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Two Wheeler Adjustment Factor to Estimate Queue Length at Signalized Intersection under Heterogeneous Traffic Conditions

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Abstract

The two-wheeler adjustment factor derived in the present study to predict queue length at approaches of signalized intersections in mixed traffic conditions. The statistical distribution investigation carried out to understand the queuing behavior by using observed queue length obtained from the field. Field data was collected at Suchitra and KBR park intersections in Hyderabad City by using video graphic technic. Highway Capacity Manual (2010) adopted for estimating queue length with adjustment of saturation flow rate model given in the manual. Average number of vehicles in the queue estimated by using Highway Capacity Manual (2010) methodology with and without application of two-wheelers adjustment factor to saturation flow rate model given in the manual. The estimated queue length by using Highway Capacity Manual (2010) methodology with and without application of two-wheelers adjustment factor was compared with observed queue length obtained from the field. The comparative study showed the significance of adjustment factor for two-wheelers high for estimating queue length accurately.

Keywords: Saturation flow rate, mixed traffic, Queue length, Adjustment Factor

INTRODUCTION

Signalized intersections are most essential measure of road network disturbing performance of entire system in mixed stream of traffic situations. Stream of traffic size mounting quickly day by day in emerging nations resembling India through formation of queues at approaches of signalized intersections. Queue is the line of people or things waiting to serve. It is the phenomena, which arise in daily life mostly at approaches of signalized intersections. Queue is a line of vehicles coming at stop line for green phase to be served by a signalized intersection (Indo-HCM 2017). Vehicles in traffic stream moving slowly and joining at rear end also considered as part of queue. Queue length is the longitudinal space covered by queue or number of vehicles joined in the queue at stop line (Indo-HCM 2017). The queue formation for extended time at signalized intersection leads to delay, diver frustration and fuel consumption, etc. At signalized intersection, excessive formation of queue arises when demand exceeds saturation flow rate. Hence, analysis of queuing helps in making predictions of the traffic jams. Traffic jam is a phenomenon where the vehicles stopped completely for a particular period, at this condition queue length reaches to maximum and traffic flow becomes zero.

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Present study analyses the effect of two-wheeler proportions for predicting average number of vehicles in queue at approaches of intersection controlled by a signal under non-lane based traffic conditions. The distribution analysis carried out for understanding two-wheeler effect with varies percentages of its proportion. HCM (2010) methodology applied for estimating queue length at signalized intersection with two-wheelers adjustment factor to determinate accuracy of existing HCM (2010) queuing model.

REVIEW

Queue length prediction at signalized intersection varies with various factors. Examination of queue size at an approach of signalized intersection, under particular control situations has been issue of investigation for decades ((Webster (1958), Miller (1963), Heidemann (1994)). Signalized intersections controlled by a traffic signal with control conditions either fixed or adaptive. For optimization of control condition tractable framework is required to estimate queue length. Webster studied that semi heuristic approach for estimating the queue length. Brilon and Ning (1990) [1] studied distribution of queue length under steady-state and fixed control conditions. For that, Markov chain theory was used for estimating queue length distribution. Lin et al (1994) [2] developed methodology for estimating queue length to measure effectiveness for classifying the level of service into six levels in Taipei, Taiwan. They used analytical models to estimate queue length. Viloria and Avery (2000) [3, 4] studied comparison of queue length models between estimated queue lengths at signalized intersection in Gainesville. They estimated queue length with available queuing models and HCM (2000) approach. The HCM (2000) queue length model was estimated higher queue length values in compared to other models. Cottrell (2001) [5] developed a model to estimate the queue length and duration of queue in Salt Lake City from 161 observations. Developed model was used to analysis queuing behaviour through observed data obtained from field. Lie et al (2006) used stochastic queuing model to estimate the number of vehicles in the queue at signalized intersection in Netherlands. Furthermore, Lin and Liu (2011) [6] developed model to estimate queue length using taxi GPS data collected from every 10 seconds interval of half-hour duration in Shanghai, China. Chang and Talas (2013) [7] developed a new methodology to estimate queue length on approaches of signalized intersection in New York City. The method used a set of data such as cycle lengths, flow, detector setback, and occupancy. Murata (2014) investigated the relationship between cyclic vehicle queues at isolated signalized intersection in Turkey. They developed a multiple regression model to estimate queue length, the developed model may use to design of signal timings and phasing [8, 9].

In countries like India, the traffic is under mixed conditions it varies with different traffic composition mainly two-wheelers vehicle types, which directly affects the queue length. Most of the literature reviews applied the queuing models, estimated the queue lengths, and compared with observed queue length values obtained from the filed under homogeneous traffic conditions. Very few works of literature considered the vehicle composition this study presents the two-wheeler adjustment factor for estimating queue length using HCM (2010) methodology [10–12].

FIELD DATA ANALYSIS

The traffic data was collected from two signalized intersections in Hyderabad City, namely Suchitra Junction and KBR Park Junction. The selected intersections are four-legged (Suchitra junction) and three-legged (KBR park junction) with major and minor stream approaches. Snapshot of selected intersection shown in Figure 1 [13–22].

Videography method was used for collection of field data to record the operation of stream of traffic during different hours of the day. Video recording was performed for 6-hours at the intersections for the duration of the before noon from 6:00 AM to 9:00 AM and evening from 3:00 PM to 6:00 PM. Recorded data was extracted by playing the video files on a widescreen LED display. The field queue length was observed at the site during each cycle by counting the number of vehicles joined in the queue at approaches. As observed approaching traffic volume is mixed in nature, classified

Figure 1. Snapshot of (a) Suchitra Junction, (b) KBR Park Junction.

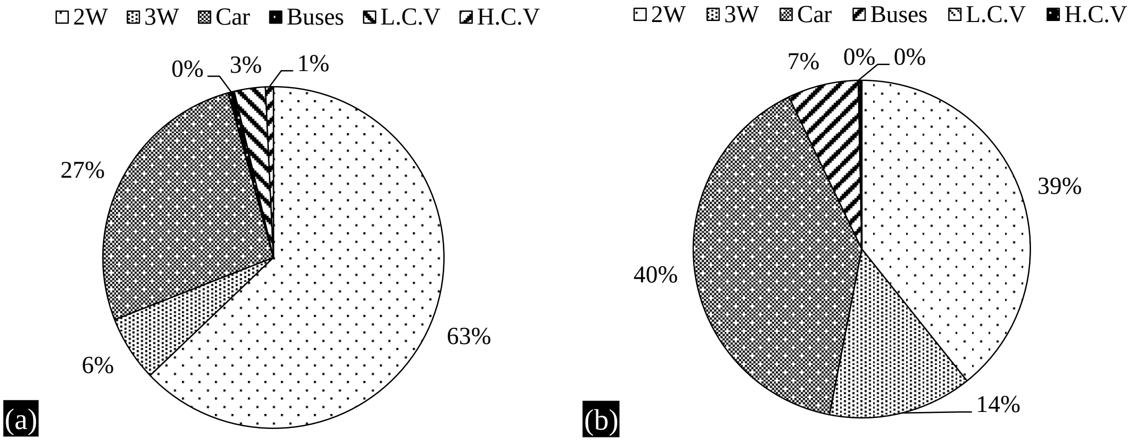

Figure 2. Composition of vehicle types at approaches of (a) Suchitra Junction, (b) KBR Park Intersection.

Table 1. Geometric, traffic, and control details of selected intersections.

Approach name	Signal phase		Approach width (m)	Approaching Volume (Veh/hr)	Average observed queue length (Veh)
	Green time (s)	*Red time (s)*			
Bowenpally Road	70	90	15	2995	99
Kompally Road	70	90	12	2444	83
Suchitra Road	30	130	18	1175	49
Old alwal Road	30	130	25	1163	41
KBR park Road	80	85	7.5	1030	61

volume count was made which comprises vehicle types such as two-wheeler, Three-wheeler, Car, Bus, LCV, and Truck. The signal timings, vehicle arrival, and service rates were also observed from field data. The Composition of vehicle types observed at respective intersections shown in Figure 2. Geometric, traffic, and control details of selected intersection shown in Table 1 [19].

DISTRIBUTION ANALYSES

The number of vehicles standing in the queue at approaches of intersections was observed during each cycle. The average queue length measured at different intersection approaches is given in Table 1 for the entire period of observation. The distribution of measured queue length was analysed to understand the queuing behaviour. The frequency of queue length was observed on different approaches of selected intersections by selecting appropriate class intervals. The distribution profiles of queue length data as developed for selected intersection. Chi-Square test was performed at the 5% significance level to check whether the observed data fits normal distribution. The statistical p-values

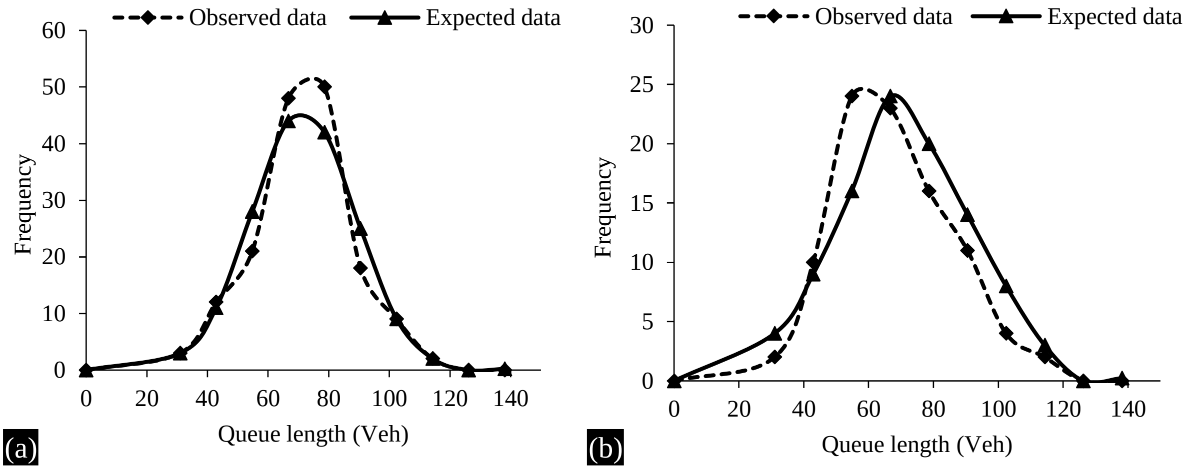

Figure 3. Frequency Analysis of (a) Suchitra Junction, (b) KBR Park Intersection.

estimated for each non-parametric test range between 0.234 to 0.934 which showed the distribution of queue length observed at the intersections are not conforming with normal distribution. The percentage of vehicle type two-wheeler varies from 32% to 69% which may also be the reason for affecting the queuing behaviour. Distribution profiles pertaining to different selected intersections are shown in Figure 3.

PREDICTION OF QUEUE LENGTH

The present study was estimated the queue length at approaches of signalized intersections through two different approaches of HCM (2010) methodology. One of this based on existing HCM (2010) model and another one is HCM (2010) queue length model with application of two-wheelers adjustment factor to saturation flow rate equation given in manual. The two-wheelers adjustment factor applied to estimate the saturation flow rate for the existing saturation flow rate equation of HCM (2010). The following equations are existing HCM (2010) methodology for estimating the queue length.

$$Q = Q_1+Q_2+Q_3 \tag{1}$$

Where; Q is average number of vehicle in queue, Q_1 is the first term back of queue size (veh/ln), Q_2 is the second term back of queue size (veh/ln), and Q_3 is the third term back of queue size (veh/ln).

$$s = S_oF_wF_{HV}F_gF_pF_{bb}F_aF_{LU}F_{LT}F_{RT}F_{Lpb}F_{Rpb} \tag{2}$$

Equation 2 is the saturation flow rate equation of HCM (2010) methodology. This existing equation was used to estimate the saturation flow rate, which used for the estimation of queue length by using existing HCM (2010) model. Where, s is the adjusted saturation flow rate (veh/hr/ln), So is the base saturation flow rate (pcu/hr/ln), Fw is the lane width adjustment factor, FHV is the heavy vehicle adjustment factor in the stream, the approach grade adjustment factor, Fp is the existence of a parking lane and parking activity adjustment factor, Fbb is the bus blockage adjustment factor, Fa is the adjustment factor for area type, FLU is the lane utilization adjustment factor, FLT is the adjustment factor for left-turn vehicle presence in a lane group, FRT is the adjustment factor for right-turn vehicle, FLpb is the pedestrian adjustment factor for left-turn groups, and FRpb is the pedestrian–bicycle adjustment factor for right-turn groups.

ADJUSTMENT FACTOR FOR TWO-WHEELERS

The two-wheelers adjustment factor F_{TW} accounts for the difference in the operational performance and additional space occupied by the two-wheelers. The values of this factor are computed with the following equation with varies percentages rages from 32% to 69%.

$$\frac{100}{(100-PTW(ET+5))}$$

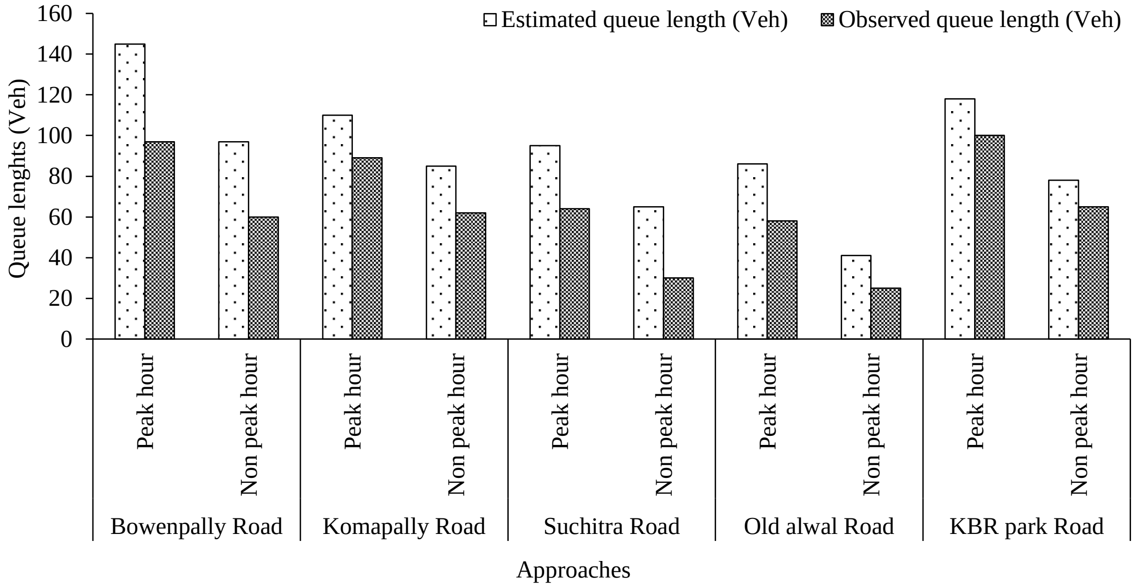

Figure 4. Comparison of estimated queue length and observed queue length (without adjustment factor for two-wheelers).

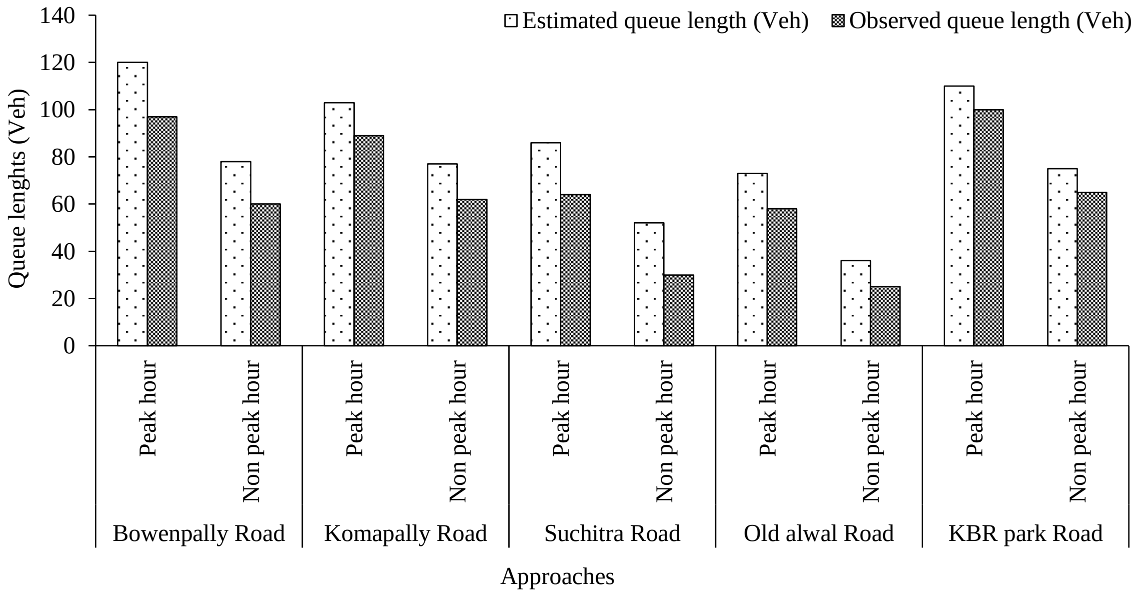

Figure 5. Comparison of estimated queue length and queue length (with adjustment factor for two-wheelers).

Where;

P_{TW} = percent of two-wheelers in the corresponding lane group or approach of a signalized intersection (%)

ET = equivalent number of through car instead of two-wheelers = 5.0

Adjusted saturation flow rate equation with two-wheeler adjustment factor is

$$s = S_o F_w F_{HV} F_g F_p F_{bb} F_a F_{LU} F_{LT} F_{RT} F_{Lpb} F_{Rpb} F_{tw} \quad (3)$$

Average queue length estimated for an individual approach of Suchitra intersection and KBR intersection covering peak and non-peak hours. The average number of vehicles in the queue was estimated by using Highway Capacity Manual (2010) methodology with and without application of two-wheelers adjustment factor to saturation flow rate model given in the manual. The estimated queue length by using Highway Capacity Manual (2010) methodology without application of two-wheelers adjustment factor to saturation flow rate model was compared with observed queue length obtained from the field shown in Figure 4. Similarly, estimated queue length by using Highway Capacity Manual (2010) methodology with application of two-wheelers adjustment factor was compared with observed queue length obtained from the field shown in Figure 5.

The percentages of two-wheelers in both the cases in distribution analysis and estimating queue length using HCM (2010) methodology played a major role because of the queuing behaviour changes with this vehicle composition. KBR intersection approach was less two-wheeler's proportion compared to Suchitra intersection approaches hence the RMSE of KBR intersection reduced compared other approaches.

VALIDATION OF MODEL

Validation is necessary stage in modelling which denotes the amount at which the model conforming to an actual system. The models in the present study calibrated with 70% of the data and validated with remain 30% of the data. The statistical methods Mean Absolute Percentage Error (MAPE) (equation 4) and Percentage error (equation 5) used in the present study for validation purpose.

$$MAPE = \frac{1}{n}\left|\frac{Y_{exp}-Y_{pred}}{Y_{pred}}\right| \times 100 \quad (4)$$

$$PercentageError = \frac{(Y_{pred}-Y_{exp})}{Y_{exp}} \quad (5)$$

Where;

Y_{exp}= field observed queue length values,

Y_{pred} = model estimated values,

n= number of observations.

CONCLUSION

The estimated queue length results were successfully compared with the observed queue lengths obtained from the field with and without application of adjustment factor for two-wheelers. The queue length was estimated initially by using existing HCM (2010) methodology. Later, the adjustment factor for two-wheelers was derived which is in the range of 1 to 1.06. The RMSE was calculated to compare the estimated queue length values with the observed queue length, an indication of the robustness of the model.

The RMSE of estimated queue lengths using HCM (2010) queuing model with two-wheelers adjustment factor is better accurate than the without adjustment factor, but not mark up to the observed queue length values. Therefore, the existing model with adjustment factor for two-wheelers may play significant role to estimate queue length under mixed traffic conditions. The study recommends development of a new model to estimate the queue length at an approach of signalized intersection under mixed traffic conditions by considering various geometric, traffic and control condition parameters.

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