 30 – 60 min.
Mugla	Weekday 17:00 – 18:00	Left	40.14	41.51	38.73
		Center	24.79	23.71	25.86
		Right	27.37	28.35	26.48
Mugla	Weekend 12:00 – 13:00	Left	39.91	42.81	37.22
		Center	27.54	27.79	27.29
		Right	33.23	34.29	32.01
Hasan Tekin Ada	Weekday 08:00 – 09:00	Left	51.75	56.45	48.17
		Right	67.05	67.66	66.46
Hasan Tekin Ada	Weekend 08:00 – 09:00	Left	58.24	58.84	57.68
		Right	70.87	75.70	66.36
Tali	Weekday 17:00 – 18:00	Left	67.37	74.61	62.16
		Center	68.57	65.12	71.18
		Right	17.26	17.86	16.53
Tali	Weekend 12:00 – 13:00	Left	61.03	59.35	63.07
		Center	54.47	50.95	57.82
		Right	19.12	18.20	20.00

Forty eight sample cases were examined and evaluated in this work. First thirty minutes observation results and second thirty minutes observation results were compared with hourly observation results and each other. The comparison of the results can be seen in Fig 3, Fig 4 and Fig 5.

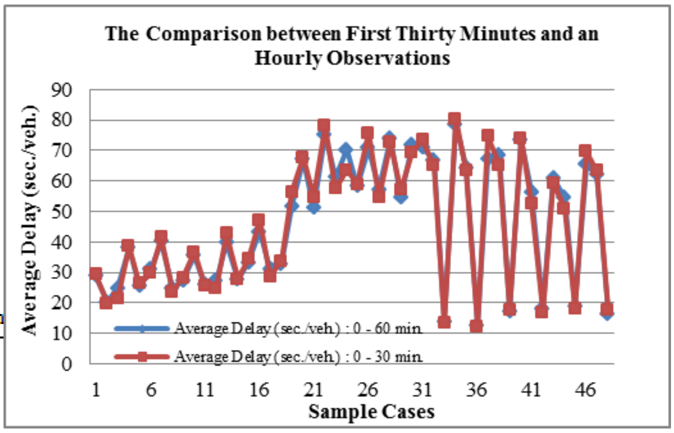

Fig. 3. The Comparison between First Thirty Minutes and an Hourly Observation

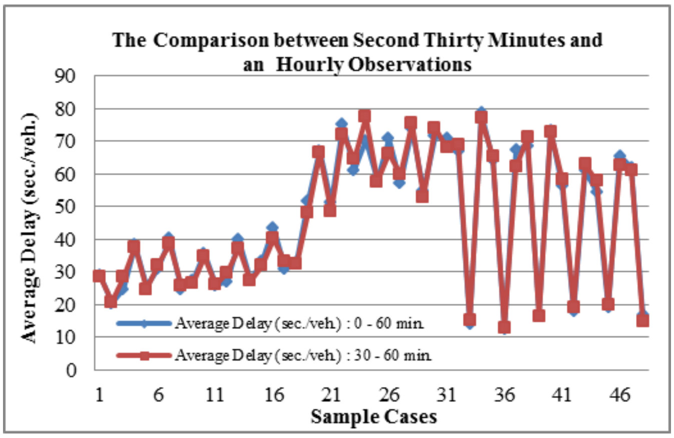

Fig. 4. The Comparison between Second Thirty Minutes and an Hourly Observation

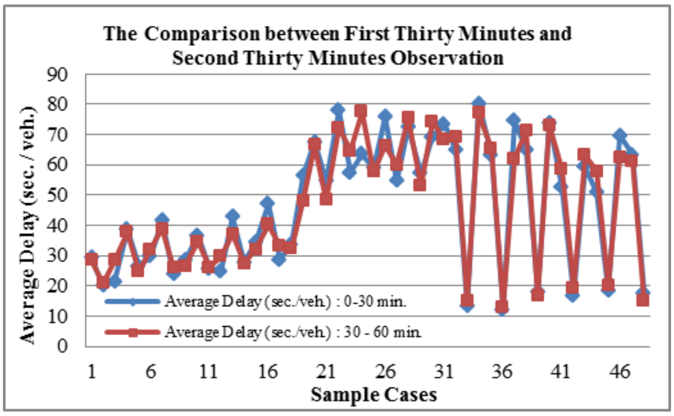

Fig. 5. The Comparison between First Thirty Minutes and Second Thirty Minutes Observations

C. *Statistical Tests*

As seen on Figure 3, Figure 4 and Figure 5, it can be simply understood that vehicle delay measurements considering different time durations are quite similar to each other. These similarities are examined statistically considering Kolmogorov-Smirnov and Wilcoxon Signed Rank Test made by using SPSS (Statistical Product and Service Solutions) which is a software package used for statistical analysis.
Kolmogorov-Smirnov test used for test of the normality in the statistics is one of the most useful and general nonparametric methods for comparing two samples. H_0 and H_a hypotheses of this test can be written in the following:

H_0: The data are suitable for normal distribution.

H_a: The data are not suitable for normal distribution.

If significant value is the greater 0.05, H_0 hypothesis is accepted. Thus, it can be said that data are suitable for normal distributions. If significant value is less than 0.05, H_0 hypothesis is rejected (Kalayci, [11]).

Wilcoxon Signed Rank Test is a non-parametric statistical hypothesis test used when comparing two related samples or matched samples. This test can be used as an alternative to the Paired student's t-test. As Paired student's t-test is used for data suited to normal distribution, Wilcoxon Signed Rank Test is used for data not suited to normal distribution. Data are paired and come from the same population in this test.

If significant value is equal to 0.05 or less than 0.05, it can be said that a meaningful difference exists between two data sets statistically according to the Wilcoxon Signed Rank Test (Kalayci, [11]).

III. RESULTS AND DISCUSSIONS

In this work, vehicle delay measurements considering different time durations were investigated statistically.

Firstly, Kolmogorov-Smirnov distribution function test was applied on hourly and thirty minutes delay observations. Conformity of delay observation values for the normal distribution was examined. Results of Kolmogorov-Smirnov distribution function test are given in Table 3.

TABLE III. RESULTS OF THE KOLMOGOROV-SMIRNOV DISTRIBUTION FUNCTION TEST

Observation periods and values	Kolmogorov-Smirnov		
	Statistics	df	Sig.
An Hourly Observation Values (0-60 min.)	.129	48	.045
Thirty Minutes Observation Values (0-30 min.)	.136	48	.026
Thirty Minutes Observation Values (30-60 min.)	.153	48	.007

Finally, Wilcoxon Signed Rank Test which is one of non-parametric hypothesis tests was applied on comparisons between first thirty minutes and hourly observation values, between second thirty minutes and hourly observation values and between first thirty minutes and second thirty minutes observation values. Results of the Wilcoxon Signed Rank Test for comparison between first thirty minutes and hourly observation values, results of the Wilcoxon Signed Rank Test for comparison between second thirty minutes and hourly observation values, result of the Wilcoxon Signed Rank Test for comparison between first thirty minutes and second thirty minutes observation values are shown in Table 4.

TABLE IV. RESULTS OF THE WILCOXON SIGNED RANK TEST

Wilcoxon Signed Rank Test - Test Statistics[a]			
	First Thirty Minutes - An Hour	Second Thirty Minutes - An Hour	First Thirty Minutes - Second Thirty Minutes
Z	-.231[b]	-.210[b]	-.200[b]
Asymp. Sig. (2-tailed)	.817	.833	.841

a. Wilcoxon Signed Ranks Test
b. Based on Negative Ranks

IV. CONCLUSIONS

In this study, an efficient and time saving method for measuring vehicle delay is searched. One of the main purpose of this study was to save observation time and labor. On the other hand, it is aimed to get a reliable, efficient and valid observation method.

For this aim, instead of hourly observations, fifteen minutes and thirty minutes time periods are considered and validation of these periods are investigated.

Kolmogorov-Smirnov distribution function test and Wilcoxon Signed Rank Test are applied for validation searching stage.

As can be seen on Table 3., Significant values for different time durations are less than 0.05. According to these results, it can be said that distributions of observation values for each time duration is not suitable for normal distribution. Consequently, it is determined that parametric hypothesis tests cannot be applied on observation values. Thus, Wilcoxon Signed Rank Test are applied for the observation values.

As seen on Table 4, Because of significant values is greater than 0.05, it is concluded that a meaningful differences do not exist between two data set for three comparison and these data sets resemble to each other. Namely, There is no meaningful differences between these time periods. Thus, any of them can be used for measuring purpose.

As a result, use of thirty-minute delay observation instead of hourly delay observation is proved considering Wilcoxon Signed Rank Test.

New methods and technologies such as plate recognition can be used for automated measurement of vehicle delay in future.

Similar investigations should be made for following headways of vehicle and saturation flow measurements at signalized intersection.

References

[1] Webster, F. V., Traffic Signal Settings, Road Research Technical Paper, No 39, Road Research Laboratory, Her Majesty Stationary Office, 1958, London, UK.

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

[3] TRB. Special Report 209: Highway Capacity Manual, Trasportation Research Board, National Research Council, 1985, Washington D.C., USA.

[4] Ban, X., Herring, R., Hao, P., Bayen A. M. "Delay Pattern Estimation for Signalized Intersections Using Sampled Travel Times", Transportation Research Board of the National Academies, Vol 2130, 2009 pp 109-119.

[5] Dion, F., Rakha, H., Kang, Y. S., "Comparison of Delay Estimates at Under-Saturated and Over Saturated Pre-Timed Signalized Intersections" Transportation Research Part B-Methodological, 2004,Vol 38/2 pp 99-122.

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

[7] Akgungor A. P, "Mathematical Modeling of Delay Estimation at Signalized Intersections I: A New Time-Dependent Delay Model for Various Analysis Time Periods", Technology, 2004, Vol 7/3 pp 369-379.

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

[9] Su, Y., Wei, Z., Cheng, S., Yao, D., Zhang, Y., Lı, L., "Delay Estimates of Mixed Traffic Flow at Signalized Intersections in China", Tsınghua Science and Technology, 2009, Vol 14/2 pp 157-160.

[10] Murat Y.S., Kutluhan S., Cakici Z., "Investigation of Cyclic Vehicle Queue and Delay Relationship for Isolated Signalized Intersections" Procedia - Social and Behavioral Sciences, 2014, Vol 111 pp 252-261.

[11] Kalayci S. Multivariate Statistical Techniques with SPSS Applications, 2nd ed., 2006.