Computational Research Progress in Applied Science & Engineering

ISSN 2423-4591

CRPASE Vol. 04(02), 43-47, July 2018

Estimation and Comparison of the Discharge Headway at the Outlet and Inlet Legs of Signalized Intersection

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Keywords

Signalized intersection,
Startup delay,
Inlet leg,
Outlet leg,
Average discharge headway.

Abstract

The time values of the saturation flow rate in signalized intersections play a key role in their schedule and performance. So far, many studies have been conducted to estimate the average discharge headway of the inlet legs of intersection, while, its values are not the same as the outlet legs due to the number of lines, driver behavior and other physical characteristics. In the present paper, with the help of the field data acquisition at five signalized intersections in Rasht city, the values of the discharge and delay time are estimated and compared in the inlet and outlet legs of the signalized intersection. The results show that the saturation conditions occur between the second and last vehicle in the outlet legs and between the fifth or sixth vehicle in inlet legs intersection. In other words, the number of vehicles with start-up delay is 1 or 2 vehicles and 4 or 5 vehicle in the outlet and inlet legs respectively. Also, the amount of saturation headway of outlet legs is less than the inlet legs.

1. Introduction

The amount of several basic parameters of intersection performance, such as saturation and delay flow rates, are derivatives of the evacuation headway, so that the use of inaccurate values of discharge time point leads to incorrect estimation of the density, delay, and saturation flow rates.contributors.

The evacuation headway of the vehicles is defined as the elapsed time between the vehicles on the back of each other and the stop line. The first headway, is the time interval between the start of the green phase and the time of the front wheel drive of the first vehicle from the line and the second headway, is the necessary time to pass the front wheel of the first vehicle to the front wheel of the second one of the stop line, and, to the end [1].

The headway of each vehicle decreases from its front vehicle and, with the continuation of this process, it reaches a point that from this point on, the headway will remain fairly constant until all vehicles within the queue cross the intersection or the green time is over. This constant headway is called the saturated saturated headway and can occur for vehicles from third to sixth. Of course, in different sources, there is a difference between the occurrence location of the saturation headway due to different local conditions in the data acquisition [1].

The sum of the difference in saturation headway with the headways of some vehicles of the first-line, which take extra time to react to the start of the green time and increase the speed, is called the initial waste time (start delay time). According to the highway capacity manual (HCM), saturation conditions occur between the headway of the fifth vehicle and the last vehicle in-line, and the time spots of the first four vehicles begin to be used to determine the delay time. Various studies have been done about delay and saturation flow rate at the intersections [2-5] and roundabout [6, 7] of Rasht, Iran. Bargegol et al. evaluated the average discharge headway at inlet legs of signalized intersections in 2015 [8]. In this regard, in the present study, by collecting the field data from 5 signalized intersections in Rasht city, the saturation evacuation headway and the start delay time in the outlet legs have been determined and evaluated with inlet legs result.

2. Literature Review

The first study on the evacuation headway was conducted in 1947 by Greenshields et al. In this study, the effect of left turning was not considered. The amount of time headway for the sixth and higher vehicle was equal to 2.1 seconds and a starting delay time was equal to 3.6 seconds [9]. During the preparation of the second edition of HCM, data from 1100 signalized intersections were collected between 1955 and 1956 and the saturation headway was 2.4 seconds.

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Received: 10 May 2018; Accepted: 30 June 2018

In subsequent years, due to the increased vehicle efficiency, the amount of headway was decreased and in other words the saturation flow rate increased. Therefore, the amount of saturation time in HCM85 was 2 seconds and in HCM94 was proposed to be 1.9 seconds, which was also suggested in the HCM 2000, 2010, and 2016 for the same 1.9 seconds [10-14].

Al-Ghamdi in 1999, with the study of the arrival time of transit vehicles for direct traffic at the 8 signalized of the city of Riyadh, Saudi Arabia, picked up the crossing time of the vehicles from the line at two-way and three-way legs. The amount of saturation headway in the two-way paths was equal to 1.57 seconds and in the three-way paths was equal to 1.64 seconds, which was lower than the results of previous studies in other countries [15]. In 2002, Misa Nour et al. [16] determined the saturation flow at 9 signalized intersections in Yokohama town (Japan) and the city of Dhaka (Bangladesh capital), using the ANOVA for the queue of traffic in the different points of the queue and in the mean time of evacuation headway of all vehicles in the saturation flow region was estimated which was different with the results of HCM method. The results showed that the saturation headway range obtained in this study was higher than that of HCM.

In 2005, Vien et al. for the estimation of the ideal saturation flow rate based on the conditions in Malaysia, collect the saturated time information in dry weather conditions and saturated traffic flow for different latitudes at the signalized intersections. The amount of saturation headway in this study was 1.6998 s, which was less than in the HCM (1.895 s). They see it as the "fugitive" rule of drivers in Malaysia [17]. Gonzalez, during his Ph.D dissertation in 2006, reviewed three different intersections in the city of Monterrey, Mexico, pointing out that the saturated headway in Mexico was determined from the sixth vehicle of the queue. The initial wasting time was also equal to 1.9 seconds, which is different from that of Greenshields (3.7 seconds). He concluded at the end that because the amount of time averaged varies from 2.1 to 2.3 seconds depending on the location of the site, there can not be a certain amount for Mexico's evacuation headway [18].

In a cross-sectional booklet in Iran with title "Journal of 145 Planning and Budget Organization", using macroscopic method, the number of passing vehicles in each band during the time of saturation without disturbance of each phase was measured and then by matching the corresponding cultivars in different cycles, The average headway was equal to 18.2 seconds [19].

3. Data Acquisition Method

In the present study, 5 inlet paths and 5 outlet paths with saturation flow from five signalized intersections in Rasht were selected. The city is located in the northern part of Gilan province and has a population density of 4340 people per square kilometer [20, 21].

The information needed to estimate the amount of saturated evacuation headway and the time delay was started using the filming method and recording with a chronometer at the peak hour of the evening. After watching the videos taken, the shield at the front of the first queue car was considered as the reference point (the reference point) in the exit paths of the vehicles from the end of the pedestrian line and on the inlet legs because the vehicles stopped ahead of the line. In this study, in each outlet direction, the information of 18 saturated cycles and information of 11 first vehicles were queued and in each inlet leg, information of 15 saturated cycles and information of the first 12 vehicles were selected. For each location, the queues of maximum, minimum and average queues were calculated.

The data was not used if there were any conspicuous rules of conduct and vehicle interference in two successive phases. In the present study, due to the low number of heavy vehicles at the intersections, the data related of them have been eliminated. Also due to the impact of marginal park maneuvers and right-turn vehicles on the information of the near-line table, the headway information of other lines was considered.

4. Results and Data Evaluation

4.1. Field data of Saturation Headway and Initial Loss Time in the Studied Outlets

The results obtained from the average values of the headway and the initial waste time in the outlet paths studied are shown in Table 1. Also, as example, in Figure 1, the maximum, minimum and average values of the evacuation headway at the intersection No. 1 are shown. According to the obtained data, the following points are notable

- Based on the results observed at the 5 intersections, only the first vehicle has a delay and the values of the next headways of the trend are found to be roughly invariable and reach a constant value.
- For each desired outlet path, the saturated evacuation headway obtains from the average of the second cars headway to the last and the initial waste time obtains from the difference between the headway of the first vehicle and the saturation headway.
- The range of average values of saturation headway in the outlets are between 1.65 and 2.22 seconds.
- The range of starting delay time in the outlets is between 4.50 and 8.50 seconds.

Table 1. General results of saturation headway and initial wasted time values at the studied intersections

Studied Inlet		Studied Outlet		Intersection name
Saturation headway (sec)	Initial wasted time (sec)	Saturation headway (sec)	Initial wasted time (sec)	
2.38	4.52	2.22	8.50	1
2.12	2.62	1.82	4.64	2
2.03	2.59	1.65	4.50	3
2.16	2.54	1.87	5.91	4
2.29	2.4	2.18	5.34	5

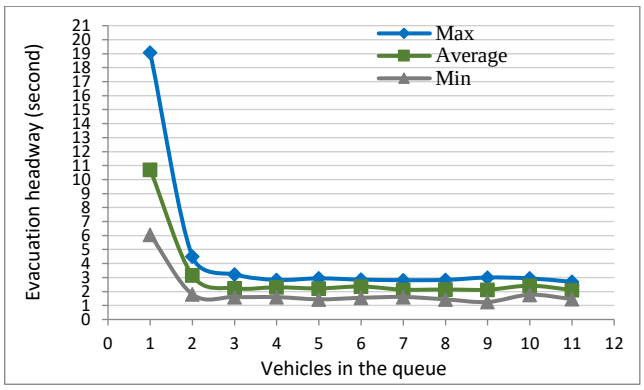

Figure 1. Maximum, minimum and average values of evacuation headway at the intersection of the outlet number 1

According to Table 1, intersection No. 1 has the maximum saturation headway and start time delay due to the fact that this intersection can be located in the central business district, the public park (especially taxies) marginal park at the studied outlet of the which causes traffic jams at the beginning of the avenue and reduces effective width. Intersection No. 3 has the minimum saturation headway and start delay time due to the wide width of the desired outlet and the greater freedom of movement for drivers.

4.2. Field Data of Saturation Headway and Initial Loss Time in the Studied Inlets

The results obtained from the average values of the headway and the initial waste time in the inlet paths studied are shown in Table 1. Also, as an example, in Figure 2, the maximum, minimum and average values of the evacuation headway at the intersection No. 1 are shown. According to the obtained data, the following points are notable:

- Based on the observed data, at intersection No. 1, 5 first vehicles and at four other intersections, similar to the results of the HCM book, the first four vehicles were delayed. The next passing vehicles have approximately the same amount of headway.
- The range of average values of the saturation headway range is between 2.03 and 2.38 seconds, and the values of the start delay time are between 2.40 and 4.52 seconds.
- The average values of the saturation headway in the inlets examined in this study were higher than the results of HCM2000 studies (1.9 seconds), Nitmaki (less than 2 seconds), Al-Ghamdi (1. 57 and 1.64), and Levine (1.699 seconds).
- In his 2006 doctoral dissertation, Lewis concluded that since the headway values varies depending on the location in question, a certain amount for the evacuation headway can not be provided. In this study, different values for the average headway were obtained depending on the type and conditions of the intersection.
- The values of the delayed start time observed in the inlets in the city of Rasht are more than the result of the study of Louis (1.9 seconds) in Monterey, Mexico. According to the table (1), intersection No. 1 has the maximum value of the delay time and the saturation headway point due to the fact that this intersection can be located in the central trading area, the traffic volume in the entrance, the high delay caused by the discharge the inappropriate queue is due to the marginal taxi park at the beginning of the outlet, which causes the queue drain in the entrance to the studied inlet. Intersection No. 3 has a minimum amount of saturation headway due to the width of the desired outlet path and the freedom of the drivers to move further.

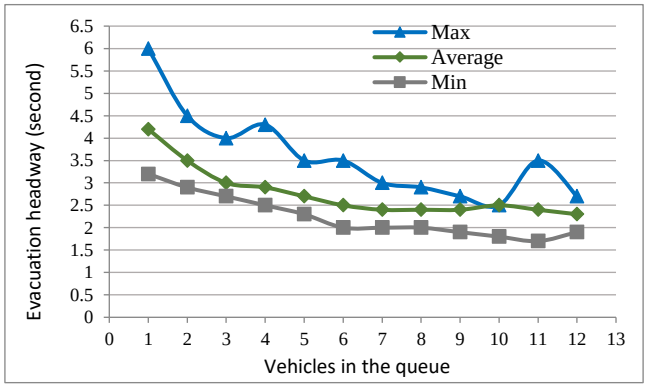

Figure 2. Maximum, minimum and average values of evacuation headway at the intersection of the inlet number 1

4.3. Evaluation and Compare of the Values of the Saturation Headway Header and the Start-up Delay Time in the Studied Inlet and Outlet Paths

According to Figure 3, which shows the average values of the saturation headway in the studied outlet and inlet legs, the values of the evacuation headway in the outlet legs are less than the values in the inlet paths.

The average values of the average evacuation headway in the outlet and inlet legs studied are shown in Figures 4 and 5, respectively

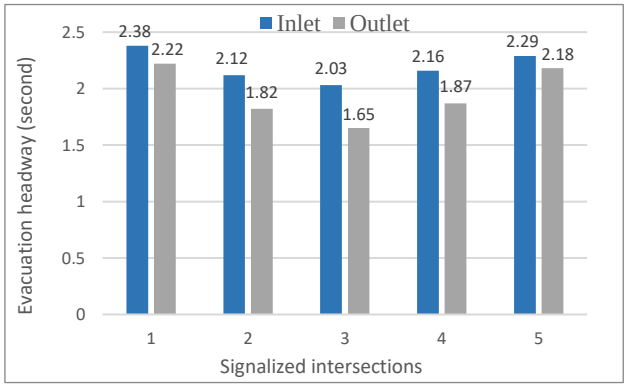

Figure 3. The average values of the saturation headway in the studied outlet and inlet legs

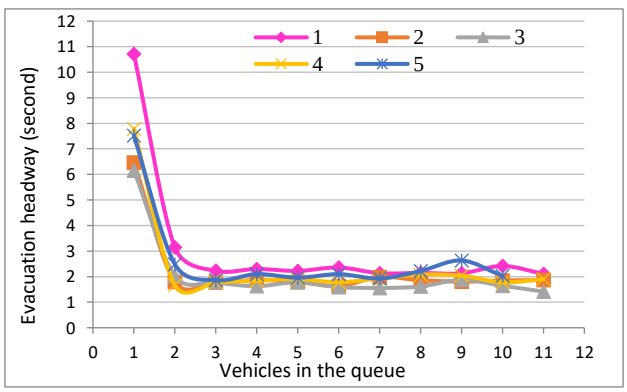

Figure 4. The average values of the average evacuation headway in the studied outlet legs

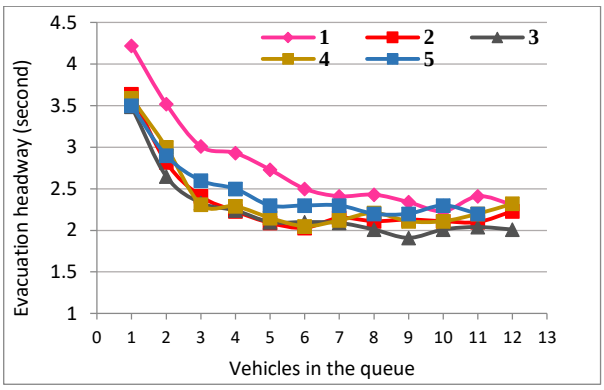

Figure 5. The average values of the evacuation headway in the studied inlet and outlet legs

The general results of the minimum, average and maximum headways and the start delay time at the intersections are presented in Tables 2 and 3, respectively. According to Table 2, in the studied outlets, the values of the minimum saturation headways range are between 1.11 and 2.33 seconds, and the maximum saturation peak time range is between 1.2 and 3.04 seconds. Also, in the inlets, the values of the minimum saturation headways range are between 1.7 and 1.94 sec and the maximum saturation headway range is between 2.69 and 3 seconds. According to Table 3, in the studied outlets, the minimum starting delay values are between 2.9 and 4.51 seconds, and the maximum delay time values are between 6.31 and 17.78 seconds. Also, in the studied inlets, the initial start delay values are between 1 and 4.1 seconds, and the values for the maximum start delay are between 2.58 and 8.52 seconds. In Figures 6 to 10, the average values of the evacuation headway are compared in the outlet and inlet legs.

Table 2. Values of saturated headways in studied intersections

Studied Inlet saturated headway (second)			Studied outlet saturated headway (second)			Intersection name
Max.	Ave.	Min.	Max.	Ave.	Min.	
2.88	2.38	1.9	2.9	2.22	1.55	1
2.69	2.12	1.77	2.54	1.82	1.11	2
2.74	2.03	1.70	1.2	1.65	2.33	3
2.9	2.16	1.71	2.62	1.87	1.22	4
3	2.29	1.94	3.04	2.18	1.53	5

Table 3. Values of start delay time in studied intersections

Studied Inlet start delay time (second)			Studied outlet start delay time (second)			Intersection name
Max.	Ave.	Min.	Max.	Ave.	Min.	
8.52	4.52	4.1	7.78	8.50	4.51	1
3.23	2.62	1.04	6.31	4.64	2.9	2
6	2.59	1.3	7.26	4.50	3.31	3
3.4	2.54	1.17	6.83	5.91	4.19	4
2.58	2.4	1.54	8.42	5.34	3.03	5

Due to the amount of saturation headway and start delay time in the table and diagrams above, the number of vehicles with start delay in the outplet path is one device and in the inlet path of 4 or 5 devices. Therefore, the amount of start-up delay in the outlet leg is obtained from the difference between the time of the first vehicle and the amount of saturation headway and on the inlet path from the sum of the differences between the values of the time interval of 4 or 5 of the first vehicle with the amount of saturation headway. In other words, on the outlet path, the number of vehicles with a lower start delay and the start delay time is greater than or equal to the values of the inlet path.

The difference between the amount of headway of the first vehicle with the saturation headway on the exit side is much higher than the entry side. In the outlet path of the first device, in addition to having the delay time on the inlet side, it takes some time to pass through the internal space of the intersection (part of this difference due to the time it takes to cross the intersection). Saturation headway at the exit path is lower than the corresponding values at the internal space of the intersection, which leads to an increase in the saturation flow rate as well as the throughput capacity of the outlet.

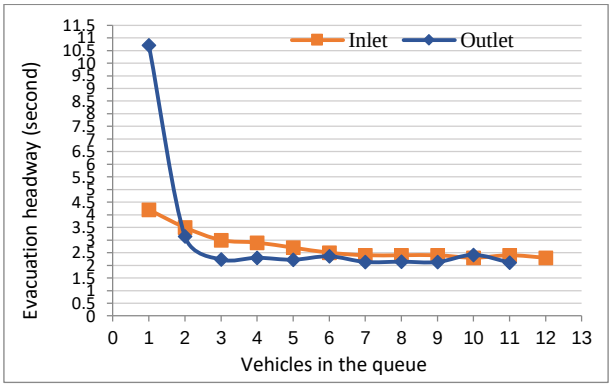

Figure 6. The average values of the evacuation headway in the studied inlet and outlet at the intersection number 1

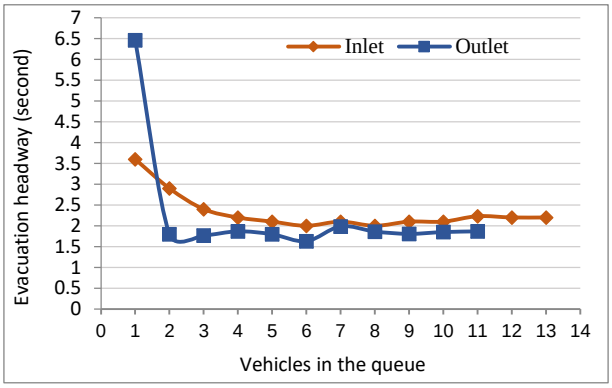

Figure 7. The average values of the evacuation headway in the studied inlet and outlet at the intersection number 2

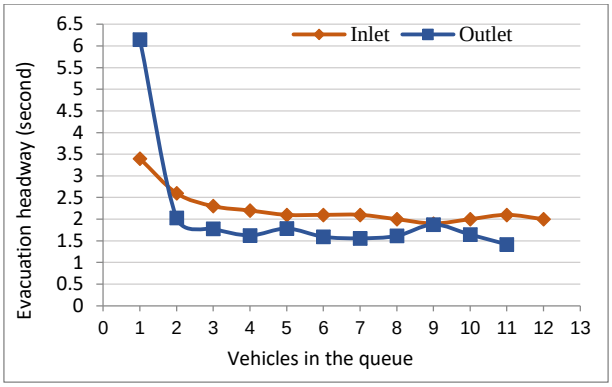

Figure 8. The average values of the evacuation headway in the studied inlet and outlet at the intersection number 3

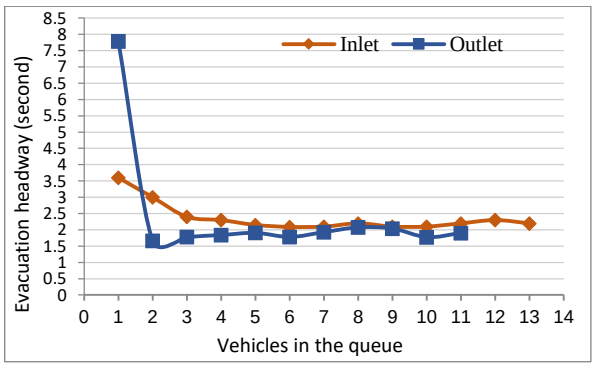

Figure 9. The average values of the evacuation headway in the studied inlet and outlet at the intersection number 4

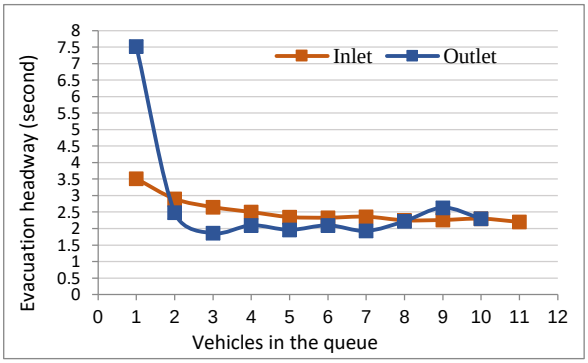

Figure 10. The average values of the evacuation headway in the studied inlet and outlet at the intersection number 5

5. Conclusion

In the present study, the saturation headway and start delay time at the entrance and outlet legs of the 5 signalized intersections of Rasht city have been calculated and evaluated. The main results of this study are as follows

- Evacuation headway of vehicles on outlet legs, after a maximum of two vehicles, have a constant value, while in the inlet legs this uniformity can be seen in the fifth or sixth vehicle.
- The values of the saturation headway and the initial waste time in the inbound and outbound paths of the CBD and the intersections located in city's other parts are different.
- The average values of the saturation headway of the outlet legs are less than that of the inlet ones. The range of average amounts of the saturation headway range in the outlet paths is between 1.65 to 2.22 s and the range in the desired inlet paths is between 2.03 to 2.38 s.
- The delay times for the outlet paths are greater than that of inlet paths, so that the range of average values of the delay time for the studied outlet legs is between 4.50 to 8.50 seconds and the range in the desired inlet paths is between 2.40 up to 8.52 s and its values in the outlet legs are also a function of intersection dimensions.

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