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Simulation of Travel Time Delays at Signalized Intersections under Mixed Traffic Conditions

Anita Gunwantrao Kale[1], Dipshikha Naringe[2]

Assistant Professor[1], Student[2]

Department of Civil Engineering

Institute of Engineering & Technology, Calicut University

Corresponding Author's Email: -*naringesipshikha57@gmail.com[2]*

Abstract

Signalized junctions are critical places in any road network system, where saturation traffic and latency are significant metrics for evaluating signalised intersections, which also impacts signal timing design. To predict vehicle delay at signalised junctions, several approaches have been utilised. There have been very few studies to assess delay at signalised crossings with mixed traffic. The current study's goal is to create a model for delay in mixed traffic situations. The current research will focus on three four-legged signalised junctions in Calicut. Saturation flow is calculated in PCU/hr by dividing the number of vehicles during the saturation green phase by the length of the saturated green time. Both licence plate and object matching approaches are used to predict delay. In the current work, a non-linear model is created to estimate the delay. The link between delay and several factors is established, and it is discovered that delay grows exponentially with flow, logarithmically with degree of saturation, and linearly with proportion of heavy vehicles.

Keywords: *Saturation Flow, Signalized Intersection, Non-Lane Based Heterogeneous Traffic, Non-Linear Regression*

INTRODUCTION

An intersection is a point on the road network where cars are directed in the desired direction to reach their goal. Delay is one of the primary performance indicators used to judge the quality of service at both signalised and unsignalized junctions. Because of the non-

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deterministic nature of arrival and departure processes at signalised junctions, estimating delay is difficult. The literature has thoroughly investigated the various ways of estimating delay at signalised junctions. The majority of research on delay estimates at signalised crossings was done under homogenous traffic circumstances with lane discipline. There have been very few studies to predict delay for mixed traffic circumstances in underdeveloped nations. The current study attempted to create a non-linear model for calculating delay at three signalised crossings in the city of Calicut.

REVIEW OF LITERATURE

R. Prasannakumar and G. Dhinakaran (2012) found site specific PCU values using area to velocity ratio. Delay was estimated from the field using HCM 2000 field delay procedure and they found LOS of signalized intersections in Tamil Nadu.

Sazi Murat and Ozgur Baskan (2006) used Artificial neural network approach for modelling delay of traffic flows and the developed model is compared with Webster, HCM and Akcelik delay calculation methods. The developed model shows reliable results when compare to other standard models.

Ragab M. Mousa (2002) presented a methodology for measuring stopped delay as well as acceleration and deceleration delay at signalized intersections. Results indicated that deceleration and acceleration lengths of stopped vehicles varied over a wide range and the deceleration delay was estimated at 11.8 sec/veh. Relationship between delay components were modelled and the analysis showed a ratio of 2 between the total delay and stopped delay.

M. Hossain (2001) developed a model for the estimation of saturation flow which has been applied as a tool for analysis of signalized intersections under mixed traffic conditions. The model allows variation of all geometric, traffic, driver and signal control elements.

P. Olszewski (1999) studied about overall delay, stopped delay and stops at signalized intersections. Delay was estimated using HCM delay model and new equations were proposed for stopped delay. It was found that the ratio of average delay to stopped delay was close to 1.3 which is given by HCM.

Cesar A Quiroga and Darcy Bullock (1999) presented a new methodology for measuring delay at signal-controlled

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intersections, which uses GPS receivers and GIS dynamic segmentation tools. The methodology uses vehicles equipped with automated position and speed data collection devices. Measurement of test car delay was made using GPS.

Arasan V. T. and Jagadeesh K (1995) developed a model to estimate delay at signalized intersections. A probabilistic approach based on first order second moment method was adopted to estimate the saturation flow and delay caused to traffic, under heterogeneous traffic conditions at signalized intersections. The data required for these models and the data required to validate the calculated values were collected by conducting extensive traffic studies.

Many models for estimating control delay at signalised junctions have been developed in various studies on control delay at signalised crossings across the world; however the majority of them are based on homogenous traffic circumstances. A non-linear model is created in this study utilising statistical software for the social sciences (SPSS). The field observed control delay is used as the dependent variable, while the flow, saturation level, and fraction of heavy vehicles are used as independent factors.

METHODOLOGY

Study area

The current study will focus on three isolated signalised crossings in Calicut, Kerala, India. All of them are four-legged junctions. Without lane discipline, the traffic at these intersections is reported to be diverse. A reconnaissance assessment is conducted to examine the appropriateness of various sites for collecting data on delays and to pick suitable spots for installing video cameras and recording traffic flow.

Data collection and reduction

All of the junctions chosen for the current study are subjected to traffic surveys. The analysis takes into account all four approaches to the three signalised crossings. The traffic movement is graphically recorded on video. The video camera is set at a level that is somewhat higher than the road surface. From this vantage point, the traffic is easily seen. Data is collected throughout peak morning and evening hours, as well as off-peak hours. Primary information such as approach width, green time, and cycle time are also captured. The captured material is digitalized and recovered using a slow movie player. The geometric details for the selected junctions are shown in Figures 1, 2, and 3.

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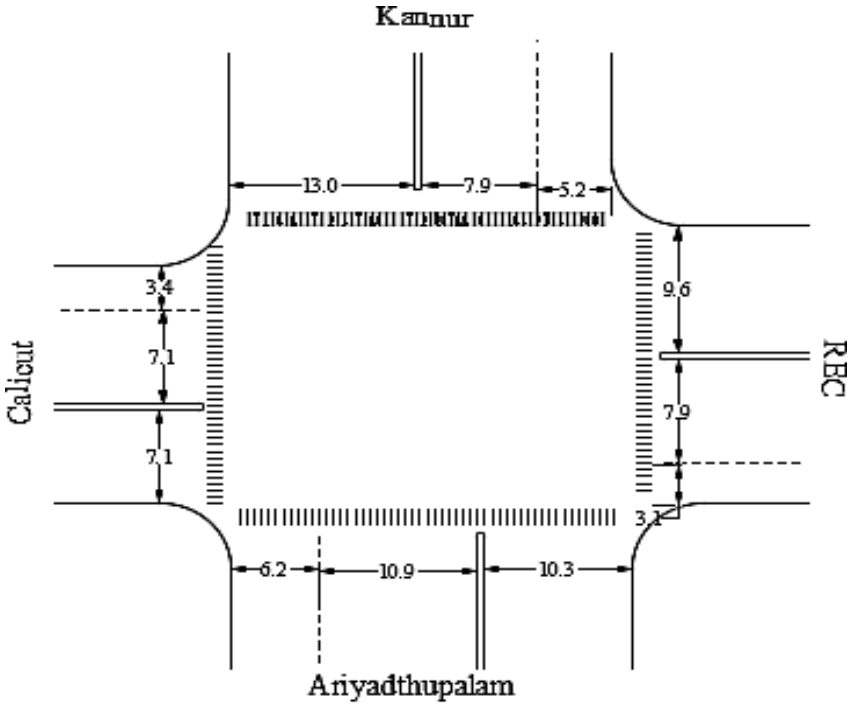


Fig: 1. Geometric details of Eranhipalam

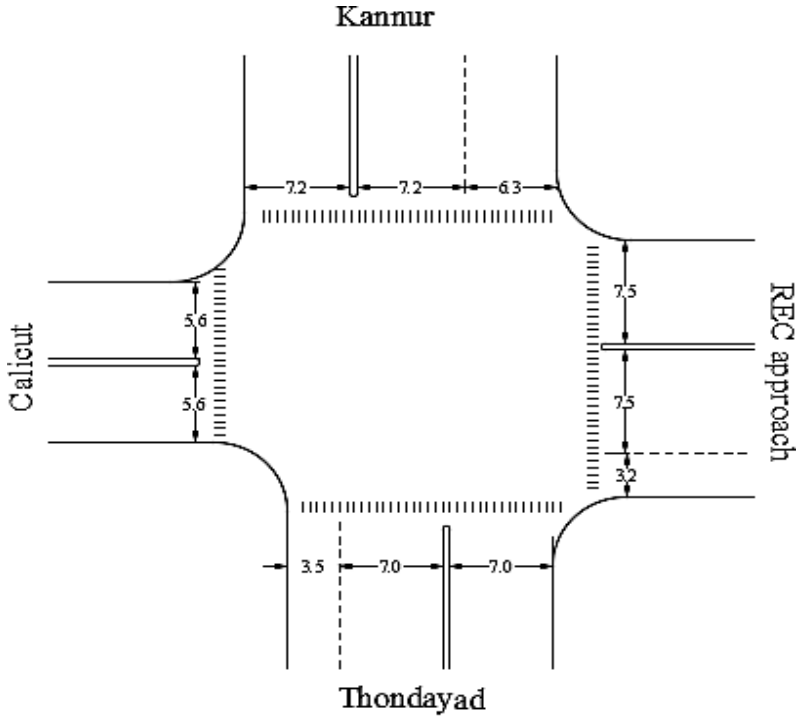
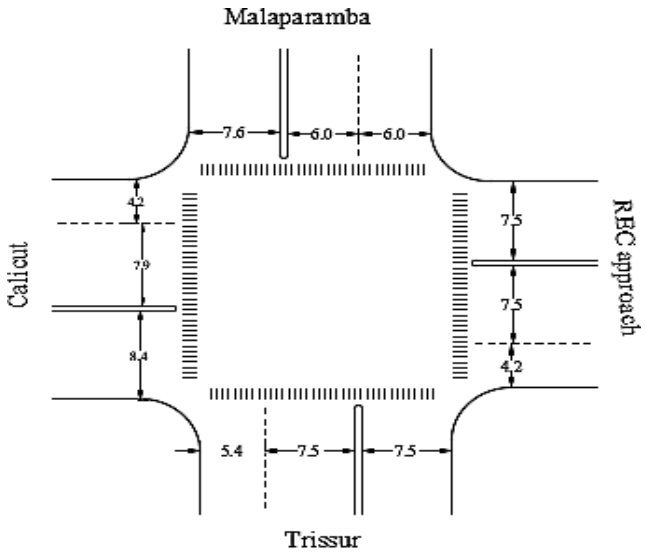


Fig: 2. Geometric details of Malaparamba

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Thondayad intersection

Fig: 3. Geometric details of Thondayad

Estimation of saturation flow

Saturation flow is defined as the highest continuous departure rate from the standing queue during the green time, which remains constant until the green period expires or the queue is depleted. In general, saturation flow is represented in PCU/hr/lane/green interval.

The categorised volume count for each interval of five seconds is conducted for all approaches during peak hours to estimate saturation flow.

The number of cars during the saturated green phase divided by the duration of the interval is the saturation flow.

S= (total number of vehicle PCU/maximum green time (s)) ×3600 (1)

Field measurement of control delay Delay is measured using both licence plate and object matching methods. The control delay caused by the vehicles to cross the intersection could be known by subtracting the entry time of vehicles from the exit time (deceleration delay+ stopped time delay+ acceleration delay). The control delay is taken as the total time elapses from the initiation of deceleration of vehicles to its reacceleration.

ESTIMATION OF DELAY

Webster observed that for a given traffic and physical factors average delay depends on the cycle length. Delay will be very high if the cycle length is too short and the delay will be exceedingly high if the cycle length is too long.

$$d = \frac{c(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)} + 0.65\left(\frac{c}{q^2}\right)^{1/3} x^{(2+5\lambda)} \quad (2)$$

Where, d=average delay per vehicle, C=cycle time, λ=proportion of the cycle

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that is effectively green for the phase under consideration, q=flow, x=degree of saturation, s=saturation flow.

The first term in this expression is the delay due to a uniform rate of vehicle arrival. The second term is due to the random nature of the vehicle arrivals. The third term was derived from the simulation of traffic flow (correction term).

The renowned Webster's delay equation is used to estimate delay under homogenous traffic circumstances, and it is only applicable when lane discipline is maintained. However, traffic in India is heterogeneous, with little or no lane discipline. As a result, a model for calculating control latency under mixed traffic situations must be developed. Control delay measurement is difficult. However, precision in measuring is critical.

In the current study, latency is assessed using both the Object matching approach and Webster's model. The control delay induced by the cars crossing the junction might be determined using the object matching approach by subtracting the vehicles' entering time from their exit time. The licence plate and object matching approach is well-known for being a basic and straightforward method of field delay estimate. However, this strategy necessitates field personnel noting the entrance and exit times of cars passing through the intersection.

Table 1 shows the range of delay values observed at the signalised junction and those estimated using Webster's model. Table 1 clearly shows that delay values acquired from the field are fewer than delay values derived using Webster's model. This suggests that Webster's delay model overestimates the delay values.

Table: 1. Range of Observed delay values

Name of the intersection	Approach	Range of observed delay (s)	Webster’s delay
Eranhipalam	Calicut	79-509	181-632
Eranhipalam	Kannur	60-535	121-543
Eranhipalam	REC	74-614	165-666
Eranhipalam	Ariyaduthupalam	62-625	190-666
Malaparamba	Kannur	35-526	290-652
Malaparamba	Thondayad	87-589	107-667

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Malaparamba	Calicut	55-609	109-650
Malaparamba	REC	61-532	105-636
Thondayad	Malaparamba	64-582	168-637
Thondayad	Trissur	57-575	175-709
Thondayad	Calicut	136-603	221-720
Thondayad	REC	156-621	174-616

MODEL DEVELOPMENT AND VALIDATION

In the present study a non-linear model is developed for delay at signalized intersections under mixed traffic flow conditions. In the model, delay is taken as dependent variable and flow, degree of saturation and percentage of heavy vehicles are taken as independent variables. The developed model is given in equation 3.

$$d=(e^{0.03\times q})+(465.571\times\log(X))+(387.28\times P\text{-}hcv)+898.870 \quad (3)$$

Where,d=average control delay per vehicle, q=flow in veh/hr, X=degree of saturation, P-hcv=percentage heavy vehicles.

Validation of the model is done using SPSS. *R*2 value is 0.894. RMSE value is 12.872. From the model, it is clearly visible that delay increases exponentially with flow, increases logarithmically with degree of saturation and linearly with percentage heavy vehicles. A standard relation between control delay and flow has been observed and it is shown in figure 4.

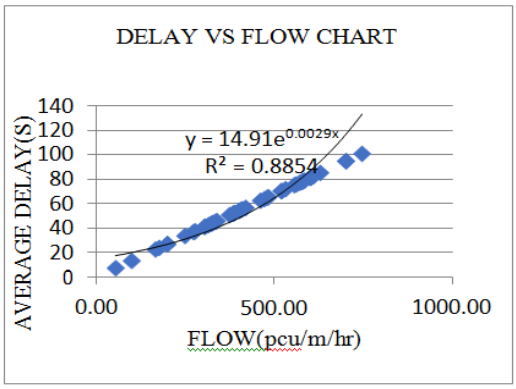


Fig: 4. Delay vs flow diagram

As seen in Figure 4, the field control delay is exponentially related to its flow, varies logarithmically with degree of saturation, and varies linearly with fraction of heavy vehicles. The created model predicts control delay values accurately for both under and over saturated settings, and it may be employed in mixed traffic scenarios.

COMPARISON OF DELAY VALUES

Table: 2. Comparison of delay values

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Name of the intersection	Name Of the approach	Field delay(s)		Model delay(s)	
		Min	Max	Min	Max
Eranhipalam	Ariyaduthupalam	62	625	178	663
	Calicut	79	509	80	555
	Kannur	60	535	35	541
	REC	74	614	117	659
Malaparamba	Calicut	55	609	70	626
	Kannur	35	526	121	615
	REC	61	532	71	538
	Thondayad	87	589	103	652
Thondayad	Calicut	136	603	182	699
	Malaparamba	64	582	30	588
	REC	156	621	203	642
	Trissur	57	575	172	650

Table 2 compares field delay values, model delay values, and delay values from Webster's model. When compared to Webster's delay values, it is obvious from table 2 that the range of delay values produced from the created model is near to those acquired from field measurements.

CONCLUSIONS

The calculated saturation flow values are similar to those observed in the field. The Saturation flow is shown to be directly linked to the breadth of the intersection's approach. It has also been discovered that delay has an exponential connection with flow, a logarithmic relationship with degree of saturation, and a linear relationship with the percentage of heavy vehicles in traffic. The suggested delay model has an excellent correlation with field observed delay, and the separate models outperform the combined model in terms of estimating delay due to high R2 and low RMSE values. The proposed model can forecast delay for both under and over saturation circumstances. The field delay values are compared to both model and Webster's model delay values, and it is found that model delay values are near to observed delay values.

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