ESTIMATION OF INTERSECTION DELAY WITH THE AID OF SIMULATION

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Abstract - In a heterogeneous traffic condition where vehicle do not follow lane discipline, delay estimation at signalized intersections is complex. Delay at an intersection affects the overall efficiency of the road network. Various methods for measuring control delay in field at Signalized intersection for under and oversaturated conditions is as follows, Test car delay measurement; Tracing path of individual vehicles; Recording arrival and departures manually; Input - Output techniques; Zoned survey technique; and Hybrid technique. In both these methods either observers or sensors are placed in the queuing locations and they count the number of vehicles entering the queue. These methods become uneconomical. Data collection information for the investigation was completed in Thuraipakkam intersection in IT Corridor, Chennai through Video graphic survey and GPS was fitted in 10 probe vehicles runs at the study intersection. Traffic flow rate and turning movements were obtained from video graphic records. With the probe vehicle data, control delay (which includes acceleration, deceleration and stopped delay) was estimated for all the runs. Stopped delay was calculates for each cycle by recording the time of arrival and departure of vehicles. A micro simulation model was developed for the study intersection with VISSIM software. The results of the measured delay and that estimated by simulation model was compared and reported in this paper.

Keywords – Delay control, Simulation, VISSIM, Intersection, US-HCM

I. INTRODUCTION

Delay is the difference between the time required by an unimpeded passage of a flow unit through the intersection and the time actually needed under the prevailing geometric, traffic and control conditions. The delay can be classified as Stopped; Approach; Travel time ; Time in Queue ; and Control Delay. The need for the study to simulation are average delay per vehicle, average queue length, and number of stops. Signalized intersection is the place for through and turning movements of traffic flows, where conflicting traffic are segregated by time for safe crossing, therefore vehicles are subjected to the delay. When the delay is minimized the overall efficiency of the network can be improved. Hence the task of proper planning, analysis and performance evaluation of road infrastructures is complex but mandatory. The main objectives of the study are, To collect data from the field in the study intersection with the help of video graphic survey and vehicle trajectory data from the GPS fitted in probe vehicles. To analyse the probe vehicle data and to estimate the field delay experienced by various category of vehicles. To develop a model for the estimation of control delay at signalised intersection for Indian heterogeneous traffic condition. To develop a simulation model for the study intersection using VISSIM software and calibrated to justify the results of the developed model. To compare the results obtained from the developed model, field estimated delay and the results from the simulation model.

Cesar A. Quiroga and Darcy Bullock (1999) worked on the measurement of control delay at signalized intersections. A methodology to compute delay at signalized intersections using GPS receivers and GIS dynamic segmentation tools for the measurement of control delay which includes deceleration delay, acceleration delay and stopped delay was proposed.

Ragab M. Mousa (2002) worked on the analysis and modelling of measured delays at isolated signalized intersections. Their study was to give a new methodology for delay measurement using the field data collected from an isolated signalized intersections in Muscat city. The data collected from field by tracing the individual vehicle trajectory with the help of 12 screen lines in upstream and downstream of the intersection approach. The vehicles deceleration ranged between 0.23 to 1.2 m/s2 and the acceleration ranged between 0.6 to 0.9 m/s2. The average deceleration - acceleration delay was estimated as 11.8s. The results obtained were compared with the HCM model of control delay and it was found that the HCM delay estimates more delay than the actual one.

Wassim kebab (2007) worked on the field measurement of approach delay at signalized intersection using point data. The cameras were so placed to record the three different vehicle events. The results are compared with the HCM queuing delay model. The method discussed in this, measures through delay accurately than the HCM method. Because it is possible to reliably measure turning movement delay with only point detection traffic data.

Anuj Sharma and Darcy bullock (2008) compared the field evaluation of alternate real time methods for estimating approach delays at signalized intersections. They compared three techniques, they are Input Output (IO) technique, Hybrid technique, and HCM delay model. The average delay results for morning phases were 10.22, 12.35 and 8.89 seconds and for evening phases were 40.95, 42.91 and 42.91 seconds for IO technique, Hybrid technique and HCM delay estimation methods. All the three technique gave more or less same results with very less variation. Hence they concluded by saying HCM delay model can be used at the initial stage for estimating delay until any special cases occurs. Among IO and Hybrid technique, hybrid technique seems to be more accurate in data collection and delay estimation.

Chu Cong MINH (2009) determined the delay estimation under heterogeneous traffic conditions. This study was to improve the conventional Webster's delay model using taylor series. Saturation flow was determined using multiple regression analysis and with the PCU values of vehicles saturation headway was estimated and saturation flow was determined. Delay was estimated using Webster's formula. Taylor series was used to expand the Webster's formula and to find out the mean and variance of delay. The results showed the delay estimated by the proposed method was accurate than the conventional Webster's model.

R Prasanna Kumar and G Dhinakaran (2012) worked on estimation of delay for the mixed traffic for a developing country. They selected five 4-armed intersections in an individually fast developing city of Tamil Nadu, India. All these intersections had similar geometry and least hindrance of pedestrian, bus stops, parked vehicles etc. The data was collected by video cameras. The study intersections 1, 2 and 4 are operating at LOS "B" with average control delay of intersection 23.11, 26.71 and 22.05 s/PCU respectively. Whereas the other two intersections namely Intersections 3 and 5 operating at LOS "A" with average control delay of intersection 14.64 and 13.5 respectively. The difference between measured delay and theoretical delay is quite high that one single adjustment factor for the HCM delay procedure cannot be developed.

Pruthvi Manjunatha (2012) attempted to develop a methodology for calibrating a micro simulation model for Indian mixed traffic conditions. The methodology was tried with the help of VISSIM software. Indian heterogeneous condition constitutes of vehicles having diverse static length, width, etc., and dynamic acceleration/deceleration and velocity. In this paper tried to identify the calibration parameters by multi parameter sensitivity analysis and setting their ranges heuristically and determining the parameter values by an optimization model. The lateral and longitudinal spacing was less when compared to the default values. The proposed methodology with genetic algorithm can be used for Indian mixed traffic condition.

Siddharth and Gitakrishnan Ramadurai (2013) presented a study on Calibration of VISSIM for Indian heterogeneous traffic conditions. This paper gave an automatic method of calibration of VISSIM model after choosing the calibration parameters and by analyzing it with ANOVA a statistical technique. Data required for the model was collected from the TIDEL park intersection in IT corridor, Chennai. The vehicle flow input was given in start of link near first foot over bridge and the outflow was found by placing detectors after intersection. They processed the prepared model number of times using sensitivity analysis and determined the calibration parameters affecting the driving behavior. With number of sensitivity analysis trails they finally reached a stage where the error was 7.47 and

7.79% between actual and simulated flow. Automated calibration reduces the manual effort of calibrating the VISSIM model.

Thamizh Arasan V and Vedagiri P (2006) worked on the estimation of saturation flow of heterogeneous traffic using computer simulation. Their study was to shoe the effect of road width on saturation flow measured in passenger car units (PCU) per unit width of road. They used HETROSIM to develop a model and to replicate the heterogeneous conditions. The traffic flow at the study intersection was recorded for 30 signal cycles. The model gave PCU values of 2.5, 2.5, 1.2, 1.0, 0.6, 0.35, 0.3 and 1.2 for bus, truck, LCV, car, three wheeler, two wheeler and tricycles respectively. The developed simulation model was compared with the actual field results which gave an average of 5.8% error. It has also been found that under heterogeneous traffic conditions, there is a significant increase in the saturation flow rate in PCU per meter width with increase in the width of approach road.

Joonho Ko et al. (2006) worked on measuring control delay using second by - second GPS speed data. They proposed a new approach to identifying control delay components based on second by-second vehicle speed profiles obtained from GPS devices. This suggested that this methodology could be applied to any GPS probe vehicle data to present the control delay at signalised intersection. Their methodology worked on smoothening the speed profile of probe vehicles and prepared a acceleration based algorithm which detects deceleration onset points and acceleration ending points. In addition, stopped time periods were directly identified from de-noised speed profiles. With the help of this algorithm huge data could be automated and analysis can be made simple.

Kai Liu et al. (2010) worked on the estimation of delay time at signalized intersections by probe vehicles using advanced traveller information systems (ATIS). They tried to simplify the comprehensive process of measuring control delay. They developed 2 algorithms of different frequencies, one with high frequency probe data at 5 second intervals and other at lower-frequency data from 10 to 60 seconds. Data was obtained from ten probe vehicle taxis at the high frequency of 5 seconds interval. Acceleration-time graph was plotted for different frequencies like 5, 10, 20, 30, 40, 50, 60 seconds. By comparing the data high frequency data set showed the exact trajectory of the vehicle. The 5 seconds data have the advantage of judging travel conditions accurately and thus provides much better delay results. The 10 seconds probe data provides correct judgments in about 74% of cases and has an average error of 12% in delay time. Hence they concluded by stating lower frequency data are not suitable for developing algorithms for estimating delay.

II. Background

Initially identification of the Problem in the determination of study area. In the selection of study area was T - intersection, which includes Pallavaram, Madhya kailash, and Siruseri. Here, the Delay estimation is calculated by using Video graphic survey camera 1 fitted on Thuraipakkam road to cover straight movement from madhya Kailash to siruseri and right turning movement from madhya Kailash to Pallavaram. Camera 2 fitted on again Thuraipakkam road to cover straight movement from siruseri to madhya Kailash and right turning movement from siruseri to Pallavaram. Delay was measured by using GPS fitted were in the probe vehicles of two autos, three cars, five two wheelers. While we started to collect the secondary data of the Geometrics of the intersection which includes Road width, Median width, Gradient, Turning radius. These data has been extracted for further used to find out the vehicle trajectory. Development of analytical model is used for control delay estimation. Comparison of delay model with existing analytical model presented by developed countries. Hence finding the results and presented the conclusions.

2.1. Study Intersection–

Study signalized intersection is located in Okkiyam Thuraipakkam. It is a T - intersection (Thuraipakkam - Pallavaram) and is a part of IT expressway shown in figure 1. IT expressway is a 6 - lane divided with curb separated service roads. It is a major arterial in Chennai which runs from Madhya Kailash temple near Adyar and continuing south till Mahabalipuram. Major approaches of the intersection connect siruseri on one side and madhya Kailash on the other side along the IT expressway. The signal also helps in regulating the traffic coming from Pallavaram and merging into IT expressway. The approach from Pallavaram is a 4 – lane divided carriageway.

Figure 1. Google Maps of Thuraipakkam Signalized Intersection

III. EXPERIMENT AND RESULT

3.1 Data Collection–

Data collection was collected on a fine week day during peak hours at the study intersection through two different methods.

- Video graphic survey and
- Vehicle trajectory data.

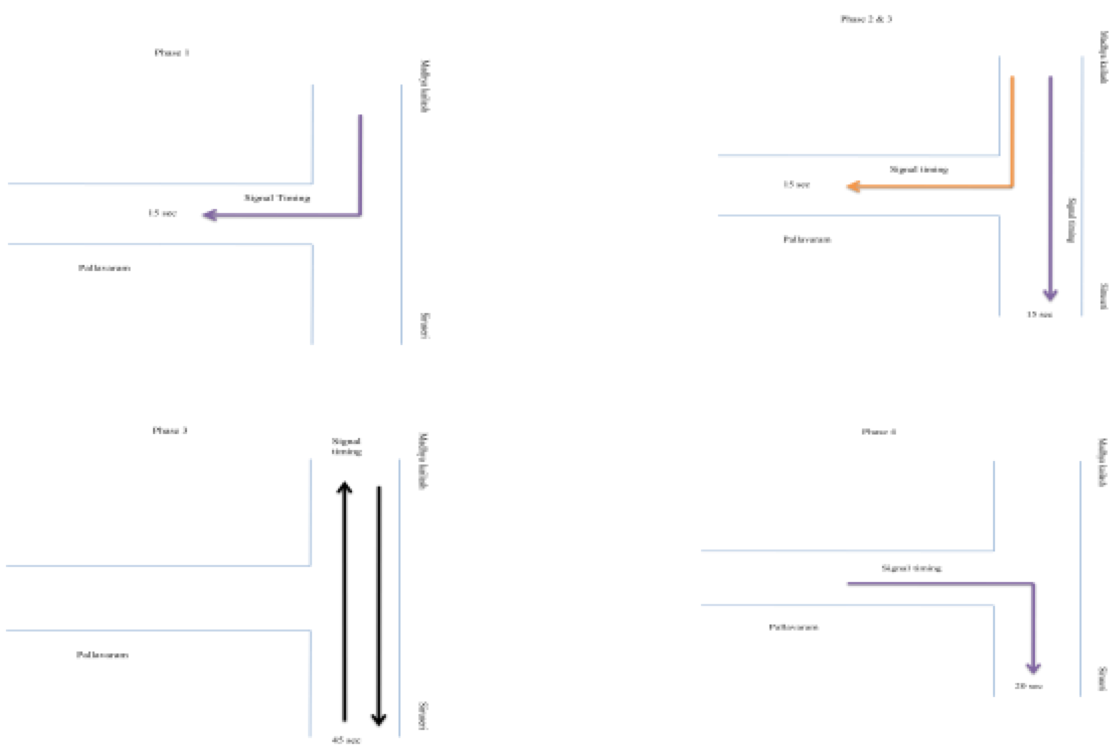


Figure 2. Details of Signal Phase Timings

The detailed split up of the signal timing for the four phases is as shown in figure 2. The traffic signal is being operated in four phases with fixed cycle time of 103 seconds which includes amber time of 8 seconds. In this the major approach had a big share in cycle time. Traffic movement from Madhya Kailash to Siruseri and Madhya Kailash to Pallavaram has 60 and 15 seconds of green time respectively. Similarly green time for the straight movement from Siruseri to Madhya Kailash takes 45 seconds.

3.2 Video graphic Data–

Video graphic survey was carried out with the help of 2 cameras fitted on buildings near the study intersection. Video was recorded for duration of 6 hours from morning 11 am till evening 5 pm. Video graphic survey was done during the time when signal was operated automatically with fixed timings during non-peak hours. Because during peak hours signals are operated manually where the green time of an approach is extended till the queue is empty, which leads to enormous amount of unexpected delay and long queue length. Capturing such long queue length is practically not possible with camera. Hence data was proposed to collect during fixed time signal only when the traffic volume was not too high.

Figure 3. Camera 1 View of the approach from Pallavaram to Siruseri

Figure 4. Camera 2 View of the approach from Pallavaram to Madhya kailash

In Figure 3, Camera 1 fitted on the intermediate location started from Pallavaram to madhya kailash for cover the straight movement from siruseri to madhya kailash and turning movement from siruseri to Pallavaram. Figure 4 Camera 2 fitted on the intermediate location started from Pallavaram to madhya kailash for cover the straight movement from madhya kailash to siruseri and turning movement from madhya kailash to Pallavaram.

3.3 Vehicle Trajectory Data–

GPS units were fitted in the different category of vehicles which includes two autos, three cars and five motorized two wheelers. All these GPS fitted vehicles were made to run along with the traffic to cross the intersection and the vehicle trajectory was obtained. GPS unit records the location by means of latitude and longitude for every 10 seconds with the speed of the vehicle. The delay estimation here is done with the help of 10 second data stamps obtained through GPS units fitted in 10 probe vehicles. Hence in order to justify the developed delay model accuracy, the accurate delay measure with 1 second interval data was also collected. A probe vehicle (car) was fitted with a GPS unit which gives data for every 10 seconds.

Table - 1 Details of probe Vehicle Runs fitted with GPS

Category of probe vehicle		Runs (upward + downward)	Total Runs
Auto	1	26+26	52
	2	8+8	16
Car	1	16+16	32
	2	14+14	28
	3	20+20	40
Two Wheeler	1	37+37	74
	2	13+13	26
	3	3+3	6
	4	40+40	80
	5	24+24	48
Total Runs		201+201	402

Table 1 shows the details of the GPS vehicle runs.

3.4 Data Extraction–

Data extraction was done for both the type of data collected. Video graphic data was extracted for the signal timings, flow rate, turning movements, traffic composition, queue length, etc. video was played repeatedly to get the classified volume count of the approach arms of the intersection. The GPS unit transmitted the data to the server and the details of the run like date, time, status, latitude , longitude, speed, altitude were estimated in a excel spreadsheet for every 10 seconds interval.

Figure 5. Snapshot of the video extraction software

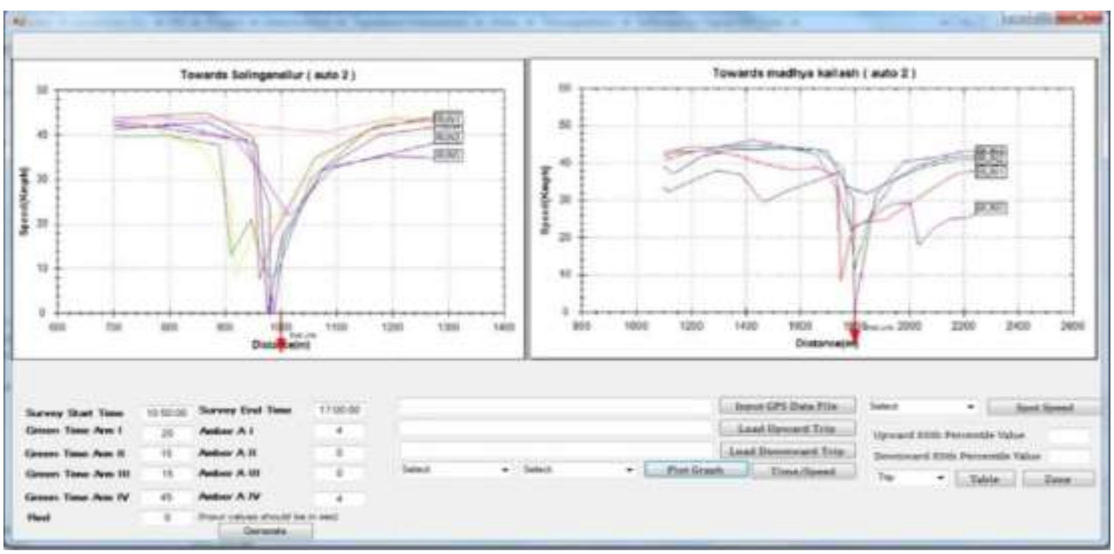
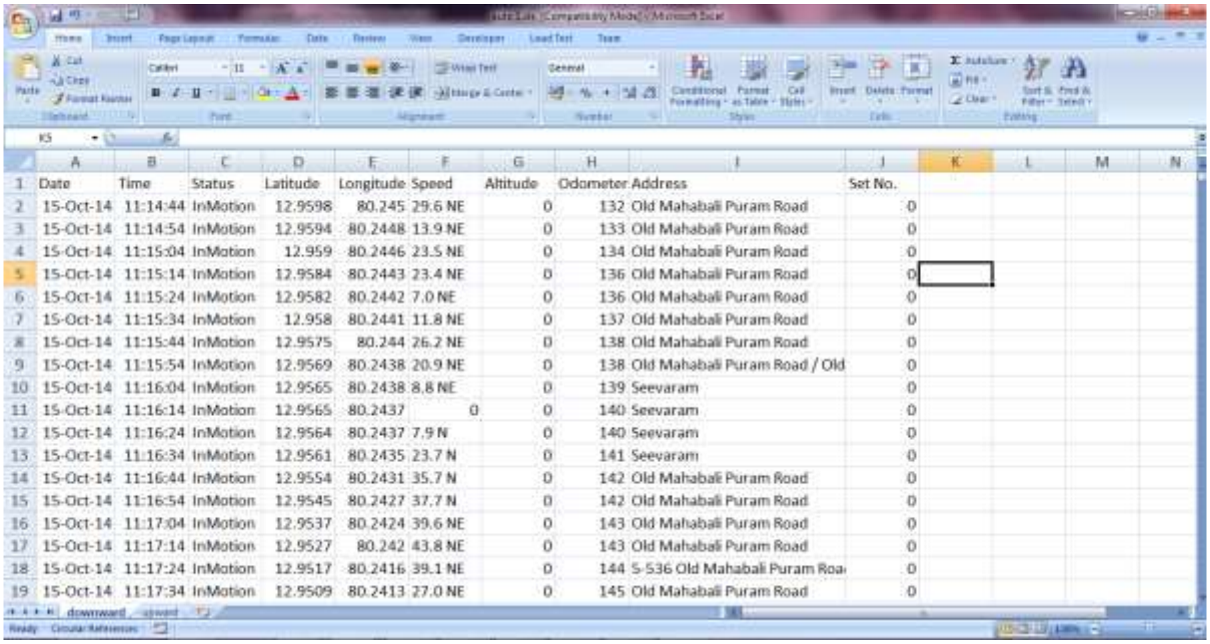


Figure 6. Snapshot of the GPS data extraction software.

Figure 5 and Figure 6 shows the data extraction applications which were developed in-house for the extraction of video graphic and GPS data respectively.



Date	Time	Status	Latitude	Longitude	Speed	Altitude	Odometer	Address	Set No.
15-Oct-14	11:14:44	InMotion	12.9598	80.245	29.6 NE	0	132	Old Mahabali Puram Road	0
15-Oct-14	11:14:54	InMotion	12.9594	80.2448	13.9 NE	0	133	Old Mahabali Puram Road	0
15-Oct-14	11:15:04	InMotion	12.959	80.2446	23.5 NE	0	134	Old Mahabali Puram Road	0
15-Oct-14	11:15:14	InMotion	12.9584	80.2443	23.4 NE	0	136	Old Mahabali Puram Road	0
15-Oct-14	11:15:24	InMotion	12.9582	80.2442	7.0 NE	0	136	Old Mahabali Puram Road	0
15-Oct-14	11:15:34	InMotion	12.958	80.2441	11.8 NE	0	137	Old Mahabali Puram Road	0
15-Oct-14	11:15:44	InMotion	12.9575	80.244	26.2 NE	0	138	Old Mahabali Puram Road	0
15-Oct-14	11:15:54	InMotion	12.9569	80.2438	20.9 NE	0	138	Old Mahabali Puram Road / Old	0
15-Oct-14	11:16:04	InMotion	12.9565	80.2438	8.8 NE	0	139	Seevaram	0
15-Oct-14	11:16:14	InMotion	12.9565	80.2437	0	0	140	Seevaram	0
15-Oct-14	11:16:24	InMotion	12.9564	80.2437	7.9 N	0	140	Seevaram	0
15-Oct-14	11:16:34	InMotion	12.9561	80.2435	23.7 N	0	141	Seevaram	0
15-Oct-14	11:16:44	InMotion	12.9554	80.2431	35.7 N	0	142	Old Mahabali Puram Road	0
15-Oct-14	11:16:54	InMotion	12.9545	80.2427	37.7 N	0	142	Old Mahabali Puram Road	0
15-Oct-14	11:17:04	InMotion	12.9537	80.2424	39.6 NE	0	143	Old Mahabali Puram Road	0
15-Oct-14	11:17:14	InMotion	12.9527	80.242	43.8 NE	0	143	Old Mahabali Puram Road	0
15-Oct-14	11:17:24	InMotion	12.9517	80.2416	39.1 NE	0	144	S-536 Old Mahabali Puram Roa	0
15-Oct-14	11:17:34	InMotion	12.9509	80.2413	27.0 NE	0	145	Old Mahabali Puram Road	0

Figure 7. Snapshot of the 10 Seconds GPS Data

The snapshot of the excel sheet of GPS data of runs made by an auto is shown in figure 7.

3.5 Traffic flow characteristics at the Study Intersection–

The study intersection has a cycle time of 103 seconds with four phases. Data was extracted to obtain the hourly volume count, turning movement, composition of traffic of the intersection.

Table - 2 Hourly Volume Count of Study Intersection

Vehicle Type	11 AM - 12 PM	12 PM - 1 PM	1 PM - 2 PM	2 PM - 3 PM	3 PM - 4 PM	4 PM - 5 PM
Bus	**278**	**189**	**212**	**198**	**263**	**328**
Auto	**345**	**312**	**321**	**278**	**304**	**476**
Car	**1760**	**1530**	**1340**	**1598**	**1774**	**1881**
LCV	**489**	**398**	**343**	**603**	**515**	**522**
Jeep/Tempo	**402**	**412**	**458**	**504**	**437**	**449**
HCV	**109**	**134**	**149**	**111**	**155**	**152**
Two Wheeler	**3994**	**4096**	**3502**	**3450**	**3511**	**4468**
Total	**7377**	**7071**	**6325**	**6742**	**6959**	**8276**

Table 2 shows the hourly volume count of all the category of vehicles for all the six hours data collected.

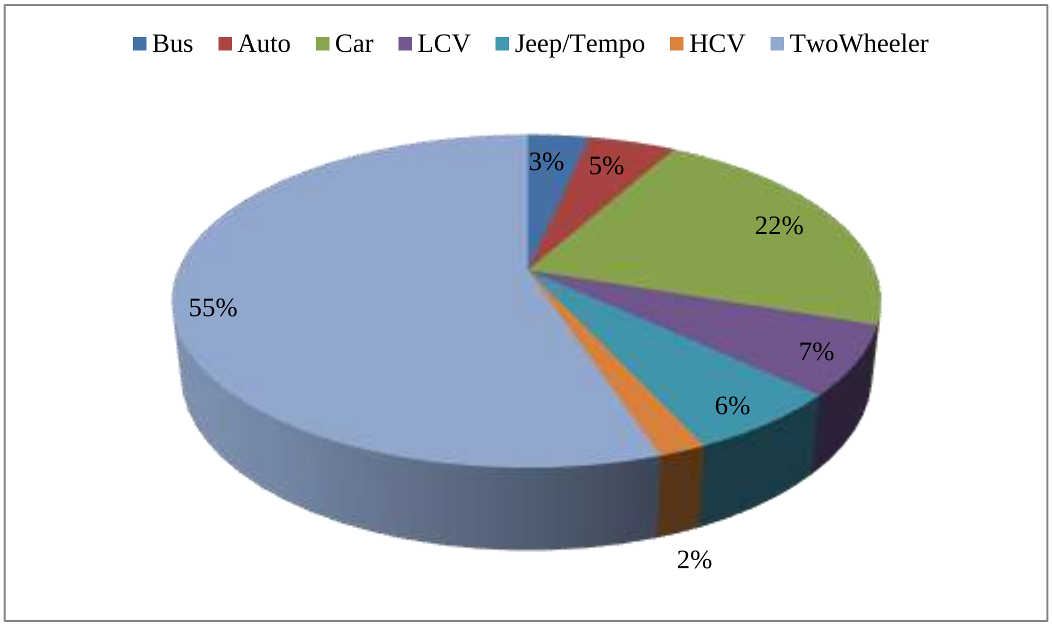


Figure 8. Average composition of traffic

Traffic was composed of 55% two wheelers which dominated the traffic. Composition of cars 22%, jeep with 6%, LCV with 6%, auto with 4%, bus with 3%, and HCV with 2% respectively as shown in figure 8.

Table - 3 Values of Delay components based on Red Time of the Approach

Vehicle Category	Delay Components	Average value of delay components with respect to red time (sec)		
		0 - 33% of Red time	33 - 66% of Red time	> 67% of Red time
Auto	Deceleration Delay	10.7	12.8	14.2
	Stopped Delay	31.6	12.7	3.5
	Acceleration Delay	12.3	14.7	13.6
Car	Deceleration Delay	12.0	11.2	8.9
	Stopped Delay	37.0	19.8	3.8
	Acceleration Delay	13.7	22.0	25.0
Two Wheeler	Deceleration Delay	19.8	13.9	11.7
	Stopped Delay	31.9	13.2	1.5
	Acceleration Delay	11.0	14.0	12.0

In table 3 the arrival time of probe vehicles with respect to red time of the corresponding cycle was categorised into 0 to 33%, 33 to 66% and greater than 67% of red time of the cycle and the average value of delay components for different category of vehicles were compared and presented.

It was observed that the vehicles arriving at the beginning of the red time experienced more stopped delay than the vehicles arriving greater than 33% of the red time. Because of the seepage behaviour of two wheelers into the traffic queue, it experiences a higher deceleration delay when the vehicles join the queue after 67% of red time. Two wheeler experiences lesser stopped delay when the arrival of vehicles greater than 67% of red time when compared to other category of vehicles. Auto and two wheeler experiences lesser delay when compared to car in all the three situation because of its seepage behaviour.

3.6 Development of Simulation Model using VISSIM–

Delay can also be measured with the help of a simulation software tool like VISSIM. Simulation is the process of imitating the real time characteristics of a system. Here the traffic flow characteristics observed at study intersection is simulated in the software and control delay is measured. Figures 9, 10, 11, and 12 shows the snapshot of the stages of development of micro simulation model. The simulation model is developed with the data collected from the study intersection. The observed parameters of study intersection like flow rate, turning movements, vehicle routing, traffic compositions, signal timing and phasing, vehicle input, data collection points, etc as shown in chapter 3 were used for the development of the model.

Figure 9. Screenshot of drawing links and connectors in VISSIM

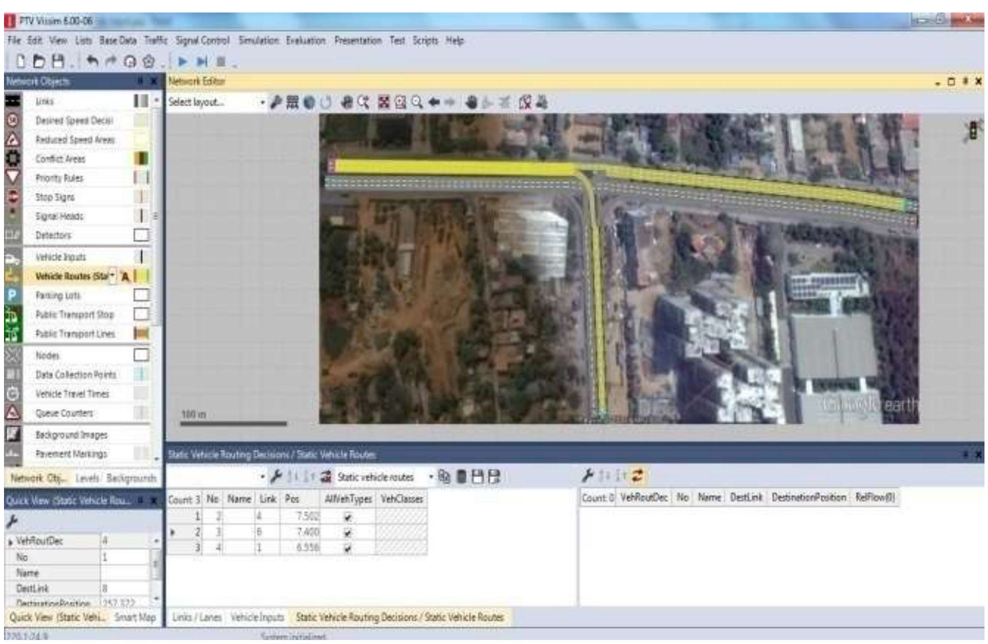


Figure 10. Screenshot of Vehicle Routing in VISSIM

Figure 9 shows the snapshot of creating links and connectors of the approaches of the study intersection. Figure 10 depicts the creation of vehicle routes for the turning movements.

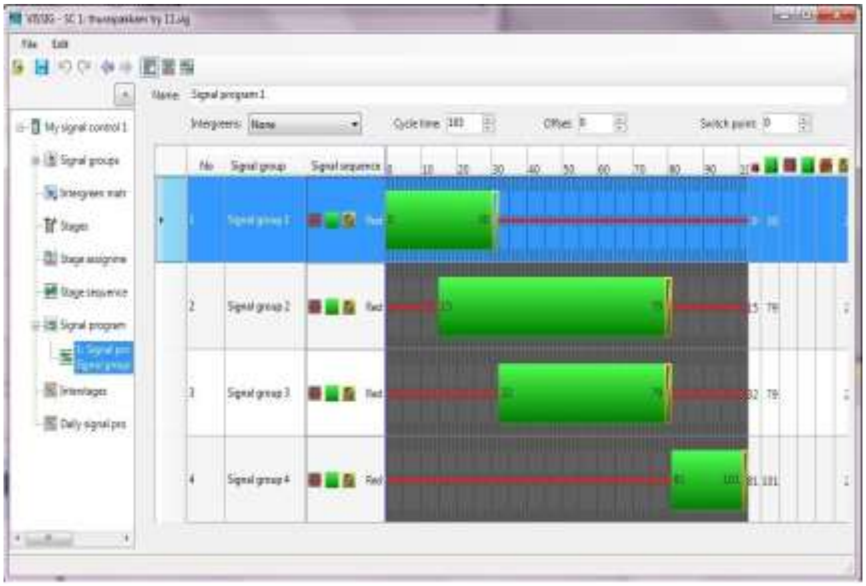


Figure 11. Screenshot of signal phasing in VISSIM

Figure 12. Screenshot of Simulation in VISSIM

The signal timing and phasing was entered in the signal control settings as shown in figure 11. Finally the model is simulated for a certain time period (say 1 hour). Screenshot in figure 12 was during the simulation run in VISSIM. Calibration based on driver's behaviour is done by observing the driver and vehicle characteristics in the site.

Table - 4 Parameters for Calibration of the Model

Parameters		Default Value	Value
Average Standstill distance		2.00	1.00
Additive part of safety Distance		2.00	0.20
Multiplicative part of safety Distance		3.00	0.75
Minimum Headway (front/rear)		0.50	0.10
Safety distance reduction factor		0.60	0.50
Lateral spacing (@ 0 kmph)	Car, Big Car, LCV	1.00	0.30
	Bus, HCV	1.00	0.35
	Bike, Auto	1.00	0.10
Lateral spacing (@ 50 kmph)	Car, Big Car, LCV,	1.00	0.75
	Auto, Bike	1.00	0.50
	Bus, HCV	1.00	1.00

In table 4 the calibrated parameters with the default and the calibrated value used for the simulation model are as listed.

Table - 5 Comparison of simulation results - flow rate

Approach	Flow (veh/hr)		
	Simulated	Actual	Error %
From Madhya Kailash to Siruseri	2322	2226	4.31%
From Siruseri to Madhya Kailash	2367	2212	7.01%
From Madhya Kailash to Pallavaram	1654	1512	9.39%
From Pallavaram to Madhya Kailash	1105	1009	9.51%
Total Flow	7466	6959	7.03%

In table 5 the results of the calibrated simulation run and the actual observed results were compared and the difference was identified. The simulation model gave an average of 7.03% difference in flow rate when compared the observed flow rate as presented.

3.7 Comparison of Measured Delay and Estimated Delay–

The developed delay model is compared with the other analytical delay model developed by other countries. The delay values were computed for various degree of saturation for all the delay models. In this comparison, the Webster's delay model goes oblate beyond the degree of saturation one. Other models predict for over saturated conditions. According to a study made by Prasanna kumar [9], US HCM delay model gives twice the delay than the field observed average stopped delay, which is observed in this comparison. The delay estimates of the developed delay model were close with the estimates computed from Australian delay model.

Table - 6 Comparison of Simulation results – Delay

Approach Name	Delay Type	Delay (sec)		
		Simulated	Actual	Error %
Traffic from Madhya Kailash	Stopped Delay	45.37	49.38	8.12%
	Control Delay	110.11	103.23	6.67%
Traffic from Siruseri	Stopped Delay	38.29	42.22	9.31%
	Control Delay	98.21	91.99	6.77%

In table 6 the control delay and stopped delay of the major approaches were compared and the average difference in percentage was 7.34% and 8.04% for flow towards Madhya Kailash and Siruseri respectively.

Thus the simulation model gave results with less than 10% error. A calibrated simulation model was compared with the actual flow and delay values, where the average error was 7.03% for the actual and simulated flows. Similarly the delay results were also compared with the simulation model results. It was observed an average error of 7.72% was observed during the comparison.

IV.CONCLUSION

Measurement of delay at signalised intersection in India is carried out at the field by involving number of observers. This way of measuring delay is not economical and varies with intersections. No analytical model or methodology has been proposed for the estimation of control delay at signalised intersections for Indian traffic conditions. Analytical models developed by foreign countries for delay estimation doesn't suit our mixed traffic conditions. Hence, data collected with the help vehicle tracking system using GPS which provides trajectory of the vehicles and location data at regular intervals. This data was analysed and delay results were obtained. Traffic flow characteristics of Thuraipakkam intersection were recorded, extracted and analysed.

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