INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 4)
Available online at: www.ijariit.com

Redesign of traffic signal timing for minimal delay of Chamrajpete junction in Bengaluru city, India

Anirban Sarkar
anirbanboon@gmail.com
Dayananda Sagar College of Engineering, Bengaluru, Karnataka

ABSTRACT

This research is intended to highlight the delay occurred by the vehicular traffic at Chamrajpete traffic signal junction. Also, the time and fuel loss by the vehicle user at the same junction due to the split-green time at Road 1- Basavanagudi Road (Bull Temple Road) and Road 2- Sirsi Circle Road. Hence, the redesign of traffic signal timing for the minimal delay is studied and the improvements are suggested to overcome the delay at the junction.

Keywords: *Growth of traffic, Delays at signalized junctions, Traffic problems at junctions*

1. INTRODUCTION

In developing countries, the traffic scenario is significantly different from the developed countries. Predominantly the traffic is composed of passenger cars in developed countries and can be termed as "homogeneous" traffic, whereas in developing countries the traffic is composed of various vehicle types with a wide variety of static and dynamic characteristics, which occupy the same right of way, resulting the vehicle movement in an unsynchronized way. Apparently, other characteristics of this traffic are the absence of lane-discipline, resulting from the wide variation and maneuvering abilities of the vehicles. These also result in phenomena called vehicle creeping which allows the engine of the vehicle to rest at idle. They are absent in the homogeneous traffic. Therefore, this kind of traffic characteristics can be termed as "heterogeneous" traffic or "mixed" traffic.

Most of developing countries, the traffic have a fair share of two and three-wheeler motor-vehicles and non-motor vehicles with different characteristics such as static and dynamic, which results in a different flow characteristic or traffic stream. It is mostly because of the differences in sizes and maneuverability of the vehicles. In normal traffic stream scenario, the vehicles in the developing countries do not follow the lane-discipline, whereas, in developed countries, the lane-discipline rules are very strict.

At junctions, the traffic signal controls vehicular traffic and pedestrian traffic by assigning priorities to various traffic movements for the traffic flow. The traffic signals have been developed to a high degree of sophistication over the past many years and it is proposed to deal with the design and operation of the traffic signals. Any type of road traffic signal whether it is manual, electrical or automatic alternately directs to proceed and stop in a specified direction for a particular road thus providing an equal opportunity to all the vehicles waiting at the junction or at a signalized intersection.

1.1 Growth of traffic

The growth of road traffic in India has been growing at a rapid rate during the past several years, especially in the last three decades. In India, during the last few years, the number of motor vehicles has been growing at a rate of nearly 10 percent per annum. The growth rate of various vehicular classes in India has been given below,

(i) Cars: 7-10 percent
(ii) Buses: 5-10 percent
(iii) Trucks: 6-15 percent
(iv) Two-wheeler: 15-17 percent

The motor vehicle allows the driver and passengers to move comfortably and frees the traveler from subservience of tight schedules of bus transport, it is also speedier and more convenient. In fact, it is a status of the symbol in the modern society and has become a necessity in the present times. Higher income in urban area group is easily attracted by its virtues. Almost every family and individual owns a car in most of the developed countries. In the future, it is very difficult to see any new method of transportation appearing on the horizon which will be a serious competitor to the motor vehicles. Though the present oil crisis has given a serious impact in the automobile industry, still nothing can possibly replace the motor vehicle from the pedestal of supremacy.

Therefore, it will have an account with the inevitability of the motor vehicle on the roadway. The increasing number of motor vehicles will depend upon a number of factors, chief among them being the growth of family income and availability of disposable income in the family.

Other factors are, such as prices of cars, petrol rates, insurance rates, taxation levels, measures adopted to curb the private car, demand for private and public transport, etc. will also be significant. Considering the motor vehicle trend over the world, it can be easily predicted that the city traffic in the developing countries will grow at a very fast rate in the coming few years, which will arise the problems with regards to the pollution, accidents, and road safety issues.

1.2 Advantages of traffic signals

When the traffic signal is properly designed, located and operated, they may have many of the following advantages,

(i) A traffic signal can provide a uniform movement of traffic flow.
(ii) A traffic signal can increase the traffic-handling capacity of the intersection when proper geometric layouts and controls measures are employed.
(iii) They can certainly reduce the frequency of many types of accidents, especially the right-angle arm type and pedestrian accidents.
(iv) Under certain conditions, they can be coordinated to provide for a continuous movement or nearly continuous movement of traffic at a defined speed along a given route.
(v) A traffic signal can be used to interrupt heavy traffic at intervals to permit other traffic like vehicular traffic or pedestrian traffic to cross.
(vi) Traffic signals collaboration with police control can be effective and economical.
(vii) If traffic signals are properly designed and set, they can assign right of way impartially to traffic efficiently, unlike manual controls which can stop and interrupt traffic streams at the personal interest of the traffic controller.

1.3 Disadvantages of traffic signals

As regards their disadvantages, the following may be mentioned, especially if the signals are installed improperly,

(i) Excessive delay to vehicles may occur at intersections, particularly during off-peak hours of the day.
(ii) More than required signal installations may tend to encourage the disobedience of the signal indications.
(iii) More than required signal installation may be induced by the driver to use less adequate and less safe routes to avoid delays at signals.
(iv) The increase of the accidents frequency, especially of the rear-end type, may occur.
(v) Widespread confusion and difficulties might occur when the signal installations break down, due to any fault in the system.

1.4 Delays at signalised junctions

Delay is an important aspect of effectiveness in measures of traffic signal design, as it might present the direct cost of fuel consumption and indirect cost of time loss of motorists. The parameter of delays is difficult to estimate because it includes the delay associated with decelerating to stop, the stopped delay, and the delay associated with accelerating from a stop.

This is particularly true in oversaturated traffic demand conditions, where vehicles continuously decelerate and accelerate before clearance at the junction. In particular, the increase of continuous traffic in central urban areas, traffic queues and delays are often experienced in the location of signalized intersections.

Signalized intersections congestion can also be prevented by building new transportation facilities or by increasing the capacity of the intersection. However, new facilities construction is not always feasible in urban areas or cities, where congestion problems are very severe. Moreover, the addition of new facilities does not necessarily result in a complete elimination of the congestion. Capacity can be increased by proper channelization, peak period parking restrictions, prohibition of certain movements during the peak hours, installation of traffic control devices, and other conventional control measures like free left-turn for vehicles at the intersection level. Therefore, this measures also have certain kind of limitations, and at most signalized intersections, congestion during the peak period of hours is again kind of unavoidable.

1.5 Problems at junction

(i) *Traffic variations:* Traffic variation activity mostly occurs due to the following factors, a number of the vehicle, and the speed of the vehicle, mix traffic conditions and acceleration and deceleration of the vehicle. Generally, traffic variation depends on following factors such as time of the day, the day of the week, type of road, the season of the year, traffic characteristics of that road.

(ii) *Time of The Day:* Movement of traffic is different throughout the day, it depends on the hour of the day or hourly flow. There are three type of hourly flow, i.e. Peak-hour flow, Off-peak hour flow and Lean hour flow. Peak-hour flow is normally the busiest hours during the day. When the traffic is flowing at the peak on the roadways. Generally, it's the morning time when people go to offices, schools, business etc. and the evening time when they come back home.

Off-peak hour flow is the time when the traffic is minimum on the road during the daytime. In other words the traffic flow on roadways at odd hours. Generally, it is the early morning hours or the mid-night hours of the day.

Lean-hour flow is the time when traffic flows is mostly uniform and there are very minimal changes in traffic flow. Mostly the traffic flow is steady and constant during this period. Normally it is the afternoon hours and night hours of the day depending on the characteristics of the road.

(iii) Day of The Week: The variation in the traffic flow is different for a different day of the week. Normally the variations are minimal throughout the working days of the week i.e. Monday-Friday or Monday-Saturday in some places. Traffic is more on week-days unless there is any holiday in between and traffic is less on weekends. It is observed that the traffic flow is more going outside the city on holidays. Therefore, the traffic flow also varies according to the day of the week i.e. weekdays traffic flow and weekend traffic flow.

(iv) Type of Road: Traffic flow also varies by the class of road. On arterial roads, the traffic flow is more than other classes of road and therefore variation of traffic is less than other roads. On the other hand, it is very less traffic flow variation on other roads because there is so much traffic variation throughout the day, week and month.

(v) Season of The Year: Traffic flow varies with the season of the year. It is observed that different seasons have different traffic flow. It is very difficult to forecast exact traffic variation throughout the year. Therefore, the traffic flow varies according to the season of the year needs to be considered in the design of traffic facilities.

2. PRESENT INVESTIGATION AND DATA COLLECTION

The traffic of Bengaluru city is composed of various categories of vehicular traffic and the pedestrian traffic. The overall objective of traffic signal control is to provide for the safe and efficient traffic flow at intersections, along with the routes and in street networks. A well-timed signal system can reduce the quantity of fuel consumption, eliminate unnecessary stops and delays, improve safety and enhance the environment.

There are many big, medium and small size intersections in terms of traffic volume operate all over the city of Bengaluru, which serves the traffic almost all day long between mornings 7 am to night 11 pm.

One of them is Chamrajpeta Traffic Signal junction where four important roads intersect i.e. Basavanagudi Road (Bull Temple Road), Sirsi Circle Road, Bus, and Railway Station Road (Majestic Road) and City Market Road. It is also one of the busiest intersection of Bengaluru city where the traffic flows throughout the day. Chamrajpeta area consists of various kind of businesses such as shopping malls, cinema theatre and various kind of shops which also attracts many people for business and shopping.

The traffic signal at Chamrajpeta Traffic Intersection operates every day of the week from morning 7:30 am to night 10:30 pm which is almost 15hrs per day.

All the four roads which meet at the Chamrajpeta traffic junctions are designated as roads leading to as shown in the diagram below:

- Road 1: Basanavagudi (Bull Temple Road)
- Road 2: Sirsi Circle
- Road 3: Bus and Railway Station (Majestic Road)
- Road 4: City Market

Road 1- Basanavagudi (Bull Temple Road) and Road 2- Sirsi circle road has split green time in the timing of traffic signal.

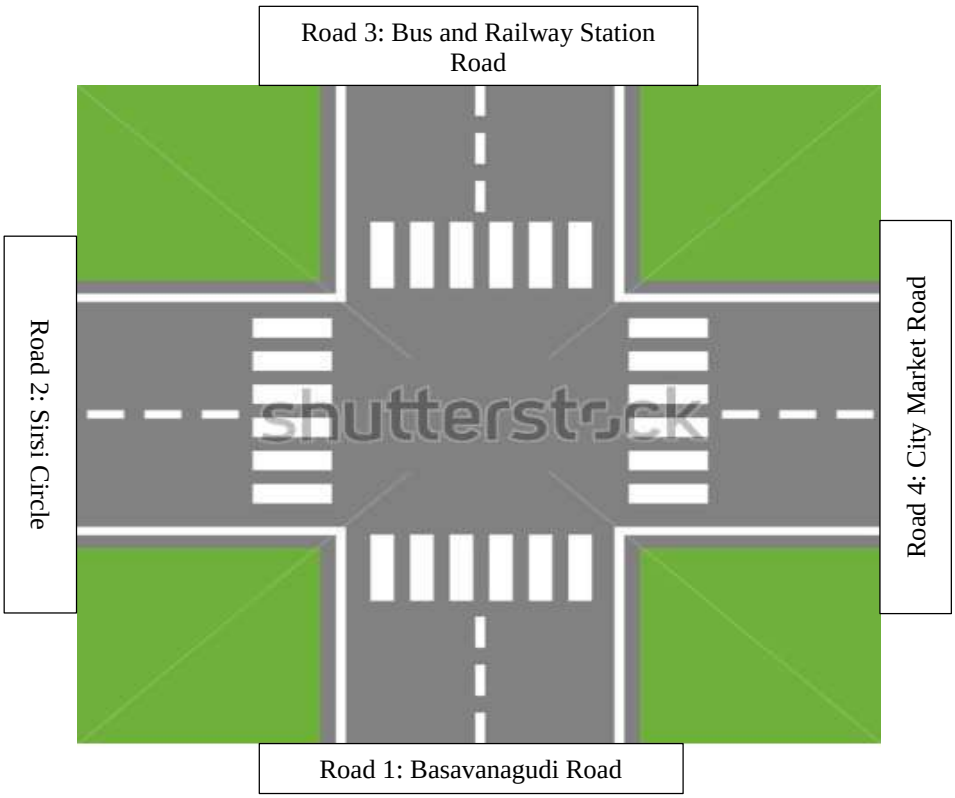

Fig. 2.1: Chamrajpet traffic signal junction with indication of all four roads

2.1 Signal timing of the Chamrajpet traffic signal

According to the Bengaluru, Traffic Police records the timing of the traffic signal changes five times a day and the timing depends on the peak hour and off-peak hour of the day.

Normally, the timing of the traffic signal changes automatically which is pre-loaded in the traffic signal system but there is also a provision to change the timing manually by the Traffic Polices at the traffic signal bay.

The timing of the traffic signal changes as follows:

- 7:30 am – 9:00 am
- 9:00 am – 11:00 am
- 11:00 am – 5:00 pm
- 5:00 pm – 8:00 pm
- 8:00 pm – 10:30 pm

2.2 Signal timing of road 1- Basavanagudi road

This road has a split green timing, therefore the green timing towards Road 4- City Market Road is shorter than other two roads i.e. Road 2- Sirsi Circle Road and Road 3- Bus and Railway Station Road.

Green time for Road 1 as follows:

- 7:30 am - 9:00 am = 60 secs (split-green time 15 secs)
- 9:00 am – 11:00 am = 90 secs (split-green time 35 secs)
- 11:00 am – 5:00 pm = 70 secs (split-green time 20 secs)
- 5:00 pm – 8:00 pm = 90 secs (split-green time 35 secs)
- 8:00 pm – 10:30 pm = 70 secs (split-green time 20 secs)

2.3 Signal timing of road 2- Sirsi circle road

This road also has a split green timing, so the green timing is different too. The green timing towards Road 1- Bull Temple Road is shorter than other two roads i.e. Road 3- Majestic Road and Road 4- City Market Road.

Green time for Road 2 as follows:

- 7:30 am - 9:00 am = 60 secs (split-green time 10 secs)
- 9:00 am – 11:00 am = 90 secs (split-green time 20 secs)
- 11:00 am – 5:00 pm = 60 secs (split-green time 10 secs)
- 5:00 pm – 8:00 pm = 75 secs (split-green time 15 secs)
- 8:00 pm – 10:30 pm = 50 secs (split-green time 10 secs)

2.4 Signal timing of road 3- Bus and railway station road

This road doesn't have split-green timing, but there is no entry towards Sirsi Circle Road. For Road 1- Basanavagudi Road and Road 4- City Market the green timing is common.

Green time for Road 3 as follows:

- 7:30 am - 9:00 am = 30 secs
- 9:00 am – 11:00 am = 50 secs
- 11:00 am – 5:00 pm = 40 secs
- 5:00 pm – 8:00 pm = 45 secs
- 8:00 pm – 10:30 pm = 40 secs

2.5 Signal timing of road 4- City market road

This road doesn't have split green time, the green timing is same towards all other three roads i.e. Road 1- Bull Temple Road, Road 2- Sirsi Circle Road and Road 3- Bus and Railway Station Road.

Green time for Road 4 as follows:

- 7:30 am - 9:00 am = 30 secs
- 9:00 am – 11:00 am = 50 secs
- 11:00 am – 5:00 pm = 40 secs
- 5:00 pm – 8:00 pm = 60 secs
- 8:00 pm – 10:30 pm = 50 secs

2.6 Traffic volume study conducted at Chamrajpet traffic signal junction

Traffic volume survey is the determination of the classes of vehicle, number of vehicles and the movement of it at a given location of the roadway. Traffic volume studies are conducted to determine the volume of the vehicles moving on the different roads during different hours of the day.

Traffic volume is defined as the number of a vehicle crossing a section of road per unit time at any selected period of time. Traffic volume studies are conducted to record data on the number of vehicles and pedestrians that pass a point on a roadway during a specified period of time.

2.6.1 Procedure of traffic volume count

Manual counts are typically used to gather the data for evaluating the traffic volume by three observers at each road throughout the day.

- The traffic volume study at Chamrajpeta Signal Intersection was conducted for each road separately from morning 7:30 am to night 10:30 pm which is almost 15 hours.
- A tally sheet was prepared for recording different classes of the vehicle using the intersection with respect to time. The tally sheet was different for different roads.

- The interval for observing the traffic volume count was 15 minutes in one hour for each road.
- A total number of a vehicle passing the intersection for 15 minutes were recorded in the tally sheet which at the end of the day will give the total volume of vehicles using the intersection.
- The classes of the vehicle using the intersection are as follows,
    1. Two-wheelers
    2. Auto-rickshaws
    3. Cars
    4. LGV (light goods vehicle)
    5. Buses
- The problem arises in the heterogeneous traffic or mixed-traffic condition are different classes of vehicle occupies different volume on the roads. Therefore, for the sake of the mixed traffic condition the different classes of vehicle are converted into Passenger Car Unit (PCU).

Table 2.1: PCU values for signalised intersection as per the IRC guidelines

S. No.	Vehicle Class	Equivalency Factors
1.	Passenger car, tempo, autorickshaw, agricultural tractor	1.0
2.	Bus, truck, agricultural tractor-tailor unit	2.8
3.	Motorcycle, scooter, and pedal cycle	0.5
4.	Cycle rickshaw	1.5
5.	Horse-drawn vehicles	4.0
6.	Small bullock cart and handcart	6.0
7.	Large bullock cart	8.0

- PCU value for 15 minutes was then converted into PCU/hour by multiplying 4 times.
- Totally 12 reading was recorded in the tally sheet which means 12 hours of traffic volume were observed from morning 7:30 am to 10:30 pm at night.

Note: to avoid fatigue, observers were relieved every hour for 15 minutes. No heavy-trucks are allowed in the city during the operation of the traffic signal

2.7 Saturation flow study conducted at Chamrajpet traffic signal junction

Saturation flow rate can be defined with the following scenario, assume that an intersection approach signal was to stay green for an entire hour and the traffic was as dense as it would be expected. The number of the vehicle that would pass through the intersection during that hour is the saturation flow.

Saturation flow is indicated by ‘s’ and the unit is PCU/hour.

2.7.1 Procedure for saturation flow

Manual counts at the intersection were used to evaluate the saturation flow by three observers at each road throughout the day.

- The saturation flow at Chamrajpeta Signal Intersection was conducted separately for each road from morning 7:30 am to night 10:30 pm.
- A tally sheet is prepared for observing different classes of a vehicle passing the intersection. The tally sheet was different for each road.
- The interval for observing the saturation flow for each road was 15 minutes in one hour.
- A total number of a vehicle passing the intersection at each road during the green time was recorded in the tally sheet which at the end of the day will help to evaluate the saturation flow.
- The classes of vehicle are,
    1. Two-wheelers
    2. Auto-rickshaws
    3. Cars
    4. LGV (light goods vehicle)
    5. Buses
- Different classes of the vehicle were then converted into Passenger Car Unit (PCU) for getting some reliable results.
- PCU value for 15 minutes was then converted into PCU/hour by multiplying 4 times.
- Totally 12 reading was recorded in the tally sheet which means 12 hours saturation flow were observed from morning to night.

Note: to avoid fatigue, observer took 15 minutes to break in between every hour.

2.8 Sample vehicle delay study conducted at Chamrajpeta traffic signal junction

Vehicle delays studies are conducted at the traffic intersections or major driveways where congestion problems exist. Vehicle delay study is considered as the detailed investigation of the stopped-time delay conditions at a traffic intersection being evaluated for traffic signalization.

During the periods of congestion, the intersection vehicle delay study should be analyzed. Normally, the peak delay occurs during the peak hour traffic flow, which can be identified from the traffic volume counts. During the major street peak hour or during the minor street peak hour flow, the peak delay may occur. So extensive care should be taken when evaluating the study time period. Both time periods need to be studied to determine the peak delay hour, in some of the cases. It is better to start the delay study 30

minutes prior to the peak hour traffic flow and stop it 30 minutes after the peak hour flow to obtain the peak vehicle delay is observed correctly.

2.8.1 Procedure for vehicle delay study

Individual vehicle tracking method was used to gather the delay occurred by the vehicle at the intersection. One percent of traffic volume data were observed for evaluating the vehicle delay studies.

- The delay study at Chamrajpeta Traffic Intersection was conducted separately for each road between mornings at 7:30 am to night 10:30 pm.
- One percent of the traffic volume sample was observed for different classes of vehicle.

E.g. one percent of two-wheeler traveled from any road were observed for evaluating delay studies and similarly, other classes of the vehicle were observed.

- A tally sheet was prepared for observing different classes of vehicle delay time at the intersection. For each road, the different tally sheet was made.
- As soon as the vehicle stops at the intersection the stopwatch timer starts and as soon as the same vehicle starts moving the stopwatch timer stops. The timing recorded in the timer gives the delay occurred by the vehicle at the intersection.
- The total delay occurred by all vehicles at the intersection gives the vehicle delay time which might be indicated by seconds/hour or hours/day.

2.9 Traffic volume study, saturation flow study and vehicle delay study conducted at Chamrajpeta traffic signals

All the studies conducted at Chamrajpeta traffic signal is done for 12 hours. The procedures for the studies is mentioned above. The studies were conducted separately for each road between mornings at 7:30 am to night 10:30 pm.

(i) Road 1- Basavanagudi (Bull Temple Road)
Traffic volume for 12 hours- 16604 pcu/day
Saturation flow for 12 hours- 15436 pcu/day
The total delay time for 12 hours- 8600 hrs/day

(ii) Road 2- Sirsi Circle Road
Traffic volume for 12 hours- 12923 pcu/day
Saturation flow for 12 hours- 15700 pcu/day
The total delay time for 12 hours- 7501 hrs/day

(iii) Road 3- Bus and Railway Station Road
Traffic volume for 12 hours- 16944 pcu/day
Saturation flow for 12 hours- 15862 pcu/day
The total delay time for 12 hours- 10401 hrs/day

(iv) Road 4- City Market Road
Traffic volume for 12 hours- 14350 pcu/day
Saturation flow for 12 hours- 13582 pcu/day
The total delay time for 12 hours- 8901 hrs/day

3. ANALYSIS OF DATA

3.1 General

Designing the traffic signal timing is never an easy task especially in heterogeneous traffic or mixed-traffic conditions, where there is no certainty of only predominantly composed of passenger car vehicles. In fact, it has to deal with the wide varieties of vehicles which occupy the same right of way.

Traffic signal timing should be such that the delay of the vehicle should be minimal and the traffic volume flow should be smooth and steady. But designing the same thing is not an easy task. Traffic Engineer have to consider a lot of aspects for designing the traffic signal for the minimal delay at the intersections.

A few junction characteristics as observed during fieldwork is as follows,

- Traffic Volume Study
- Saturation Flow Study
- Vehicle Delay Study

Chamrajpeta Traffic Signal is one of the important traffic signals in the city of Bengaluru. The traffic signal timing in Chamrajpeta Signal Junction is sometimes unsynchronized to the traffic flow which results in delays. Sometimes the vehicle at traffic signal delays more than the usual rate due to the unmatched signal timing with the traffic flow.

The split-green timing at Road 1- Basanavagudi Road (Bull Temple Road) and Road 2- Sirsi Circle Road are not so useful as the split-green time to the right side is much less than the actual traffic flow resulting in more than usual delay to some vehicles. It is observed that the elimination of split-green time at Road 1 and Road 2 will reduce the vehicle delay and increase the traffic flow which will result in more efficient and smooth flow of vehicles. It is also observed that the vehicle delay at the intersection due to the split-green time results in the long queue of the vehicle, which can be resolved by the elimination of split-green time at Road 1 and Road 2.

Therefore, the redesigning of Chamrajpeta Traffic Signal time would minimize the vehicle delay and queue of the vehicle at the intersection which will increase the traffic flow at the intersection.

3.2 Field work for traffic volume count

Traffic volume count is the evaluation of the classes of vehicle, number of vehicles and the turning movement of traffic at a given location of the highway. Traffic volume studies are conducted to determine the volume of the vehicles moving on to the different roads during different hours of the day. The study was conducted between 7:30 am to 10:30 pm on samples basis. Traffic volume is defined as the number of a vehicle crossing a cross-section at any given period of time. To record data on the number of vehicles and pedestrians that pass a point on a junction during a specified period of time, traffic volume studies are conducted.

3.3 Traffic signal timing calculated By Webster Method and IRC Method

The existing signal timing at Chamrajpet junction is sometimes more than the required time and sometimes way less as observed. Therefore, the redesign of the traffic signal timing is needed with the help of data collection and studies conducted at the junction. We can calculate the actual signal timing by Webster method and IRC method and choose between them, whichever meets the requirement of the actual scenario.

Table 3.1: Comparison of Existing Signal Time, Signal Timing by Webster Method and Signal Timing by IRC Method

Roads	Descriptions	Time 7:30-9:00am (secs)	Time 9:00-11:00am (secs)	Time 11:00-5:00pm (secs)	Time 5:00-8:00pm (secs)	Time 8:00-10:30pm (secs)
Road 1	Existing Signal Time	60	90	60	90	75
	Webster Method Signal Time	24	31	31	35	28
	IRC Method Signal Time	40	106	60	120	55
Road 2	Existing Signal Time	60	90	60	75	50
	Webster Method Signal Time	20	30	28	30	25
	IRC Method Signal Time	30	96	55	105	40
Road 3	Existing Signal Time	30	50	40	45	40
	Webster Method Signal Time	18	25	26	26	26
	IRC Method Signal Time	45	113	67	113	45
Road 4	Existing Signal Time	30	50	40	60	55
	Webster Method Signal Time	21	30	30	29	26
	IRC Method Signal Time	36	99	65	105	40

4. CONCLUSION

(i) In mixed traffic situation that existing in India, traffic is highly fluctuant which makes it difficult to design traffic signal timing and also the variation in volume and saturation flow affects the final signal time settings.

(ii) Saturation flow is not constant as assumed in many of the literature work. It also varies with volume observed at that particular location of signal and time of the day.

(iii) Split-green time is not used as a method of signal design as it results in the blocking of the vehicles waiting for turning to the right. This has been observed at many of the junctions where split-green time exists.

(iv) Theoretical delay calculated based on equations already in use may not be useful in arriving at the actual delay as the calculations are based on converting the volume of mixed vehicles to PCU as per the existing practice may not match as time cannot be connected to any other measurement.

(v) Any method of delay calculation as per the existing practice obviously does not match with the ground situation for mixed traffic conditions.

5. ACKNOWLEDGMENT

I would like to express my sincere gratitude to my Project guide **Dr. M.R. Rajashekhara** Professor and PG Coordinator Department of Civil Engineering, DSCE, for his constant support and guidance throughout my project.

I would also like to thank **Dr. Nagaraj Sitaram,** professor and Head of Department Civil Engineering Dayananda Sagar College of Engineering, Bangalore and **Dr. Basappa** Principal, Dayananda Sagar College of Engineering Bangalore for their help and coordination for the completion of the project.

I would like to thank the Teaching and Non-Teaching staff members who were in some way or the other responsible for the successful completion of the project. I would like to thank all my M.Tech batch mates for their help rendered towards the completion of my project. I would also thank my parents and friends with whose timely help contributed to the completion of my project work.

I have drawn deeply from various textbooks, websites, numerous technical papers authored by scholarly and prominent professionals, consultants and also academicians published in many journals. I am grateful to all of them and also the journals and books I referred. I also acknowledge that I am honored and fortunate to be in this institution, Dayananda Sagar College of Engineering, which has supported us ethically and technically towards a better completion of the course of study. I take this opportunity to express my gratitude to all those who have been kind enough to offer their suggestions and help when needed which has led to the successful completion of my M.Tech Thesis work.

6. REFERENCES

[1] Department of road transport and highways, Govt. of India.
[2] Bangalore City Traffic Police.
[3] Justo, C.E.G., and Tuladhar, S.B.S., 'Passenger Car Unit Values for Urban roads, Paper No. 362, Vol. 45-1, 1984, Journal of the Indian Roads Congress, New Delhi.
[4] Highway Capacity Manual, 2000.
[5] Guidelines for Capacity of Urban Roads in Plain areas, IRC 106-1990, Indian Roads Congress, New Delhi.
[6] Guidelines on Design and Installation of Road Traffic Signals- IRC 93-1985, Indian Roads Congress, New Delhi.
[7] Highway Engineering, S. K. Khanna, C. E. G. Justo and A. Veeraraghavan, 10th edition, 2014.
[8] Traffic Engineering and Transport Planning, Dr. L. R. Kadiyali, Seventh Edition 2013.
[9] Delay Estimates of Mixed Traffic Flow at Signalized Intersections in China. Tsinghua Science and Technology-Vol 14, No.2 April 2009.
[10] Delay at Signalized Intersection by Shivam Gupta, IIT Kanpur.
[11] Improvement of Traffic Operations in Congested Signalized Intersections- a Case Study in Bangalore City by Sunil Kumar, IJERT Vol 2 issue 7, July 2013.
[12] The use of traffic signals in developing countries, overseas center, 1996, Transport Research Laboratory, U. K.
[13] Optimal traffic signal settings-ii-a refinement of Webster's method by Katsuhisa Ohno and Hisashi Mine, Japan. Transpn Res. Vol 7, 1973.
[14] Study of the effect of traffic volume and road width on the PCU value of vehicles using microscopic simulation. Paper no. 542, Indian Highways, 2008.
[15] Determination of inter green intervals in signal time settings for heterogeneous traffic. Indian highways, August 2006.

