MEASURING SPEED VARIATION BASED ON VEHICLE MOVEMENT MECHANISM AT SIGNALIZED INTERSECTION BY PROBE VEHICLE DATA UNDER HETEROGENEOUS TRAFFIC CONDITION: A CASE STUDY IN SURAT CITY

[1]Jayesh Juremalani, [2]Anand Brahmbhatt
[1st]Assistant Professor, [2nd]P.G. Student
[1] Civil Engineering Department, Parul Institute of Engineering and Technology, Parul University, Vadodara, India.
[2] Civil Engineering Department, Parul Institute of Engineering and Technology, Parul University, Vadodara, India.

Abstract : Intersection is an important point in a road network and there are numbers of intersection in Surat city. The prime objective of traffic signal control is to minimize vehicular conflict and delay. Speed is inversely proportional to the delay and it is observed that there is a reduction in speed which is causing delay, which affects travel time. Variation of delay at an intersection has a significant effect on travel time reliability. Measurement of delay depends upon various factors such as signal cycle, saturation flow, arrival and departure of vehicles, types of intersection, amount of traffic volume, composition of vehicles and type of traffic control system, etc. Intersection in most of the Indian cities are fixed time signalized intersection. Generally, we consider total travel time for a trip which includes a delay that might be due to traffic or signalized intersection or pedestrian or any other unavoided circumstances. The aim of the paper is to measure the delay variability and to find out what amount of delay accounts to signalized intersection in total travel time. Delay variability helps in predicting total travel time variability and helps in estimating accurate travel time. From the analysis, it is observed that the 3W has higher average speed in conflict area compare to 4W and lower speed at the mid-block zone. From the analysis we can conclude that the speed reduction is more than 50% at a signalized intersection.

IndexTerms **- Vehicle Movement Mechanism, Signalized Intersection, Delay, V-box, Travel time reliability, Heterogeneous traffic**

I. INTRODUCTION

In developing country flow of traffic is heterogeneous in nature and depends on vehicle characteristic, road geometry, driver behavior, etc. As the width of road is limited and due to urbanization there is an enormous growth in vehicles which leads to congestion and increases delay. The solution to this problem as the signalized intersection is more economical than providing interchanges and heavy infrastructures. Looking at the traffic problem Surat city is not an exception. At the time of designing signalized intersection finalizing the length of signal cycle is difficult due to various reasons such as random arrival and departure of vehicles. When going for a trip, generally we consider total travel time but delay variability is also important consideration to select the proper route. This travel time variability on a higher level can be used to rank and select the two alternative routes and to finalize the cost which the user can pay if we provide a route with reliable travel time.

Surat is the economic capital, Former sea trade hub of Gujarat and along with that, it is the fastest growing city of India. The selected intersection is Sahara Darwaja, which is located at 1 km from the Surat railway station. The junction carries traffic from all the three directions i.e. Delhi Gate, Udhna Darwaja and New Bombay market side. The area is surrounded by different textile markets, service centers like banks, travel agencies etc. The efficiency of traffic operations at Sahara Darwaja is very important as the majority of regional traffic and local traffic of the city; passing through ring road; connecting western and eastern part of the city passes through this intersection. Handling traffic operations at this junction has always been a challenging task for the municipal corporation and the enforcing agencies due to very high volume of mixed traffic as well as pedestrian traffic due to the presence of a number of textile markets in the vicinity of the intersection.

Intersection in city roads are present at very shorter spacing, as the spacing between the intersections is less on a stretch which results in higher delay and finally increases delay variability. Intersection is the location where the driver tries the increase or decrease the speed based on traffic flow and signal indication. Sometimes when the flow is less the aggressive drivers attempt to increase the speed and try to exit the intersection before green lights turns red. The distance which the driver covered thinking to accelerate or retard is termed as dilemma zone. The speed reduces considerably at signalized intersection. The point at which the speed of driver decreases reaches to zero and finally accelerating up to the normal speed is considered as intersection conflict area. To measure the delay at signalized intersection accurately it is important to divide it in various parts. This study finds the delay at various sections

which are described in following sections. Delay variability helps in predicting total travel time variability and helps in estimating accurate travel time.

The main aim of this study is to measure speed variation.

II. DATA COLLECTION

Following two field studies were carried out on the1st March 2019.

2.1 Classified Volume Count Survey

Sahara Darwaja is having the busiest signalized intersection in Surat which is located close to the railway station and having large vehicular and pedestrian traffic. Videography survey was carried out at morning for 5 hours (7:00 A.M. to 12:00 P.M.) consist of 2 hours of peak (10:00 to 12:00) and 2 hours of off-peak (7:00 A.M. to 9 A.M.) traffic. From the videography survey classified volume count has been extracted at the interval of 5 minutes for 5 hours so, additionally we can see the trend in the change of vehicle flow from off-peak to peak hour. The classified volume count data was extracted for the arriving traffic at an interval of 5 min. Following categories of vehicle has been considered 2W, 3W, 4W, Bus, Light Commercial Vehicle and Truck. Along with this we have collected information about the existing cycle time at signalized intersection. Free left turn is given for each approach so, basically it does not conflict with the flow of vehicle at signalized intersection therefore there is no need to consider the flow.

2.2 Speed and Delay Survey

In this study, the speed profile of stretch was collected using Performance Box (V-BOX) which works based on the Global Positioning System. Performance Box is an instrument which has been used to collect continuous data about travel time and speed over the selected sections of roads. This survey was conducted using 3 wheeler and 4 wheeler as Probe Vehicle which notes the moment to moment variation in speed. This survey was conducted simultaneously with 2 probe vehicle along with videography. Using this survey we have time versus speed and speed versus distance graph with an accuracy of 1/10th of second. Random trips were carried in both directions in peak and off-peak hour by probe vehicle. Both classified volume count and speed and delay surveys were carried simultaneously. The delay is noted for the distance of 500 meters covering the upstream and downstream side of total intersection which is consist of the vehicle speed decreases from normalizing speed and after the completion of intersection area again gaining its normal speed. The data has been analyzed for various delay components. The study stretch has been divided into 5 zones to note the traffic speed behavior.

III. DATA ANALYSIS

3.1 Traffic Volume and Composition

Traffic flow of each approach is presented in figure 1 in pcu/hr considering passenger car unit values given in Indo-HCM 2017 for signalized intersection. The traffic flow of Bombay market approach to Delhi gate direction is 1400 pcu/hr and delhi gate to udhna darwaja is 2250 pcu/hr. Where, as the traffic composition at both approach consist of higher values of 3Ws which more than 52% of the total mixed traffic. The mode wise share of the Bombay market approach and delhi gate approach is figure 2. The share of 2Ws is more than 30% and 4 wheelers share is 3%.

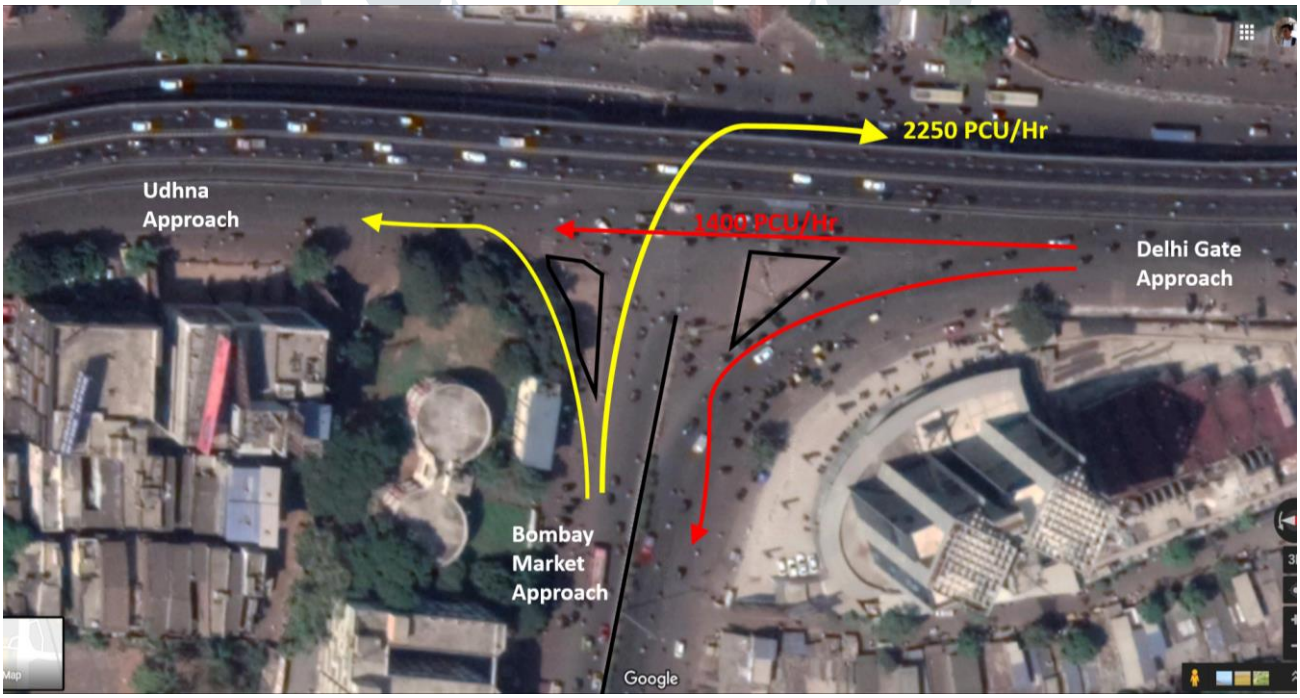

Figure 1 study location and traffic volume (pcu/hr) (source: google maps)

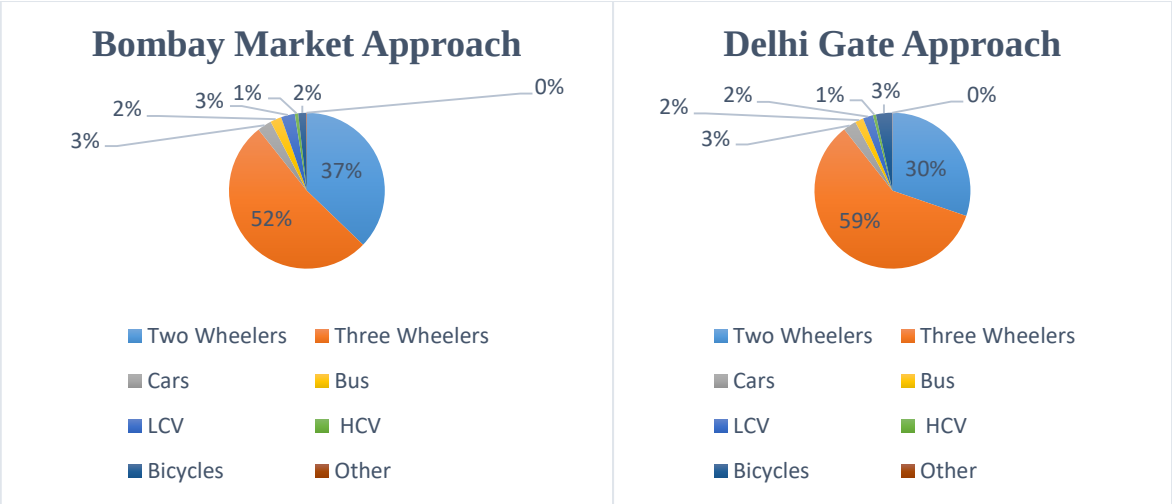

Figure 2 traffic composition at bombay market approach and delhi gate approach

3.2. Probe Vehicle Speed Variability Analysis

A. Formation of Study Sections

The speed profile using the probe vehicles has been carried out during off-peak and peak period for the stretch of 500 m inclusive of intersection area. Trips were carried out in off-peak and peak periods using both 4W and 3W as probe vehicles. A typical speed profile was taken by Probe Vehicle as shown in figure 3 indicates formation of three segments as an upstream side, downstream side and middle intersection conflict area. The vehicle movement mechanism can be realized for its variation through the five sections as marked in figure 3 to form four behavior zones (Table 1). Zone width variations and average values are extracted from speed profiles of the probe vehicles. Two zones are formed in pre and post conflict areas of intersection. The conflict area i.e. Section III, where the vehicle movements take place and due to intersection and various vehicular and pedestrian conflict which result in conflict points and increases the conflict area length.

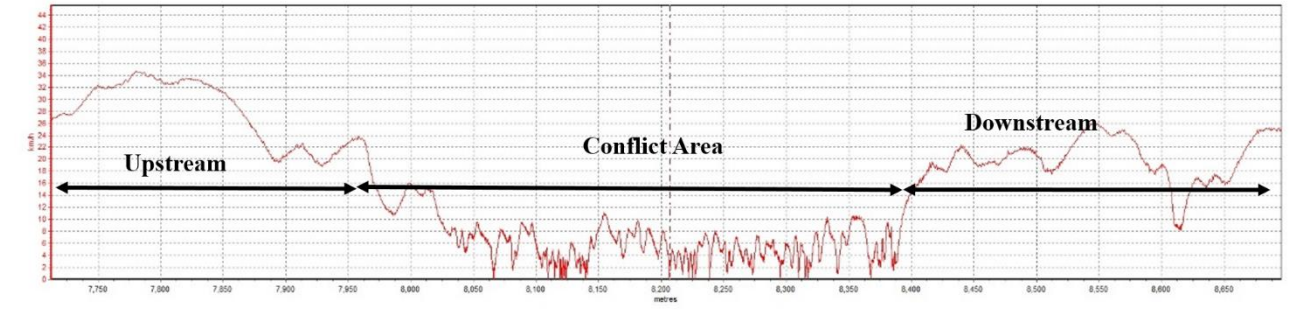

Figure 3 typical zone of speed profile of probe vehicle

Table 1 section zoning particulars

Section	Zone	Distance (m)
Section I	Mid-Block zone (Upstream)	-
Section II	Dilemma & Decision Zone	105 (60-150)
Section III	Intersection Conflict Area	150 (100-200)
Section IV	Normalizing Zone	110 (70-130)
Section V	Mid-block zone (Downstream)	-

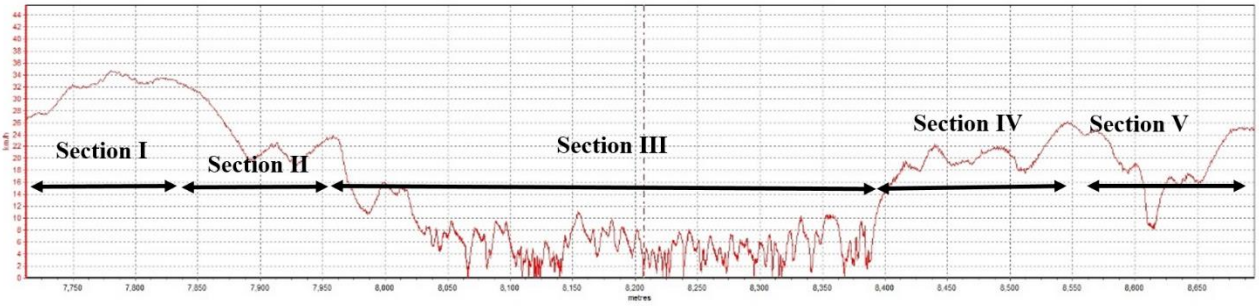

Figure 3 typical sections of speed profile of probe vehicle

B. Vehicle Movement Mechanism

Reduction in speed takes place from midblock to intersection conflict area (Section III). At this intersection the flow of vehicle and conflict between vehicle and pedestrian is significant this leads to longer length of conflict area. It sometimes it would be difficult for driver to clear this long conflict area by simply accelerating. Actually, the speed of driver reduces gradually and enters in the conflict area. The deceleration starts in section III when the driver enters the conflict area by joining the ahead waiting vehicles or moves slowly.

In downstream zone consist of two sections one is Normalizing zone and the second one is mid-block zone. Section III starts from the point when the speed of vehicle decelerates, joins queue and moves slowly and up to the point when the driver starts increasing the speed. From the point when the driver starts accelerating and reaches normal speed is zone IIIV which is normalizing zone. When the Vehicle attained the regular speed then starts the downstream mid-block section V.

3.3 Section wise Speed Variations

The speed variation depends on various factors such as driver's behavior and the driver takes decision based on traffic volume, signal indication, queue situations. The queue of vehicle depends on the arrival pattern of the vehicle. Queue has been started to accumulate when the signal is red. As soon as the signal ends initial vehicles in queue will exit the intersection at higher speed but the due to high vehicle flow and merging and diverging conflict between vehicles makes the remaining vehicles moves at the slow rate. They move at the crawling speed. This leads to a lengthy conflict area which is section III. The statistical Measures of 3W for five sections has been given in table 2 based on speed profile obtained by the probe 3W. In section I the speed of vehicle is higher as it is in mid-block section and the downstream side mid-block section has lower speed compare to the section I as it enters in a congested area as it would be difficult for 3W to accelerate in few seconds. In section II which is a dilemma zone where drivers take a decision so it has lower speed compared to the section I and V. Section III clearly shows the effect of signalized intersection where the speed has reduced drastically. The deviation and coefficient of variation are higher in section III.

Table 2 statistical measures: sectional speed (kmph) of 3w

	Section I	Section II	Section III	Section IV	Section V
Average	30	20	11	18	23
Min	25	14	2	11	20
Max	33	22	18	23	26
Standard Deviation	3.3	3.65	6.55	4.92	2.5
Coefficient of Variation	0.11	0.18	0.6	0.27	0.11

Same as above speed profile of 4W along with statistical measures is provided in table 3. Speed variation in section III is lower than 3w. While the speed is higher in section V compare to 3W as the 4W can accelerate in short duration which leads to an increase in average speed.

Table 3 statistical measures: sectional speed (kmph) of 4w

	Section I	Section II	Section III	Section IV	Section V
Average	45	30	9	15	35
Min	40	25	2	9	25
Max	55	35	18	22	45
Standard Deviation	6.24	4.1	6.6	5.31	8.17
Coefficient of Variation	0.14	0.14	0.73	0.35	0.23

The variation in speed pattern of 3W and 4W can be observed in sectional speed variation graph in fig. 4. It has been observed that the car has a higher speed than 3W and due to higher acceleration power, the speed of 4W again increases. The speed of 4W has reduced significantly in section III as car driver has less maneuverability compare to 3W. The 3W tries to penetrate the queue and fills the available gaps.

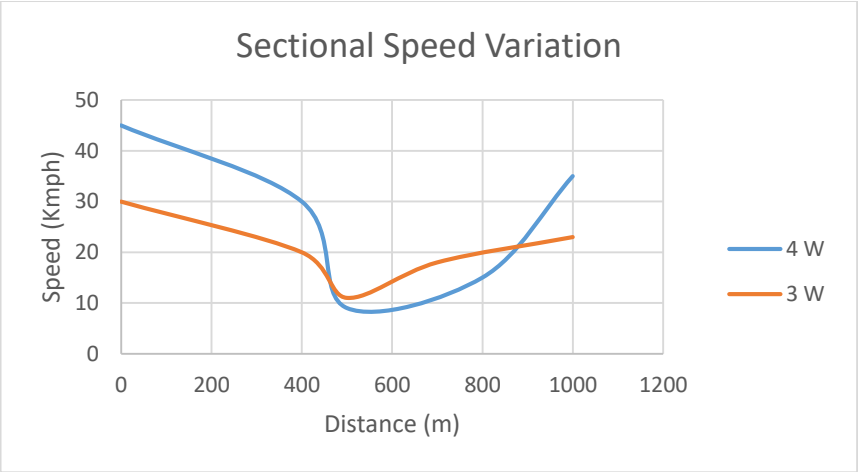

Figure. 4 sectional speed variations of 3w and 4w

IV. Results and Conclusion

Travel time variability is important to planner, designer and road users as it is associated with travel time. Here you can see due to the presence of signalized intersection there is a huge reduction in speed and based on speed profile it is observed that the vehicles crawl which leads to reduced average speed. In the case of 4 wheeler, the speed is reduced to 45 % in intersection conflict area. Travel time variability can be used to improve the traffic situation at signalized intersection. Travel time reliability can be used for simulation and evaluate the traffic parameters in VISSIM or any other transportation software with the help of microscopic simulation. We can also compare with the alternative routes or prioritize the route for the purpose of improving level of service and decreasing delay time.

The methodology used in this paper can be applied similarly to other intersection to find out travel time reliability. To apply this methodology there is need of speed profile of particular intersection. It is observed that the speed variation before, through and after signalized intersection. The data can be extracted using Geo-tracker mobile app as well, which is easily available. From the analysed data it is observed that there is a drastic reduction in speed and length of conflict area is almost 200 meter. Some of the researchers observed that 50 % of delay is due to the signalized intersection. The study here is an emphasis on the length of conflict area and dilemma and decision zone. Dilemma and decision zone is about taking decision to stop or accelerate or decelerate based on signal cycle and queue conditions. The intersection conflict area is more because of there is vehicle merging and diverging conflict between New Bombay Market approaches, traffic coming from Delhi gate approach. Sahara Darwaja is considerably important point from the consideration of intermediate public transport along with unusual pedestrian flow. This all factors has led to a reduction in speed which leads to increase in delay. Based on various section and its speed variation we can measure travel time variations.

The speed of vehicles goes down from mid-block to dilemma zone and reduce to stop or crawling speed when it enters intersection conflict area then again start accelerating and reach up to normalizing speed. While Comparing speed 3W Probe vehicle (Kmph) observed are 30, 20, 11, 18, 23 for the five zones respectively, whereas for 4W probe vehicle is 45, 30, 9, 15, 35in present study. The speed profile differs in both 3W and 4W. As the 3W has a tendency to move further in queue it has higher average speed and due to less acceleration power, it has lower speed in mid-block section. While as the 4W are tending to drive carefully due to which they have lower average speed in conflict area. Speed is inversely proportional to the delay and it is observed that there is decrease in speed which is causing delay, which affects travel time. In order to reduce the delay and increase average speed profile more clearance should be provided to the particular green approach to achieve this vehicle and pedestrian traffic should be managed by traffic officers.

References

[1] Krishna Saw, B. K. Katti, Gaurang Joshi, "Vehicle movement mechanism and delay variability analysis at signalized intersection by probe vehicle data under miced traffic condition: A case study in India" European Transport, Issue 68, Paper No. 1, 2018.

[2] Liu, K., Yamamoto T., Morikawa T., "Estimating Delay Time at signalized intersection by probe vehicles" Proceedings of International Conference on Traffic and Transportation Studies, pp.644-655,2006.

[3] Preethi, P., Varghese, A., Ashalatha,"Modelling delay at signalized intersection under heterogeneous traffic conditions," 11th Transportation Planning and Implementation Methodologies for Developing Countries, Mumbai, India, 2014.

[4] Darma, Y., Karim, R. Md., Jamilah, Md. Abdullah, S.,"Control Delay variability at signalized intersection based on HCM Method" Proceeding of the Eastern Society for Transportation Studies,5, pp. 945-958, 2005.

[5] Boyles, S.D., Voruganti, A., Waller S.T., "Quantifying Travel Time Variability in Transportation Networks", Center for Transportation Research University of Texas at Austin, Texas, 2010.

[6]Indo-HCM 2017, "Indian Highway Capacity Manual. New Delhi, India," 2012-2017.

[7]Zheng, F., Modelling Urban Travel Time Ph.D. Thesis, Delft University of Technology, Netherland, 2011.