Literature Review on Saturation Flow at Signalized Intersection under Mixed Traffic Flow Condition

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Abstract

Saturation flows, lost times and Passenger Car Units (PCU) are the significant parameters in the planning, design and control of signalized intersection. The accurate estimation of Saturation flow values is prime importance when determining the capacity of signalized intersection. Saturation flow is important for estimating signal green time. This paper attempts to literature Review on the saturation flow of signalized intersections. A saturation flow and the proportion of mix traffic, which suggest that mix traffic flow have significant impact and should be considered in the capacity analysis of signalized intersections.
Keywords: Traffic; Saturation Flow; Signalized Intersection; Capacity; Volume

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I. INTRODUCTION

A. *Basic Aspects of Saturation Flow:*

Saturation flow rate is defined as the maximum discharge rate during green time. Saturation period and direction-wise classified traffic volume is necessary to calculate saturation flow for a particular lane group. The procedure for measuring prevailing saturation flow is summarized subsequently. Saturation flow is the maximum volume stated in passenger car unit / hour (PCU/h), which can pass the stop line of approach lane at a green light and there is a row of vehicles at the vehicle lane. Regulating traffic lights is a simple tool for instructing the driver to stop or to move. This tool provides an alternative priority through the provision of priority for each traffic movement sequentially or alternately in a period of time. Saturation headway is the headway of the vehicles in a "stable moving platoon" passing through a green light. A stable moving platoon is a group of vehicles that are traveling, but not really moving in relation to each other (i.e. all going the same speed). Saturation Flow Rate can be defined with the following scenario: Assume that an intersection’s approach signals were to stay green for an entire hour, and the traffic was as dense as could reasonably be expected. The number of vehicles that would pass through the intersection during that hour is the saturation flow rate.

Obviously, certain aspects of the traffic and the roadway will affect the saturation flow rate of your approach. If the approach has very narrow lanes, traffic will naturally provide longer gaps between vehicles, which will reduce your saturation flow rate. If there have large numbers of turning movements, or large numbers of trucks and busses, the saturation flow rate will be reduced. Put another way, the saturation flow rate (s) for a lane group is the maximum number of vehicles from that lane group that can pass through the intersection during one hour of continuous green under the prevailing traffic and roadway conditions. The saturation flow rate is normally given in terms of straight-through passenger cars per hour of green. Most design manuals and textbooks provide tables that give common values for trucks and turning movements in terms of passenger car units (PCU).

B. *Terminology and Key Definitions:*

Basic concepts form uninterrupted-flow facilities: volume, flow rate, speed, density, headway, and capacity Volume and flow rate are two measures that quantify the amount of traffic passing a point on a lane or roadway during a given time interval. These terms are defined as follows:

C. *Saturation Flow:*

‘Saturation flow’ of an approach is the maximum flow (In PCU/Hour) that can pass through an intersection, from one approach, without impedance by signals.

D. Cycle:

One complete sequence of signal indications.

E. Cycle length (Co):

Total time for the signal to complete one cycle, expressed in seconds.

F. Phase:

Part of cycle allocated to any combination of traffic movements receiving the right of way simultaneously during one or more interval.

G. Interval:

Period of time during which all signal indications remain constant.

H. Change interval (Y):

The "yellow" and /or "all-red" intervals, which occur at the end of a phase to provide for clearance of the intersection before conflicting movement are released also known as "Amber Period".

I. Green time (G):

Time within a given phase during which the "green" indication is shown, stated in seconds.

J. Lost time:

Time during which the intersection is not effectively used by any movement, which occur during the change and clearance intervals (when the intersection is cleared) and at the beginning of each phase as the first few vehicles in a standing queue experience start-up delays.

K. Effective green time (g):

Time during which a given phase is effectively available for stable moving platoons of vehicles in the permitted movements, generally taken to be the green time plus the change and clearance interval minus the lost time for the designated movement, stated in seconds.

L. Green ratio (g/C):

Ratio of effective green time to the cycle time.

M. Effective red (r):

Time during which a given movement or set of movements is effectively not permitted to occur, the cycle length minus the effective green time, stated in seconds.

II. LITERATURE REVIEW

A review of literature was undertaken to critically evaluate and learn from published research findings on the study of saturation flow rates as well as relevant information pertaining to the validity of the data from a statistical viewpoint. Most research has been conducted to understand the effect of different vehicles type on the capacity of signalized intersections. Main focus of the review was on work zone factors affecting intersection capacity and identified various methods which had been used to measure saturation flow.

Yevhen FORNALCHYK et. al. (2013) examined the different methods of calculating the saturation flow volume. It was found that the none of them considers the speed of vehicles passing through the intersection. They examined the effect of including intersection passing speed has on the accuracy of assessing traffic conditions at intersection by including this parameter in tests run on VISSIM software. And output of tests showed that accurately assessing the saturation flow volume depends on including intersection passing speed and the size of the intersection. It was determined that intersection passing speed has an impact of the saturation flow volume. And analyzed the speed is the only parameter; it shows that the saturation flow volume can be considered as a function of the intersection passing speed. They found that the length of the speed restriction segment has practically no impact on the saturation flow volume when speed remains constant.

C. S. Anusha; Ashish Verma, Aff. M. ASCE; and G. Kavitha et. Al. (November 2012) attempts to study and analyze the effect of two-wheelers on the saturation flow of signalized intersections by collecting data at a few signalized intersections in Bangalore, India. Due to such complex maneuvering characteristics of two-wheelers, it is not possible to use the U.S. Highway Capacity Manual (US-HCM) model directly because it has been developed for a homogenous lane based traffic flow but in this research study the impact of various categories of vehicles on saturation flow rate and to modify the US-HCM 2000 model to suit Indian conditions incorporating the effect of two wheelers. In this present study comparison made between the theoretical and measured saturation flow. If they are comparable within the error, the process ends and is good for Indian conditions otherwise new adjustment factor are derived and again modified US-HCM 2000.

$$S = s_o N f_w f_{HV} f_g f_e f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$$

Where,
S = saturation flow rate for the lane group in vehicles per hour (veh=h);
so = base saturation flow rate per lane (pc=h=lane);
N = number of lanes in a lane group;
fw = adjustment factor for lane width;
fHV = adjustment factor for heavy vehicles;
fg = adjustment factor for approach grade;
fe = adjustment factor for parking activity;
fbb = adjustment factor for blocking effect of local buses;
fa = adjustment factor for area type;
flu = adjustment factor for lane utilization;
flt = adjustment factor for left turn;
frt = adjustment factor for right turn;
fLpb = pedestrian adjustment factor for left turn; and
fRpb = pedestrian adjustment factor for right turn.

The Indian Roads Congress (IRC) also proposes an empirical formula to estimate saturation flow. Following is the equation Proposed by IRC:

$$S = 525 * (w) \cdot \text{passenger car units(PCUs) per hour}$$

Where,
w = width. This expression is valid for widths from 5.5 to 18 m.
This empirical equation does not cater for many other factors like category of vehicle, area type, and gradient.

The effect of the type of vehicles is considered only in terms of the heavy vehicle adjustment factor, which is obtained using the following equation:

$$fHV = 1/\ 1 + PT\ (PCET - 1)$$

Where,
fHV = heavy vehicle adjustment factor;
PT = percent heavy vehicles; and
PCET = heavy vehicle's passenger car equivalent (PCE).

Shriniwas S. Arkatkar and V. Thamizh Arasan (May 2010) presented the application of a simulation model of heterogeneous traffic flow named HETEROSIM, is used to study the vehicle interactions, at micro level, over a wide range of traffic flow conditions on up grades of different magnitudes. Also they used simulation model to estimate the PCU value of different types of vehicle. In this study they collect a free flow speed on selected upgrades and estimate the acceleration rates than after develop a speed flow relationship and analyze the speed distance profile for different vehicle categories and found that effect of grade on vehicle performance may not be significant beyond a length of 1600 m. Finally they studied the effect of magnitude of upgrade and its length on PCU values of vehicles. Under heterogeneous traffic conditions, the PCU value of vehicle should be change with traffic volume. PCU value increase significantly with increase in the magnitude of grade and its length.

Md Hadiuzzaman, Md Mizanur Rahman, Md Ahsanul Karim (May 2009) The important parameters in the planning, design and control of a signalized intersection are saturation flows, lost times and passenger car units (PCU). They analyzed the methods of measurement of saturation flow and the selection of proper method to measure the parameter (saturation flows, lost times and PCU) for traffic condition prevailing in developing countries. They found PCU values using a synchronous regression method and then estimate the saturation flow in PCU/hr using the PCU value obtained at each intersection and compared the saturation flow model with field observed value.

Hien Nguyen et.al. (2008) studied the saturation flow and vehicle equivalence factor at signalized intersections in a traffic environment dominated by motorcycles. Concentrates on traffic dominated by motorcycles, i.e. where motorcycles make up more than 80% of traffic composition. Therefore, the motorcycle was selected as the basis to study other categories of vehicle as well as the whole traffic flow.The concept of MCU value was applied instead of conventional PCU value to take into account the effect of mixed traffic dominated by motorcycles. A regression model has been derived to describe the variation of saturation flow. Overall, saturation flow of a 3.5m wide approach is as high as 11000 MCU/h. The impacts of geometric and traffic factors on saturation flows were also investigated. MCU values of passenger cars, vans and buses making different movements were determined

C.J. Bester and W.L. Meyers (SATC, July 2007) studied the various situations at signalized intersections such as, turning movement, gradient, number of through lanes, and speed limit. The method included the determining of start-up lost times, saturation headways and saturation flow rates of each observed vehicle queue at each intersection. In which he was determined the saturation flow rates under ideal conditions and then compared this result with results obtained under different conditions.

Here, they were analyzed various factors in present study according to HCM 2000 and found that the saturation flow rates in Africa are much higher than in other countries. And observed that the effect of speed limit, gradient and number of through lanes on the saturation flow rate are much higher locally than in the USA.

Taylor et al (1989) used video-based equipment to estimate the character speeds and headway. This technique provided cheap, quick, easy, and accurate method of investigating traffic systems. Investigation of headways on freeway traffic allows the potential of this technology in a high-speed environment to be determined. Its application to the study of speeds in parking lots enabled its usefulness in low-speed environments to be studied. The data obtained from the video was compared to traditional methods of collecting headways and speed data.

III. CONCLUSION

Following are the conclusion drawn from the present study:

- The saturation flow analyzed for different approaches shown that it does not depends only on width of the approaches (w); the empirical formula 525w suggested for Indian condition in special publication (SP)-41 (IRC 1994) of the Indian Road Congress is inappropriate for obtaining saturation flow.
- The saturation flow estimated using the calibrated US-HCM 2000 model (TRB-2000) is closer to field values, which implies that the effects of two-wheelers and approach volume are to be considerd while modeling saturatiom flow in Indian conditions.
- This method can be treated as an alternative to the traditional 525W empirical formula method (IRC 1994), which has been proved to be inappropriate.

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