Evaluation Average Discharge Headway at Nearside Legs of Signalized Intersections

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Abstract
Average discharge headway of vehicles and start-up delay in signalized intersections play a key role in analyzing capacity, schedule, and performance of intersections. In the present study, the values of average discharge headway and start-up delay in the nearside legs of signalized intersections were calculated with the help of field data related to five signalized intersections in the city of Rasht. The results show that saturation conditions occur in the inlet path between the fifth and sixth vehicle and the last vehicle in the queue. In other words, the number of vehicles with start-up delay is in the inlet path of 4 or 5 vehicles .
Key words: *Signalized Intersection; Average Discharge Headway; Start-up Delay; Nearside Leg; Traffic Flow*

Introduction

A few basic parameters of the intersection performance such as delay and saturation flow rate are derived from the average discharge headway so that using incorrect values of average discharge headway lead to incorrect estimation of the amount of congestion, delays, and the saturated flow rate. Discharge headway of vehicles is defined in the form of passed time between the arranged vehicles to the stop line. The first headway will be the time interval between the start of green phase and the passage time of the front wheels of the vehicle from the stop line and the second headway will be the required time for passing the front wheels of the first vehicle up to passing the front wheels of the second vehicle from the stop line and so on [1, 2]. Headway of each vehicle becomes lower than the front vehicle and by continuing this process; it reaches a point that the value of headway will remain relatively constant from this point onward until the time that all vehicles in the queue cross the intersection or the green time be finished. This constant headway is also called saturation flow rate and it can be occurred for the third and sixth vehicles. However, there is a difference in different resources between the occurrence locations of the saturation flow rate which is the result of different local conditions in data collection [3, 4]. The total difference of saturation headway with the headway of some vehicles in the first queue is called the start-up lost time (start time delay) which spends additional time to respond to the start of the green time and increase the velocity. According to HCM book, saturation condition occurs between the headway of the fifth vehicle and the last vehicle in the queue and the headway of the first four vehicles are used to determine the start time delay [5]. Therefore, in the present study, the saturation headway and the start time delay in the desired inlet paths were evaluated by collecting field data belonging to five signalized intersections in Rasht.

Literature Review

The first major study of the saturation rate was conducted by Bruce Greene Shields in 1940 and average saturation flow rate of 1714 vehicles per green hour per lane (veh/hg/ln) and start-up lost time of 7.3 second were obtained [6]. In the last decades, many researchers have conducted studies in this context. Various editions of Highway Capacity Manual have addressed this issue. Reasons such as changes in traffic behavior and physical dimensions of the vehicles in each country have led to the continuing attention to this important traffic parameter in various countries. Here examples of these similar studies are mentioned. Lopez (1998) conducted a study on 19 signalized intersections in Monterrey, the capital city of the State of Nuevo Leon without stating some important details, such as queue length per cycle and treatment for the presence of vehicles other than passenger cars, time measurements recorded for the 4^{th}, 10^{th} and last vehicle positions in each lane. The mean saturation flow rate value resulted in 1876 vphgpl or an h value of 1.92

seconds; the 85th percentile value of s was also determined as 2056 vphgpl [7]. Mizanur Rahman et al (2003) compared saturation flow rate at 9 signalized intersections in Yokohama, Japan and Dhaka, the capital of Bangladesh. The Analysis of Variance (ANOVA) was performed to determine the saturation flow region of the queue for different queue regions and Saturation headway was estimated by averaging the headways of all the vehicles in the saturation flow region which was different from the existing method in HCM. After calculating the saturation flow rate, the results showed that the value of saturation headway obtained in this study was higher than HCM value which led to the low rate of saturation flow [8]. Cartagena,Tarko (2005) in a study titled "calibration of capacity parameters" analyzed base saturation flow rate and related correction factors choosing 21 signalized intersections with three factors of long queues, base condition and population in India (in Indiana city). After investigating the existing variables (population, road class, right most lane, presence of curb and lane hour volume) and their analysis, they presented a regression model using the statistical tests. The regression analysis showed that the community size and the right-most position of the lane in the lane group significantly affects the saturation flow rate [9]. Lee Vien et al (2005) to estimate the ideal saturation flow rate based on the situation in Malaysia, selected the ideal signalized intersections and recorded saturation headways for different lane widths in dry weather and saturation traffic flow. Then the average values of saturation traffic flow for different widths were calculated and regression model was developed based on the lane width. The saturation flow rate was obtained as 1930 pcu/h which is higher than the comparable value in HCM (1900pcu/h). The reason for this is the higher rate of the law evasive drivers in Malaysia [10]. Shao et al (2011) in a study on the saturation flow rate and its influence factors at 13 signalized intersections in China obtained average saturation flow rate equal to 1773 pc/h/ln (with corresponding average time headway 2.03 s).The base saturation flow rate was suggested as 1800 pc/h/ln for the through lane which is much lower than the corresponding values in HCM (i.e. 1900 pc/h/ln). The study indicated that the widened lane width, left turn-radius and approach grade for roads when the approach grade is more than 2% leads to an increase in saturation flow rate [11]. Jobair et al (2011) calculated saturation flow rate and the corresponding adjustment factors at 5 signalized intersections in Makkah, Saudi Arabia. Saturation flow rate in ideal conditions was found to be 2500 pcphpl which is significantly higher than 1900 pcphpl suggested in HCM. Also the adjustment factor for number of lanes was based on the analysis of the number of lanes and adjustment factor for lane width obtained by comparing saturation flow rate calculated on the basis of average headway for different lane width. Results showed that the saturation flow rate also falls sharply for a reduction in the number of lanes and lane width [12].

Results and analysis of data

Field data of the saturation headway and the start-up lost time in the studied inlets

The results of headway average and start-up lost time in the studied inlet paths are given in Table 1. According to the observed data, the range of saturation headway average values is between 2.03 and 2.38 seconds and the range of start time delay values is between 2.40 to 4.52.The average values of saturation headway in the studied inlets in this study are mostly from the research results of HCM 2000 (1.9 seconds) [13], Nitti Macki (less than 2 second) [14], Al-Ghamdi (1.57, 1.64) [15], and Lee Vien (1.699 second) [10]. Lewis (2006) during his doctoral thesis concluded that since the average headway changes depending on the desired location, thus a certain amount cannot be defined for the discharge headway. In this study, different values were obtained for the average headway depending on the type and environmental conditions of the intersections. The observed start-up delay values in the reviewed inlets of Rasht are mostly from the research result of Lewis (1.9 seconds) in the city of Monterrey in Mexico.

Table 1. Results of Saturation discharge headway and Start-up Delay at studied intersections

Intersection Number	Start-up Delay (s)	Saturation discharge headway (s)
1	4.52	**2.38**
2	2.62	**2.12**
3	2.59	**2.03**
4	2.54	**2.16**
5	2.40	**2.29**

According to Table 1, intersection number 1 has the maximum start-up lost time and saturation headway that one of its reason can be locating this intersection in the central business area, high volume of traffic at the studied inlet, high delay caused by improper discharge of queue due to adjust parking of taxies at the beginning of the front outlet which makes the queue discharge slow in the studied inlet. Intersection number 3 has the minimum value saturation headway that its reason is the large width of the desired outlet path and freedom of drivers for more movement.

Evaluation of headway and start-up lost time values in the studied inlet paths

Figure 1 shows the values of saturation headway in the studied inlet paths. Also, the average discharge headway values in the studied inlet paths are shown respectively in Figure 2.

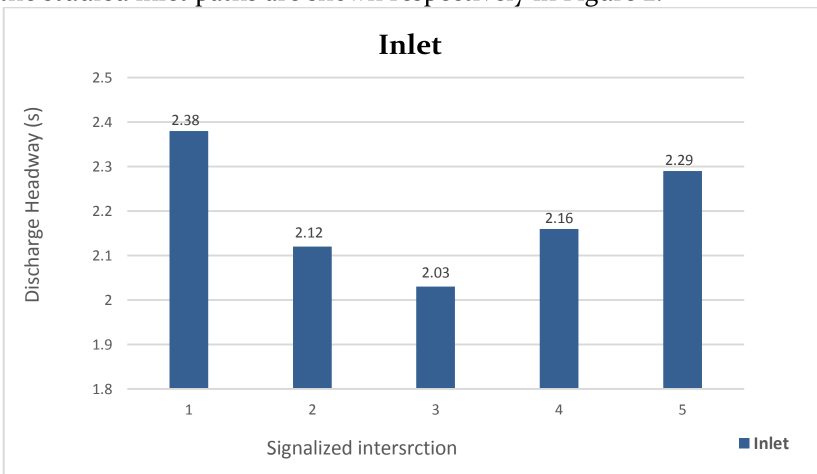

Figure 1. Saturation discharge headway value at studied intersections

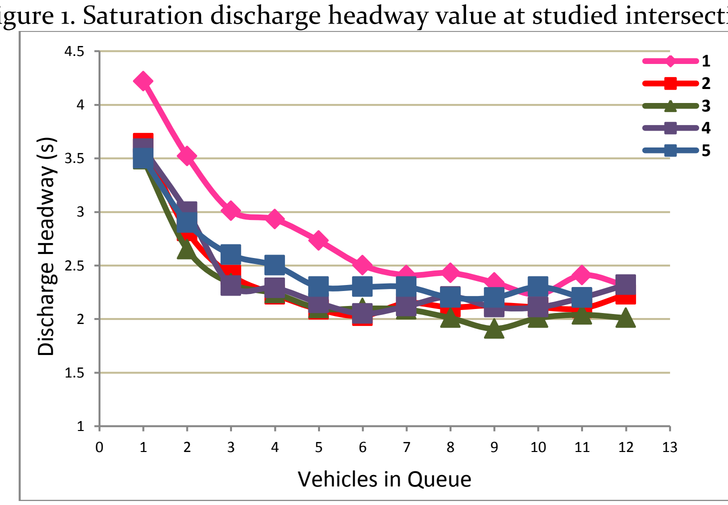

Figure 2. Start-up Delay value at studied intersections

The total results of minimum, average, and maximum of headway and start-up lost time in the studied intersections are given respectively in Table 2 and 3. According to table 2, the minimum value of the saturated headway in the studied inlets is between 1.7 to 1.94 seconds and the maximum value of saturated headway in the studied intersections is between 2.69 to 3 seconds. According to Table 3, the minimum value of start-up lost time in the studied intersections is between 1 and 4.1 seconds and the maximum value of start-up lost time is between 2.58 and 8.52 seconds. Figures (3 to 7) show the value of average discharge headway in the inlet paths.

Table 2. Saturation discharge headway value at studied intersections

Intersection Number	Min	Average	Max
1	1.90	2.38	2.88
2	1.77	2.12	2.69
3	1.70	2.03	2.74
4	1.71	2.16	2.90
5	1.94	2.29	3.00

Table 3. Start-up Delay value at studied intersections

Intersection Number	Min	Average	Max
1	4.10	4.52	8.52
2	1.04	2.62	3.23
3	1.30	2.59	6.00
4	1.17	2.54	3.40
5	1.54	2.40	2.58

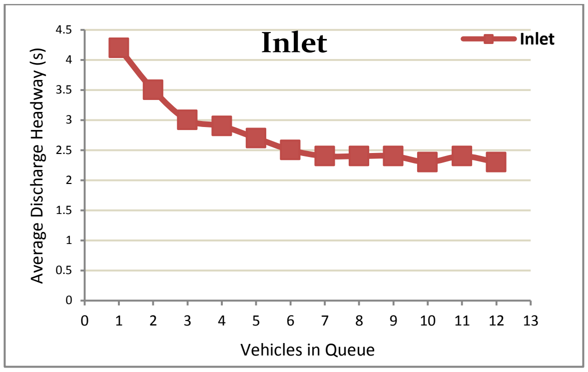

Figure 3. Average discharge headway value at studied intersections number 1.

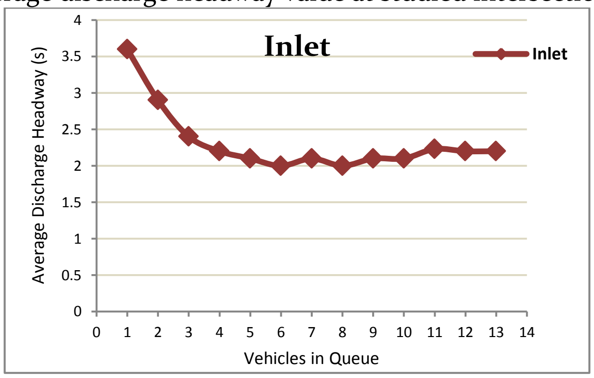

Figure 4. Average discharge headway value at studied intersections number 2.

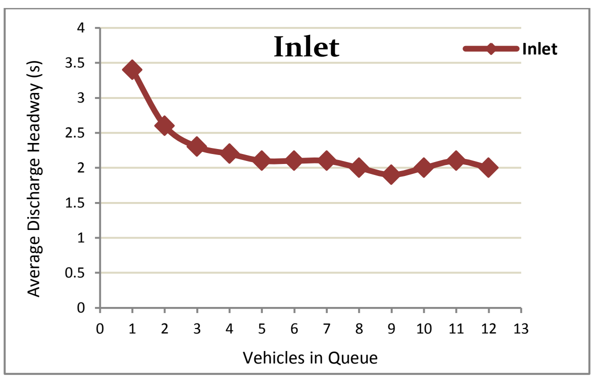

Figure 5. Average discharge headway value at studied intersections number 3.

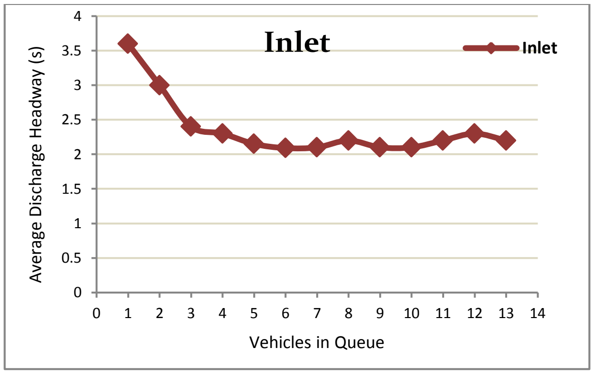

Figure 6. Average discharge headway value at studied intersections number 4.

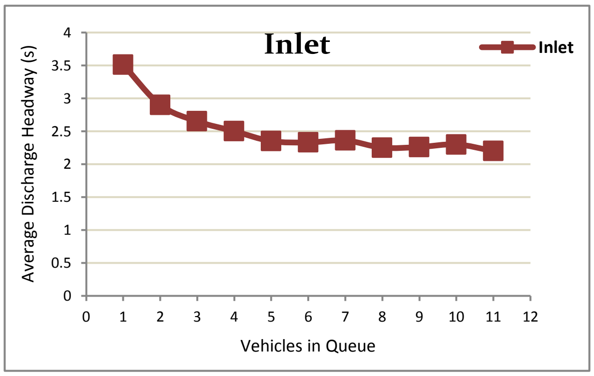

Figure 7. Average discharge headway value at studied intersections number 5.

According to the values of saturation headway and start-up lost time in the above tables and figures, it can be observed that the number of vehicles with start-up delay are in the inlet paths of 4 or 5. Thus, the start-up lost time in the inlet path obtains from the difference of the values of headway 4 or 5 for the first vehicle with the saturation headway. Also, the difference between the headway of the first vehicle with saturation headway towards the outlet is much higher than the inlet. In the outlet path, the first vehicle spends some time for passing through the interior intersection in addition to having start-up lost time in the inlet (a part of this difference is due to the required time to cross the intersection).

Conclusion

In the present study, the saturation headway and start-up lost time in the inlet paths of 5 signalized intersections in Rasht was calculated and evaluated. The results showed that the conditions of saturation occur in the inlet path between the fifth and sixth vehicles and the last vehicle in the queue. In the other words, the number of vehicles with start-up lost time is in the inlet path of 4 or 5. The range of saturation headway average values in the inlet paths is between 2.03 and 2.38 seconds. Also, the range of start time delay values in the inlet paths is between 2.40 to 4.52.

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