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Estimation of Saturation Flow Rate at Multi-Lane Intersection- A Case Study of Hyderabad

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ABSTRACT

The urbanization take place faster rate in India, the control the traffic with increasing vehicles is challenging task for traffic engineering. The installation of traffic signals involves the capacity of the signalized junction. It can be estimated in two ways such as allocation of green time and the saturation flow rate. Allocation of green time estimated based on the demand, lane and phase configuration. The effective and safe movement of vehicles at signalized intersection mainly depends on the road network, capacity of intersection, proper design and operation, saturation flow rate of a signalized intersection. The saturation flow rate depends on the locality, traffic intensity and drivers characteristics. The saturation flow rate is the most important parameter to estimate the capacity of a signalized intersection. This study is focused to determine the saturation flow rate for the multi-lane intersection at L.B nagar, Uppal Ring Road, and Tarnaka. The study revealed the maximum flow rate are occurs at particular location during the green time interval per lane at Uppal Ring Roads is higher than the Tarnaka and L.B. nagar, and also concluded the effecting parameter at particular location.

Keywords: Saturation Flow Rate, Multi-Lane Intersection, Speed, Heavy Vehicle, Traffic.

I. INTRODUCTION

The provision of safe and economical transportation while reducing the travel time of the road users an important and essential role of the traffic engineering. But the increase population and faster urbanization, the movement of vehicles are reduced at intersection. The many of the intersection are design to poor signals (traffic allow), insufficient green time, un-satisfied the drivers behavior, the estimated of poor saturation flow rate, traffic design parameter are influence. The saturation flow rate is defined as the number of vehicles crossing the roads during the green signal time. The practically not possible to measure the saturation flow rate remained the green time, because the signal does not usually green more than one minutes. The units of saturation flow rate are vehicle per hour of green or vehicle per hour of green per lane.

India is developing country, the urbanization are task place along with growing vehicles. The roads traffic of urban roads are in general and road traffic in particular is very high and the vehicles as to share the same roads without any

segregation. The despite having the lane marking, and lane discipline are not followed in developing country. To control the traffic at intersection the lane discipline and the queen of the vehicles, the appropriate gap between the vehicles, lane base traffic and the overtaking during the saturation at intersection are affect the traffic flow at the intersection. These parameters are significantly effluence the design of signalized intersection and signal plan.

II. LITERATURE REVIEW

The many of the field study are conducted and the traffic data is analyzed, the saturations flow rate of vehicles in urban are at various intersection are reported. Few of the study were discussed in this paper.

An attempt is made to estimate the base saturation at various intersections, and the factors affecting the saturation flow at intersection. The study were adopted at three different intersections, the maximum saturation is noted as 2323 vh/h/la. The author concluded that the obtained traffic flow is slightly higher than the HCM manual for the city of Doha, Qatar [1]. The study is conducted to determine the saturation flow rate under heterogeneous traffic condition. The saturation flow rate estimated at ground scenario under the mixed traffic condition, the concluded flow rate compared with the HCM 2010 and IRC:SP:41-1994 [2]. The capacity of signalized intersection was estimated under two categories, the obtained saturation flow was compared with the actual saturation flow rate equation (highway capacity manual 2000). The this study conclude that the field saturation flow rate of two signalized intersection are 1579 and 1470 vphgpl and the operational traffic flow in between 1470 to 1774 vphgpl [3]. The study is conducted to analyze the saturation flow rate at mixed traffic condition with traffic volume and speed data. The study was revealed that the certain urban intersection are handling the over saturation flow rate [4]. The study is attempted to estimate the saturation flow rate of three city with the help of t-test. The measured saturation headway of the city was compared with the HCM. The saturation headway of the city was analyzed with an empirical-based exponential model with limiting input parameters to estimate the actual saturation flow rate [5]. The field study is performed to know the base saturation flow ate at signalized intersection, the base saturation flow rate is suggested the 1800 per hour per lane. The study concluded that the lane width, turning radius and effective left-turn effect on the saturation and suggested the correction factors [6]. This paper presents the parameter affecting the saturation flow rate at three intersections, and the capacity of traffic at same location. The relations between the parameters are presented along with discussion.

III. FACTORS AFFECTING SATURATION FLOW RATE AT INTERSECTION

During the data collection the following are the factors are observed at serious of intersection approach to study site. The finally the data were collected at each intersection. The obtained data form the field enters in to the saturation flow rate equation. The following are the factors affect the base saturation flow rate at intersection.

1. Right turns,
2. Number of lanes,
3. Area population,

4. Traffic pressure,
5. Heavy vehicles, and
6. Speed limit.

3.1 Data Collection

The data was collected at four intersections to estimate the base saturation flow rate. These intersections were selected because they offered a wide range of population densities. The selection of suitable study sites was based on consideration of a range of criteria. The criteria used include: approach configuration, area population, number of study sites, traffic volume, and intersection geometry. The field study is conducted to estimate the saturation flow rate at three intersections in summer season of 2013 year. They are intended to:

- Ensure that the database contains intersection approaches that are typical to Hyderabad conditions and
- Minimize extraneous factors that may influence saturation flow rate but which are beyond the scope of this research (e.g., pedestrian effects)

1. Intersection 1 (L.B NAGAR)
2. Intersection 2 (NAGOLE)
3. Intersection 3 (UPPAL)
4. Intersection 4 (TARNAKA)

3.2 Approach Configuration

As the table indicates, approaches, with one, two, and three through lanes were sought during the site selection process. In recognition of this limitation, the study of approach configuration focused on the three through lanes and did not include the exclusive right-turn lane. In contrast, both the through and the exclusive right-turn lanes were studied simultaneously during the study of approach configurations 3 and 4.

Table.1 Range of approach configurations considered for field study.

No	Approach Configuration	Area Population (1000)					Mini AADT, veh/d/in
		<5	5 to 50	50 to 200	200 to 500	>500	
1	LB NAGAR	NA	U	U	U	NA	4000
2	NAGOLE	NA	U	U	U	NA	3200
3	UPPAL	NA	NA	U	U	U	4100
4	TARNAKA	NA	NA	U	U	U	3200

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IV. RESULTS AND DISCUSSION

The following equation for computing the saturation flow rate for a lane group:

$$s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{LPB} f_{RPb}$$

Where

S = saturation flow rate for the subject lane group, expressed as a total for all lanes in the lane group, veh/h;

S_O = base saturation flow rate per lane, pc/h/ln (i.e., passenger cars/hour/lane);

N = number of lanes in lane group;

f_w = adjustment factor for lane width;

f_{HV} = adjustment factor for heavy vehicles in traffic stream;

f_g = adjustment factor for approach grade;

f_p = adjustment factors for existence of a parking lane and parking activity adjustment to lane group;

f_{bb} = adjustment factor for blocking effect of local buses that stop within intersection area;

f_a = adjustment factor for area type;

f_{LU} = adjustment factor for lane utilization;

f_{LT} = adjustment factor for left turns in lane group;

f_{RT} = adjustment factor for right turns in lane group;

f_{Lpb} = pedestrian adjustment factor for left-turn movements; and

f_{Rpb} = pedestrian adjustment factor for right-turn movements.

The default base saturation flow rate offered is 1900 pc/h/ln. For each adjustment factor, the HCM provide a table of values or an equation that can be used to determine the value of the adjustment factor.

4.1 Effect of Right-Turn Maneuver on Saturation Flow Rate

The effect of right-turn radius on saturation flow rate is reported in several research and engineering reference documents. The general trend is one of increasing saturation flow rate with right-turn radius. This relationship is shown in Figure 2.1 in terms of the adjustment factor for right turns (f_{RT}). For a 20-ft radius, values for the adjustment factor vary from 0.70 to 0.85.for a 60-ft radius, the adjustment factors vary from 0.85 to 1.00. It appears to underestimate the effect of radius for sharp radii and overestimate the effect for flat radii. When there are no right turns in the shared lane, a right-turn adjustment factor of 1.0 is obtained. In contrast, when there are 100 percent right turns in the shared lane, it acts as a defector right-turn lane and an adjustment factor of 0.84 to 0.85 is obtained.

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4.2 Relation Between Area Type and Saturation Flow Rate

This includes an adjustment factor for "area type" to account for the relative in efficiency of intersection in business districts, relative to those in either area. It is appropriate for use at intersection in a central business district; intersection geometry, pedestrian flow, and road side friction are more restrictive. The adjustment factor recommended for these conditions is 0.90. The relationship between saturation flow rate and area type. The findings from these efforts are summarized in Table 2.

Table.2 Relationship between area type and saturation flow rate

Reference	Adjustment Factors Categorized By Area Type		
	Central Business District	Outlying Commercial District	Residential Area
HCM	0.90	1.00	1.00
Le et al.	NA	1.00	1.03
Zegeer	0.99	1.00	1.01
Agent &	0.97	1.00	1.00

4.3 Effect Of Number of Lanes on Saturation Flow Rate

Examined the effect of number of lanes on saturation flow rate, they studied the through movements on four approaches to each of 4 intersections. Saturation flow data were measured for each of 2901 signal cycles. They found that the saturation flow rate of through movements on three-lane approaches was 1910 pc/h/ln. That for two-lane approaches was 1790 pc/h/ln and that for one-through-lane approaches was 1670 pc/h/ln. Figure 1 illustrates the value of the adjustment factor for number of lanes based on the saturation flow rates reported by McMahon data. The adjustment factors shown were derived using a base saturation flow rate of 1800 pc/h/ln

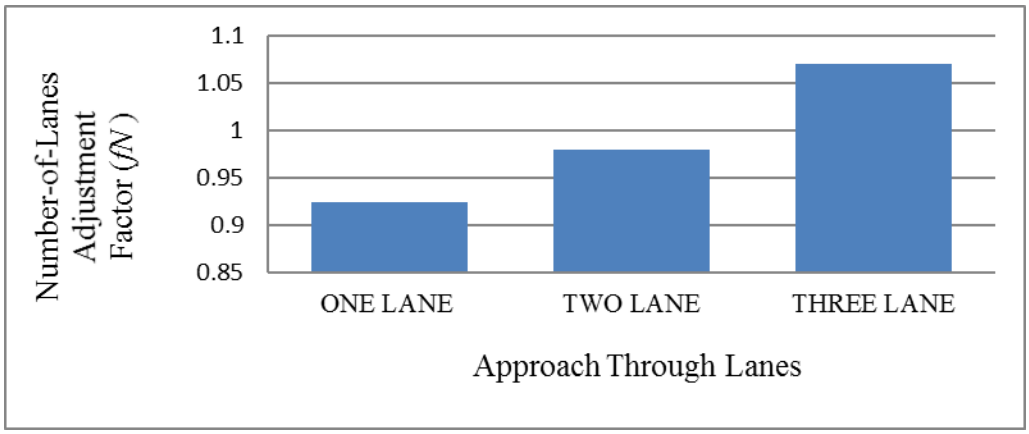

Figure 1 Effect of number of lanes on saturation flow rate.

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4.4 Relationship Between Area Population And Saturation Flow Rate

The relationship between area population and saturation flow rate, as recommended by these researchers, is shown in Figure.2. The shape of the trend line suggests that saturation flow rate is highly sensitive to population in areas with population less than 100,000. For area populations above 500,000, the effect of population appears to be negligible.

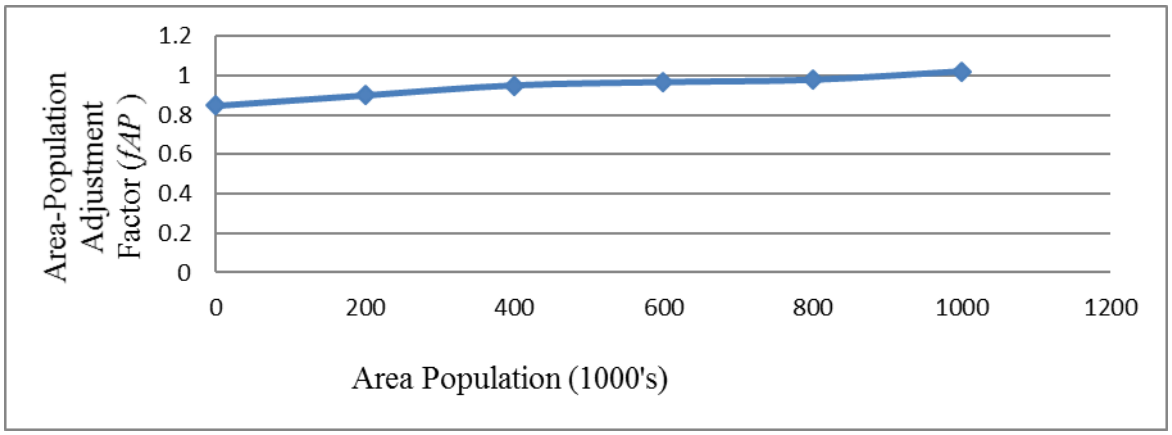

Figure.2 Relationship between area population and saturation flow rate.

4.5 Effect of Traffic Pressure on Saturation Flow Rate

In a study of saturation flow rate at high-type intersections and interchanges, Bonneson found that the number of vehicles in queue had an effect on saturation flow rate. In Figure 3, the trend line indicates that intersection approaches with relatively low volume will have a low saturation flow rate and those with high volume will have a high saturation flow rate.

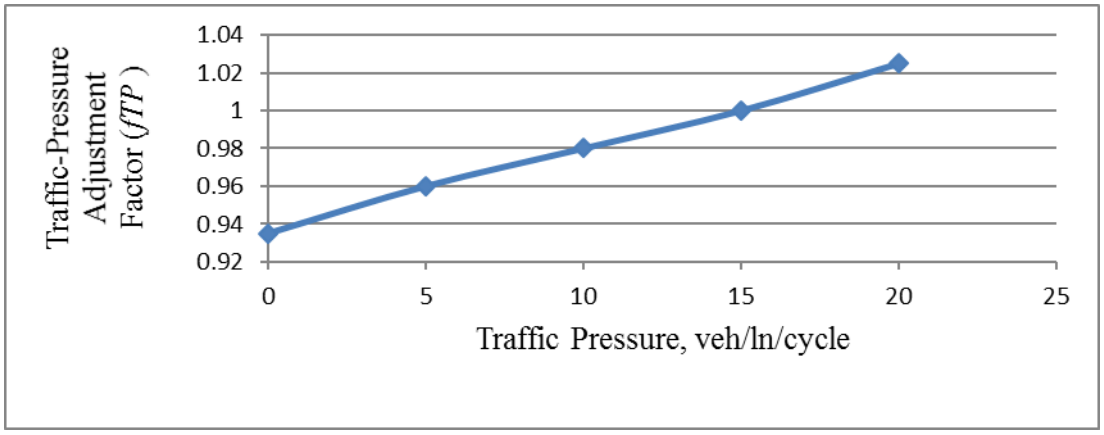

Figure .3 Effect of Traffic Pressure on Saturation Flow Rate

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V. SUMMARY

The saturation flow rate measured at each of the 4 sites is summarized in Table 3. This rate was computed using the discharge times of the fourth and eighth queue positions. The flow rates shown are median values (as opposed to an average). When the data are not normally distributed, the median is influenced less by extremely small (or large) data points than is the average value. In this instance, the median flow rates range from 2 percent lower to 6 percent higher than the average flow rates. On average, the median flow rates are about 2 percent larger than the average rates.

The flow rates listed in Table 3 are categorized by lane use to facilitate some assessment of differences among sites independent of the effects of right-turning vehicles. Around 7105 vehicles were observed in the through traffic lanes, and 3055 vehicles were observed in shared through plus right-turn lanes. Only 92 vehicles were observed in exclusive right-turn lanes.

Table. 3 Saturation flow rate of traffic categorized at intersection and lane use.

Int-Secti	No.	Site	Travel Dir.	App. Config.	Through Lanes	
					OBS.	S.F.
1	1	Sarror Nagar, Ntr Nagar	N	6	308	1916
	2		S	6	384	1912
	3	Sarror Nagar, Ntr Nagar	N	6	364	1735
	4		S	6	432	1714
	5	Maha Laxmi Theater, Rajiv Gruha Kalpa	E	3	198	1819
	6		W	5	289	1955
	7	Maha Laxmi Theater, Rajiv Gruha Kalpa	E	2	87	1770
	8		W	5	305	1678
2	1	Polytechnic Coll, Mahakaxmi Theater	N	4	311	1711
	2		S	4	102	1793
	3	Polytechnic Coll, Mahakaxmi Theater	N	4	15	1612
	4		S	4	183	1591
	5	Mohan Nagar To Indu Arranya	E	4	172	1704
	6		W	4	253	1770
	7	Mohan Nagar To Indu Arranya	E	4	NA	NA
	8		W	4	NA	NA
	1		N	8	149	1760
3	2	Nagole To Uppal Ring Road	S	8	133	1735
	3	Nagole To Uppal Ring Road	N	8	284	1763
	4		S	8	320	1808
	5	Amberpet To Uppal Ring Road	E	8	150	1862
	6		W	8	130	1694
	7	Amberpet To Uppal Ring Road	E	8	216	1639
	8		W	8	355	1600

The Values of saturation flow rate as low as 1376 veh/h/ln, and as high as 2149 veh/h/ln were observed. The overall median saturation flow rate for the through traffic lanes studied is 1735 veh/h/ln.the overall median rate for the shared through plus right-turn lanes is lower at 1591 veh/h/ln. This trend likely reflects the fact that right-turning vehicles turn at a lower saturation flow rate.

As noted previously, the lowest saturation flow rate for a through movement was found at Nagole. This flow rate is 1376 veh/h/ln. The reason for this exceptionally low flow rate was explored by evaluating the traffic characteristics and geometry associated with the site. The saturation flow rate data exhibited wide variability. However, there was no apparent reason for this variability. Lacking additional information about possible unique features of these two intersections, and given the large number of observations available for the through movement at other sites, it was decided that the data from these two sites should not be used in the calibration of the saturation flow adjustment factors.

Table 4. Saturation Flow Rate Categorized at intersection by Configuration and Population.

Lane Use	Configuration	Approach Config.	Median Saturation Flow Rate, Veh/H/Ln					
			Area Population (1000's)					Overall Median
			< 5	5 to 50	50 to 200	200 to 500	> 500	
Through Lanes Only	1		--------	1742	1594	1815	1708	1715
	2		-------	-------	1576	-------	1763	1670
	3		1612	1591	1660	-------	------	1620
	Overall median		1612	1667	1610	1815	1735	**1670**
Shared through plus right-turn lane	1		1510	1516	1600	------	------	1540
	2		---------	1521	1577	1649	1639	1610
	3		-------	--------	1521	--------	1711	1620
	Overall median			1520	1570	1649	1675	**1590**
Right turn	1		--------	---------	1890	--------	1980	1935
	2		--------	1870	------	1960	-------	1915
	3		-------	1980	---------	--------	1865	1925
	Overall median			1925	1890	1960	1925	**1930**

The distribution of median saturation flow rates by approach configuration and population is shown in Table 4.3. The saturation flow rates in the last column of Table 4.3 that are associated with approach configurations. The weight median flow rates for each of the three lanes use categories provide some insight as the correlation between population and saturation flow rate.

VI. CONCLUSION

The field study is conducted to estimate the saturation flow rate at three intersections in summer season of 2013 year. The following are the conclusion are draw form this study.

- The Saturation flow rate was found to decrease with an increase in right-turn vehicle percentage and with an increase in heavy-vehicle percentage. A base saturation flow rate of 1950 pc/h/ln was estimated from the data collected at numerous intersections. This rate is slightly larger than the 1900 pc/h/ln.
- These physical elements include roadside development, sidewalks, on-street parking, and street segment length. This influence of saturation flow rate at intersections on streets having a range of speed limits. Specifically, lower saturation flow rates were found on lower-speed streets at intersection B as 1730 pc/h/ln.
- Saturation flow rate was found to decrease with an increase in right-turn vehicle percentage and with an increase in heavy-vehicle percentage and obtained the maximum saturation flow rate at intersection **C** as 1830 pc/h/ln.

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