Review Paper on Analysis of Signalised Urban Intersections under Mixed Traffic Conditions

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Abstract: The main factors governing the planning, design and control of signalised intersections are saturation flow rates, width available for manoeuvre, lost time and passenger car units (PCU). In urban areas, the multi-modal traffic surrounding affects the saturation flow rate. In broad spectrum, traffic composition on Indian roads can primarily be categorised into two namely Highly Manoeuvrable Vehicles (HMV) and others. The vehicles capable of high lateral and longitudinal mobility are termed as Highly Manoeuvrable Vehicles. Motorized wheelers and human-power driven bicycles are put into this category. Saturation flow rates hold a prime importance in determining the capacity of an intersection and estimating green time for the signal. Saturation Flow Ratio gives an idea about the longitudinal and lateral manoeuvres shown by the vehicles over varied widths. This paper attempts to review literature related to estimation of saturation flow rates at signal controlled intersections facilitating a mixed traffic.

Key words: traffic, manoeuvrable, saturation flow, capacity, intersection.

Introduction: Saturation flow rate is defined as the highest rate of flow at which the vehicles from an approach to a crossroad can traverse the intersection if green time is available uninterruptedly. Signal controlled intersections are the largely complex locations in urban road networks. The operational situation of such intersections overwhelmingly affects the overall effectiveness of the whole transportation network in cities. When the green signal phase begins on an approach to an intersection, vehicles take some time to reach a normal running speed; but after a few seconds, the queue discharges at a more or less constant rate termed saturation flow. Saturation flow is the maximum constant departure rate from the queue during the green period, and it remains fairly constant until either the queue is exhausted or the green period ends. As the functioning quality of urban road network steadily deteriorates due to increase in traffic volume, a higher level of service is required and a well-planned and efficiently better scheme is indispensable to guarantee a reasonably comfortable condition of urban transportation at all times.

The assessment of the current status and performance of signal controlled intersections is one of the key tasks in the management and perfection of urban traffic systems. It is imperative to note that based on assessment results, traffic authorities can frame out those strategies and plans that make both the improvement measures and the allocation of limited funds more judicious. Numerous approaches to estimate the performance of signal controlled intersections have been put forward by various researchers and engineers, and are being implemented in several cities.

In urban areas signal control is a normally used remedy of capacity shortage. For satisfactory road way design and for thriving traffic management a adequately precise method of predicting the capacity of signal controlled intersections should be employed. Signal control is usually considered to be the premier form of control achievable at an at-grade intersection. If the signal control plan is not designed appropriately, the signal control may happen to be counterproductive. The ill effects of inappropriate signal plan can be congestion, fuel wastage, undue delays, reduced intersection capacity, tremendous inconvenience for the road user and of course air pollution. To keep away from such a situation , it becomes compulsory on the part of the traffic engineer to study the traffic situation meticulously, to recognize it accurately and to develop the optimum cycle time and suitable phasing to go well with the requirements of the traffic with due deliberation to the location geometrics.

The main significant constraint that affects the design of signal plan is the "saturation flow rate". Saturation flow rate is an important factor for evaluating the capacity of a signal controlled intersection. It also plays a noteworthy role in the design of signal timing plans. The capacity of a signal controlled intersection is directly affected by the saturation flow rate. Given the reasonable accuracy in computation of the saturation flow rate, the capacity of the signal controlled intersection can be analysed accurately along with delay statistics and the level of service.

Terminology:

Main concerned terms are defined as follows:

Saturation Flow rate:

Saturation flow rate is defined as the highest rate of flow at which the vehicles from an approach to a crossroad can traverse the intersection if green time is available uninterruptedly

Cycle:

A sequence of signal phases that gets repeated.

Cycle length (Co):

Total time taken by a signal to complete one cycle, in seconds.

Phase:

Allocated part of a cycle meant for a combination of traffic movements receiving the right of way in a synchronised during one or more interval.

Change interval:

The intervals (yellow and /or all-red) which happen at the end of a phase to offer for clearance of the intersection before conflicting movement are released also known as Amber Period.

Green time:

It is the Time during which the green signal is shown, in seconds.

Lost time:

There is a time for which the intersection is not effectively used by any traffic movement known as lost time. Time is lost mainly during the change and clearance intervals and at the commencement of each phase.

Effective red:

It is the Time during the intersection does not allow a given movement or set of movements effectively, the effective green time subtracted from the cycle length, measured in seconds.

Literature Review

The research carried out in the fields related to the present study is reviewed in this part. Stress is mainly put on the study of saturation flow rate estimation. The methodology suggested by Highway Capacity Manual (2000) is discussed elaborately to study the appropriateness of the application of this method to Indian urban traffic circumstances and to suggest appropriate modifications.

Kara and Raheel (2000) studied the impacts of various light duty trucks (LDTs) on the capacity of signal controlled junctions. Regression analysis developed estimates of headways linked with various categories of LDTs as well as passenger cars and determined passenger car equivalents. It was suggested that the influence of LDTs were to be given particular consideration when analyzing the capacity of signal controlled intersections [1].

Satish Chandra and U. Kumar (2003) have put forward a notion to estimate the PCU factor for a mode in a heterogeneous traffic situation employing area concept. It was found that the PCU for a vehicle is directly proportional to width of the carriageway. This was credited to the better freedom of movement on wider roads and consequently a higher speed differential between a car and a vehicle type [2].

Huang and Jianping (2004) studied the cyclist conduct in a traffic stream such as crossing speeds, crossing gap and group riding behaviour at a signal governed intersection and statistical data analysis was carried out to establish the intersecting group behaviour of cyclists valuable for perceiving the efficiency of mixed traffic at signal controlled intersections [3].

Sarna and Malhotra (1967) have put forward an empirical equation for the saturation flow rate under heterogeneous traffic situation. The central concept of the positive linear relationship between the saturation flow rate and the approach width is revealed in their model also [4]. The equation develpoed by them is

$$S= 431.7W +103.5$$

Where S = Saturation flow rate, PCU/hr; and W = Approach width accessible for the movement under deliberation, m.

Bhattacharya and Mandall (1980) have proposed an equation where saturation flow rate is shown as a function of approach width [5]. According to this model the Saturation flow rate is given by the formula

$$S= 490\ W -360$$

Where S = Saturation flow rate, PCU/hr, and

W= Approach width available for the manoeuvres under consideration, m.

Bikram Das (1984) proposed a concept for the estimation of the saturation flow rates under heterogeneous traffic scenario. Based on the composition of traffic, he has developed saturation flow rate curves [6].

S. Chandra and Sikdar (1993) have deliberated on the capacity of a signal controlled intersection under heterogeneous traffic conditions and they observed that saturation flow rate estimation for the Indian urban conditions requires a different close in that gives due stress on the dominating attendance of smaller vehicles such as two wheelers. One of the major interpretations from their study is that the increase in approach width consequently results in reduced discharge because of the increased freedom to manoeuvre available to the smaller vehicular modes [7]. Based on the saturation flow rate and the approach width, the dynamic PCU factors are proposed. According to them, the saturation flow rates for straight and right directional manoeuvres at a signal controlled intersection can be approximated as:

$$S = 1241+293\ W \text{ and}$$

$$S_r = 1895 + 250\ W - 31735.7/R$$

Where S = Saturation flow rate for straight moving traffic, PCU/hr;

S_r = Saturation flow rate for the right directional manoeuvres, PCU/hr;

W = Approach width offered for the manoeuvre under consideration, m; and

R = Radius of right manoeuvre, m.

Ravinder (1997) has concluded in his study that the direct use of Webster's equation furnishes lower saturation flow rates than what are truly observed. He has also reported that the 2/3 wheeler proportion in urban traffic is very high ranging from 60 to 90 percent. He has developed different saturation flow rate equations for straight and right turning manoeuvres at a signal controlled intersection [8]. According to their study, the saturation flow rates can be approximated as

$$S= -185.527 + 4989.18\ W - 13202.8 \text{ and}$$

$$S'' = -586.79\ 72.88\ W - 11382.4$$

Where, S = Saturation flow rate for straight,measured in vph;

S"= Saturation flow rate for right turning manoeuvre, vph

W = Width accessible for the movement under deliberation, m;

Sunil Anand (1999) studied capacity and Level of service of signal controlled urban intersections and he has recommended that saturation flow rate in vph can be estimated using an equation

$S=2000W$,

Where S denotes the saturation flow rate in vph and W is the width available for the manoeuvre in m [9].

Hari Narayana Murthy (1999) has developed an equation for the assessment of the saturation flow rate at signal controlled intersections where the slow moving vehicles proportion is high [10]. He has recommended that the Equivalent Passenger Car Units (EPCU) are dynamic in character and the saturation flow rate can be evaluated as

$$S = 1619 + 463\ W$$

Where S is saturation flow rate in veh/hr,

W=width of approach road/lane, m.

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[11].

J. Joseph and G. L. Chang (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. [12]

Conclusions:

The following conclusions can be made

1. The long-established evaluation of saturation flow rate would undervalue saturation flow rate as the habitual estimation of saturation headway does not precisely reveal the true value of headway and would overvalue it.
2. If method recommended by HCM (2000) is used to estimate saturation flow rates then the calculated values would be almost the same as field values in most of the cases. that reiterates the need to consider the effect of highly maneuverable vehicles.
3. The relation between the proportion of HMV's , capacity of signalized intersection, wdth available for traffic mobility, required cycle timings and phase timings can be modeled mathematically using multiple linear regression analysis within certain practical constraints.

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