Estimating Base Saturation Flow Rate for Selected Signalized Intersections in Al-Najaf City

Ulla G. Al-Mosawi[1,a *] and Hamid A. Al-jameel[1,b]

[1]Civil Engineering Department, University of Kufa, Najaf, Iraq.

[a]ullaalmosawi@gmail.com, [b]hamid.aljameel@uokufa.edu.iq

*Corresponding Author

Abstract. The correct saturation flow rates for the specific circumstances must be used to calculate delays and the level of Service at intersections. As a result of a lack of local data, practitioners would often use default values from overseas software developers. Base saturation flow rate is an important factor for timing traffic signals. Despite the 1,900 pc/h/ln number suggested by the Highway Capacity Manual (HCM), the base saturation flow rate differs from city to city, dependent on the local driving habits and traffic conditions. As a result, it's crucial to estimate, given the local climate. As a result, erroneous decisions may be made that have incorrect results. This study attempts to estimate the base saturation flow rate in Al-Najaf City. The following situations were observed: Turning movement (through or right); Gradient (Up and down); Number of through lanes; and Speed limit (60 and 80 km/h). The mean headway from a total of 9931 through moving vehicles from 187 lineups was calculated to be 1.55. The basic saturation flow rate was therefore determined to be 2,323 pc/h/ln. This result is substantially higher than the 1,900 pc/h/ln proposed by the HCM, but it is comparable to results from other nations with similar traffic conditions and driving habits. The results show significant differences between the saturation flow rates when the conditions of the movements are different in terms of the above characteristics. Recommendations are made regarding the most appropriate values to use under different conditions.

Keywords: Al-Najaf city, base saturation flow rate, signalized intersections.

1. INTRODUCTION

Although the definitions of saturation flow are consistent in the reference material that is currently accessible, the technique for measuring saturation flow on location is occasionally inconsistent and ambiguous. The crucial details needed for acquiring and comprehending saturation flows are provided in this fact sheet and the engineering judgment necessary for on-site measurement and subsequent calibration of saturation flows [1]. Although this is meant to be a best practice guide, the modeler may decide to apply engineering judgment and the reference materials that are currently accessible for identifying appropriate saturation flows for modeling and analysis purposes. In traffic modeling, saturation flow serves as a crucial calibration and validation parameter. Saturation flows substantially impact networks' capacity, delay queues and saturation level [2,3]. The accuracy of the models is crucial to assess the impact on the road network if applied on-site when traffic modeling is used to aid in the design of new intersections or modify existing intersections. For modeling purposes, it is crucial to measure saturation flow precisely. It helps modelers and surveyors get consistently correct data for input of models used for calibration or validation. The Saturation Flow Information document has been created. This study attempts to estimate the base saturation flow rate in Al-Najaf City. The average saturation headway was measured to be 1.55 seconds; therefore, the corresponding base saturation flow rate was found to be 2,323 pc/h/ln. This is higher than the 1,900 pc/h/ln suggested by the HCM. It includes examples of the standards for Main Roads and describes how saturation flow should be assessed on the spot A crucial element in traffic modeling is the lane saturation flow, and the accuracy of these flows has a big impact on the model's output.

Saturation flow rates have been the subject of numerous research around the globe, although they were all carried out under typical conditions [4-6]. Figure 1 lists some of the older investigations, the locations where they were done, the mean saturation flow discovered, and the number of participants in each study. The Texas Transportation Institute just finished significant research [7]. This study examined the impact of heavy vehicles, the posted speed limit, the volume of traffic, the local population, and the number of approach lanes in relation to the saturation flow rate. They discovered that the base rate (or saturation flow rate) under ideal circumstances is 1905 pc/h/ln, that a one mph reduction in the speed limit will cause a nine pc/h/ln decrease, and that an approach using the saturation flow rate of a system with two through lanes will be 130 pc/h/ln higher than that of an approach with one through lane. Bester and Meyers studied the saturation flow rate for through traffic at six signalized intersections in Stellenbosch, South Africa [8]. The reported saturation flow rates ranged from 1,711 to 2,370 (with an average of 2,076) pc/h/ln. The study concluded that these values are much higher than in other countries, which could indicate the aggressiveness of local drivers.

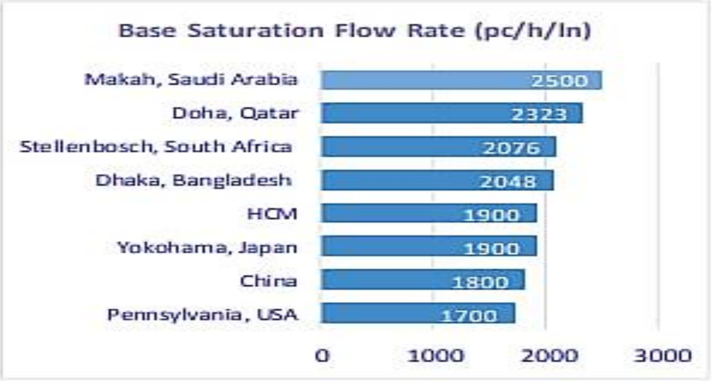

Figure 1: Previous studies saturation flow rates [9].

2. DEFINITION OF SATURATION FLOW AND METHODOLOGY

Saturation flow is defined as the most significant flow that can be discharged from a traffic lane when there is a continuous green indicator and a continuous queue on the approach. It expresses a lane's maximum capacity and can be influenced by factors such as road layout, topography, visibility, and vehicle classes, such as heavy vehicles. The basic traffic signal capacity model, depicted in Figure 1, assumes that when the signal changes to green, the flow across the stop line increases swiftly to a rate known as the saturation flow, which remains constant [10]. Continuous until the wait is full or the green window closes. Figure 2 shows a rectangle model of saturation flow rate shows an idealized depiction of saturation flow at a signalized junction:

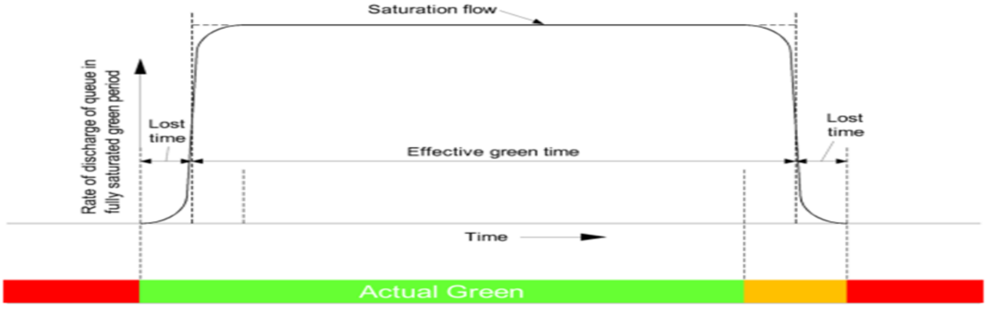

Figure 2: Typical traffic signal capacity model [11].

LinSig and SIDRA used saturation flow for calibration, Vissim and Aimsun used saturation flow for validation, and LinSig and SIDRA used it for calibration. The throughput of any technique is significantly impacted by the saturation flow predicted at signalized stop lines. The stop line saturation flow on-site may be influenced by a number of variables, all of which must be accurately simulated in the model. These elements consist of:

a) Geometry
b) Gradient
c) Visibility
d) Gap acceptance for turning traffic
e) Lane width
f) Downstream blocking.

The saturation flow is calculated for each sample using the following formula [10]:

$$\text{Saturation flow} = \frac{\text{pcu or veh}}{\text{time(s)}} * 3600 \quad (1)$$

$$s = \frac{3600}{h} \quad (2)$$

where:
s = saturation flow rate (vehicle/hour)
h = Saturation headway (second)

The saturation headway is the average headway (time gap) between vehicles occurring after the fourth or fifth vehicle in the queue and continuing until the last vehicle in the initial queue clears the intersection [10]. The saturation flow for each sample should be calculated. Outliers or measurements that do not meet the requirements are to be eliminated. The saturation flow values for the remaining valid measurements are to be averaged, representing the saturation flow for the lane. It is acknowledged that measuring saturation flows for all lanes on site can be time-consuming/costly, but it is essential to the quality of modeled outputs. It is not always possible to measure saturation flow on-site due to congested traffic conditions during peak periods, exit-blocking, low demand during off-peak periods, or insufficient green time due to network operational strategies or capacity issues.

2.1 Measurement of Similar Intersection

If it is impossible to measure saturation flow at an intersection at any time, then an alternative is to take measurements from a similar intersection. This may be a neighboring intersection with similar geometry, signal timings, and traffic volumes. The use of this method must be detailed in the modeling report.

2.2 Calculated from SIDRA Program

Where measurement of saturation flow is not possible for base cases or for proposed intersections, saturation flows can be estimated based on the site geometry and lane usage. Modelers must consider if the Sidra saturation flow values represent the driving behavior at the modeled intersection by comparing the calculated saturation flow with available site-measured values. If the average of the site values is found to be more than 4% different from the SIDRA values, the modeler must apply a local site factor to the SIDRA-calculated lanes.

3. BACKGROUND

Start-up lost time and saturation headway to determine accurate saturation flow rates; start-up lost time needs to be understood and considered. The principle of start-up lost time can be described as follows [12]: When the signal at an intersection turns green, the vehicles in the queue will start crossing the intersection. The vehicle headways can now be described as the time elapsed between successive vehicles crossing the stop line. The first headway will be the time taken until the first vehicle's rear wheels cross the stop line. The second headway will be the time taken between the crossing of the first vehicle's rear wheels and the crossing of the second vehicle's rear wheels over the stop line. The first driver in the queue needs to observe and react to the signal change at the start of green time.

After the observation, the driver accelerates through the intersection from a stand-still, resulting in a relatively long first headway. The second driver performs the same process except that the driver could react and accelerate while the first vehicle begins moving. This results in a shorter headway than the first because the driver had an extra vehicle length to accelerate. This process carries through with all following vehicles, where each vehicle's headway will be slightly shorter than the preceding vehicle. This continues until a certain number of vehicles have crossed the intersection, and start-up reaction and acceleration no longer affect the headways. From this point, headways will remain relatively constant until all vehicles in the queue have crossed the intersection or green time has ended. This constant headway is known as the saturation headway and can start to occur anywhere between the third and sixth vehicles in the queue. Figure 2 illustrates the situation described above.

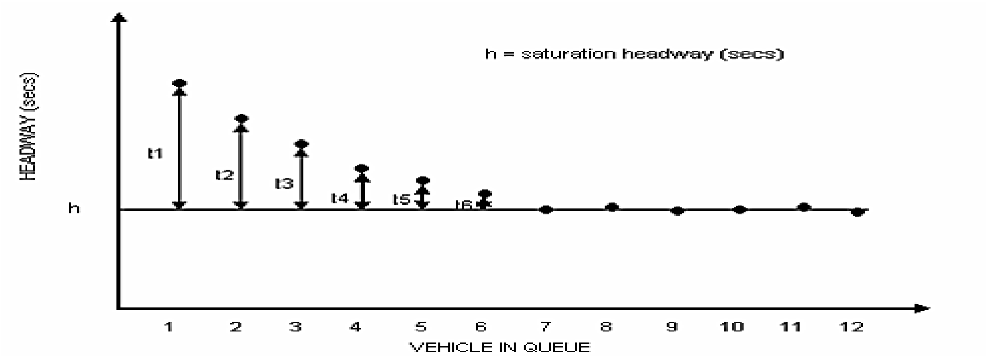

Figure 3: Headways at a traffic interruption [12].

To calculate the saturation headway from the above example in Figure 2, the following equation will be used [13]:

$$h_s = \frac{\sum_{j=n}^{i} hj}{(i+1-n)} = \frac{(h_7+h_8+h_9+h_{11}+h_{12})}{(12+10-7)} \quad (3)$$

hs = saturation headway, s
hj = discharge headway of jth queued vehicle, s
n = position of the queued vehicle from where the saturation flow region started
l = last queued vehicle position

This saturation headway (hs) can be used to determine the maximum number of vehicles that can be released during a specified green time and the saturation flow rate, s = 3600/hs. The saturation flow rate (s) is an important parameter for estimating the performance of vehicular movement at signalized intersections. The saturation flow rate for a lane group is a direct function of vehicle speed and separation distance. The established concept for the determination of capacity demands the concept of saturation flow [14].

4. Data Collection

Intersections were surveyed for this study. Identifying and observing intersections that represented the conditions described above was important. The following criteria were also taken into account for selecting intersections:

- The gradient for normal intersections should be as flat as possible;
- Standard lane widths of 3.7 m should be available;
- The queues of through traffic should be long enough to facilitate the observation of saturation flow rates;
- No parking or bus stops should be near the intersections;
- Low volumes of non-motorized vehicles and low volumes of heavy vehicles should be present. These criteria selected the following intersections for observation: 60 km/h, flat gradient. To measure the saturation flow rate at signalized intersection, one signalized intersection in Al-Najaf City was selected. Figure 3 shows the location of the study sites.

Figure 4: Aerial image from the Maps app of the Al–Salam intersection.

Especially at peak times, there are lengthy lines at some intersections. Over April and May 2023, all data were gathered during weekday peak times. To collect traffic statistics, video surveillance recorded all turning maneuvers, including left, though, and right turns. In a perfect world, the camera would be positioned to show the viewer the beginning and finish of each phase, the end of the line for each lane, and the lane's stop line. Figure 4 shows a screenshot from a video recording near the Al-Salam intersection. It's assumed that the end of the line would occur in a few instances where it was hard to observe it when there was a significant pause (greater than 2 seconds) between two sequential vehicles.

Table 1 shows the sample size from the selected intersection. The total number of queues considered from the selected intersection combined was 187, and the total number of vehicles used was 9,931.

Table 1: Chosen intersection and data collected

Approach	South	West	East	North	Total
No. Queues	49	54	38	46	187
No. Vehicles	2559	2405	2378	2589	9931

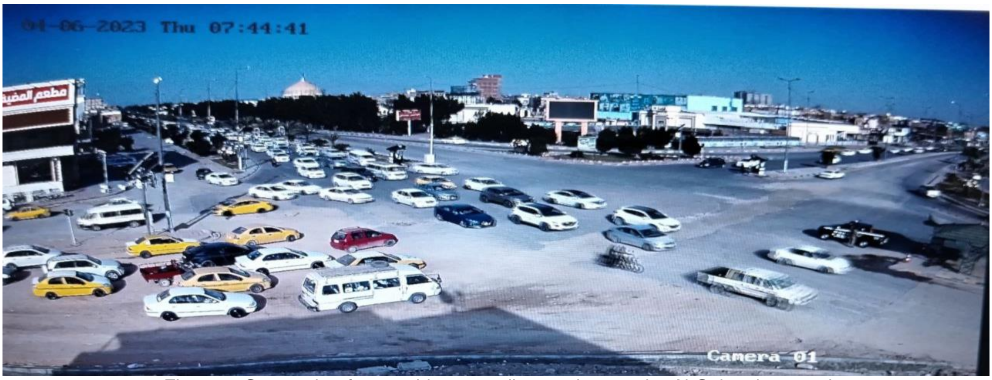

Figure 5: Screenshot from a video recording made near the Al-Salam intersection.

5. RESULTS

The results of the study are given in Tables 2 and 3. The general statistics are shown in Table 2, and the results relative to the specific conditions are shown in Table 3. The HCM has recommended the saturation flow rate. Still, it also advises that local traffic patterns and driver behavior should be evaluated because they impact how much capacity a signalized intersection has. Since it directly impacts signal timing, its precise determination for a given location is crucial to the design of signal timing.

The base saturation flow rate in Al-Najaf City was calculated in this study. Data gathered from One separate signalized junction was used to achieve this. The mean headway from a total of 9931 through moving vehicles from 187 lineups was calculated to be 1.55. The basic saturation flow rate was therefore determined to be 2,323 pc/h/ln. This result is substantially higher than the 1,900 pc/h/ln proposed by the HCM, but it is comparable to results from other nations with similar traffic conditions and driving habits. To compute the base saturation flow rate, the average discharge headway of 1.55 seconds for all intersections and Eq. (2) was used as follows:

$$s^0 = \frac{3600}{1.55} = 2{,}323 \text{ pc/h/ln} \quad (4)$$

Table 2: Degree of saturation for Al-Salam intersection.

	Approaches				Intersection
	South	East	North	West	
Degree of Saturation	3.55	3.61	3.66	3.66	3.66

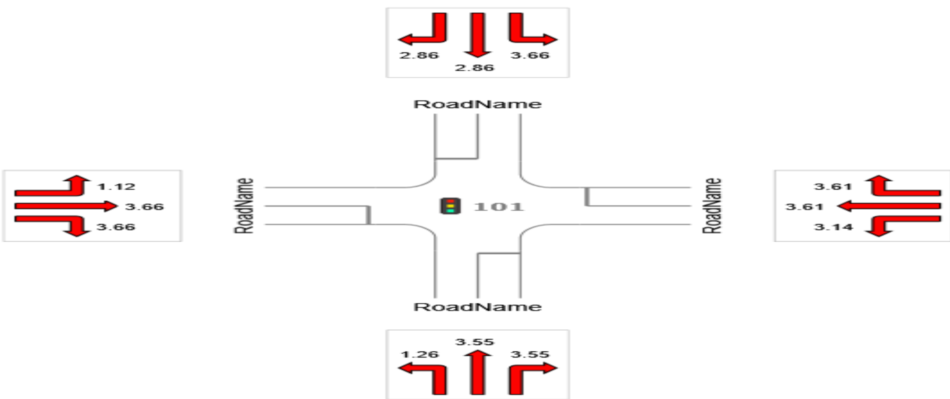

Figure 6: Degree of Saturation for Al-Salam intersection.

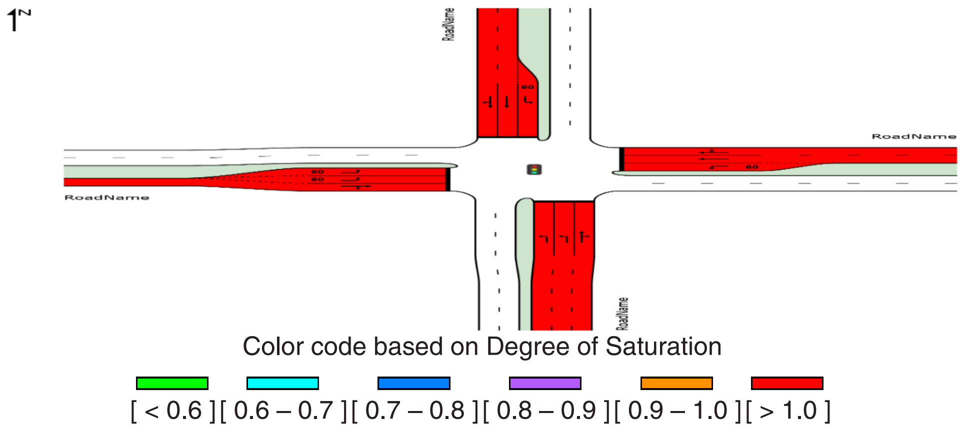

Figure 7: Degree of saturation by SIDRA program.

7. CONCLUSIONS

The HCM has recommended the saturation flow rate. Still, it also advises that local traffic patterns and driver behavior should be evaluated because they impact how much capacity a signalized intersection has. Since it directly impacts signal timing, its precise determination for a given location is crucial to the design of signal timing. The base saturation flow rate in Al-Najaf City was calculated in this study. Data gathered from one separate signalized junction was used to achieve this. The mean headway from a total of 9931 through moving vehicles from 86 lineups was calculated to be 1.55.

The basic saturation flow rate was therefore determined to be 2,323 pc/h/ln. Although this finding is somewhat higher than the 1,900 pc/h/ln predicted by the HCM, it is comparable to those from nations with comparable traffic and driving habits.

The findings of this study will aid regional engineers in providing a more accurate assessment of the capacity at signalized crossings. Road users will eventually profit from this since there will be less wait time at traffic lights, enabling them to get there faster. The results of this study, however, came from examining just one particular signalized crossing in Al-Najaf City. These findings may need to be confirmed using a larger sample size before being generalized.

REFERENCES

[1] Han C, Luk J. Guide to traffic management part 3: traffic studies and analysis. 2013 Apr.
[2] Shao CQ, Rong J, Liu XM. Study on the saturation flow rate and its influence factors at signalized intersections in China. Procedia-Social and Behavioral Sciences. 2011 Jan 1;16:504-14.
[3] Akçelik R, Besley M, Roper R. Fundamental relationships for traffic flows at signalised intersections. Sep. ARRB Research Report ARR340, Melbourne, Australia 1999.
[4] Mukwaya R, Mwesige G. Saturation flow rate for through-traffic at signalized junctions in Kampala. In Second International Conference on Advances in Engineering and Technology 2012.
[5] Bester CJ, Varndell PJ. The effect of a leading green phase on the start-up lost time of opposing vehicles. SATC 2002. 2002.
[6] Bonneson J, Nevers B, Zegeer J, Nguyen T, Fong T. Guidelines for quantifying the influence of Area Type and other factors on Saturation flow rate. Texas Transportation Institute, College Station, TX. 2005 Jun.
[7] Zimmerman KH, Bonneson JA. In-service evaluation of a detection-control system for high-speed signalized intersections. 2005 Aug (No. FHWA/TX-05/5-4022-01-1).
[8] Dey PP, Nandal S, Kalyan R. Queue discharge characteristics at signalised intersections under mixed traffic conditions. European Transport. 2013 Dec;55(7):1-2.
[9] Manual HC. Highway capacity manual. Washington, DC. 2000;2(1).
[10] Highway Capacity Manual, Transportation Research Board of the National Academies, Washington D.C., 2010.
[11] Turner J, Harahap G. Simplified saturation flow data collection methods. In CODATU VI Conference on the Development and Planning of Urban Transport, Tunis, February 1993 Feb.
[12] Bester CJ, Varndell PJ. The effect of a leading green phase on the start-up lost time of opposing vehicles. SATC 2002. 2002.
[13] Kimber RM, Hounsell NB, McDonald M. The prediction of saturation flows for single road junctions controlled by traffic signals. United Kingdom, 1986.

[14] Dey PP, Nandal S, Kalyan R. Queue discharge characteristics at signalised intersections under mixed traffic conditions. European Transport. 2013 Dec;55(7):1-2.