REAL TIME ADAPTIVE TRAFFIC SIGNAL CONTROL FOR MULTIPLE INTERSECTIONS IN HETEROGENEOUS TRAFFIC CONDITIONS

Chilveri Srinath and Moses Santhakumar S
NIT Tiruchirappalli, India
srinath.chilveri@gmail.com&moses@nitt.edu

ABSTRACT

Traffic congestion has been a problem in most of the developed and developing countries and is increasing. The cause may be due to several factors such as huge industrialization, increasing in population, urbanization, motor vehicles production, trip attractions etc.,causing huge traffic volumes in urban cities. Poor traffic signal timing contributes to traffic congestion and delay. Conventional signal systems use pre-programmed, daily signal timing schedules. Adaptive signal control technology adjusts the timing of red, yellow and green lights to accommodate changing traffic patterns and ease traffic congestion. The study aims for feasibility of the ATSC technology for an Indian traffic conditions, for which factors which have direct impact on the user are involved, that is queue and delay. A comparative study, has been done with that of scenarios and existing field conditions. The data along with optimization strategy is been input to the software. Five scenarios that are Morning Off Peak, Morning Peak, Mid-day Off Peak, Evening Off Peak, Evening Peak for different actuation type signals have been performed. Delay and Queue lengths are key features that have direct impact on the user are considered. Results showed an overall decrease in delay for actuated type signals compared to fixed and existing signal timings. Most of the intersections had 30% reduction in delay. Comparative to fixed signals actuation type signal perform better when both cycle time and delay are considered. When fully actuated is not performing then we can utilise semi actuated type. In all the different scenarios considered fully actuated signal has been performing well in compare to other two types.

KEYWORDS: Adaptive Signal, Fully Actuated, Semi Actuated, Fixed time, Delay;

INTRODUCTION

Traffic congestion is a worldwide problem, especially in Urban areas faced by general transportation users and traffic professionals. The consequences of traffic congestion include environmental pollution wasted fuel consumption, elongation of travel time and even accidents, while a variety of ways to relieve traffic congestion are being introduced and improved, such as components of ITS (Intelligent Transportation System), namely ATMS(Advanced Traffic Management System) and ATIS (Advance Traveller Information System), traffic demand contributes to traffic congestion and one of them is the Adaptive Traffic Signal Control (ATSC).

ADAPTIVE TRAFFIC SIGNAL CONTROL

Poor traffic signal timing contributes to traffic congestion and delay. Conventional signal systems use pre-programmed, daily signal timing schedules. Adaptive traffic signal control is a concept where vehicular traffic in a network is detected at an upstream and/or downstream point and an algorithm is used to predict when and where the traffic will be and to make signal adjustments at the downstream intersections based on those predictions. The signal controller utilizes these algorithms to compute optimal signal timings based on detected traffic volume and simultaneously implement the timings in real-time. This real-time optimization allows a signal network to react to volume variations, which results in reduced vehicle delay, shorter queues, and decreased travel times.

STATE OF THE ART

A traffic signal optimization model(OPT) that minimizes the total average delay of intersections for non-lane following traffic and adapts to the fluctuating traffic demands was introduced by the authors [1]. Simulation results shows significant reduction in average delay and average queue length, compared to vehicle actuated model. In [2] an adaptive method for responsive control that adjusts the stage durations as per traffic flows is introduced. The methodology used for this is approximate dynamic programming which uses a state-dependent estimate of future optimized costs to assess decisions. For a single intersection point of control the vehicle traffic volume is optimized by the maximum clique problem theory [3]. Simulation results show that the adaptive control based on the path priority has good effect on reducing Urban traffic congestion. An adaptive approach for traffic lights control is proposed based on the local real time traffic data and traffic condition of neighbour intersections through which sequences of green lights are self adjusted [4]. The work investigates the issue of adaptive traffic control using real time traffic data in multiple intersections through a self-organized model. In [5] a passenger based adaptive traffic signal control mechanism is proposed for reducing passenger delay and negative impact to environment. The authors in [6] presents a framework for real-time bus priority control system. The emergence of new technology called as intelligent traffic light controller, this makes the use of sensor n/w along with embedded technology where traffic light will be intelligently decided based on the total traffic on all adjacent roads.

STUDY AREA

ATSC is proposed for Tiruchirappalli City which contains 9 signalized intersections and 1 roundabout. The Intersections are:

1. Head post office
2. American Hospital
3. MGR statue (roundabout)
4. Puthur Four Road.
5. War Memorial
6. Thennur High
7. Dominos
8. Karur By Pass
9. Church gate
10. Main guard Gate

The Prime focus of study lies on the arterial and the sub arterial network, within Tiruchirappalli City. Arc Gis was made used to digitize the major arterial and sub arterial roads in the city area using a satellite image of 2.5m resolution. Figure 1 shows the digitized map of theTiruchirappalli City with the network of roads considered for the study

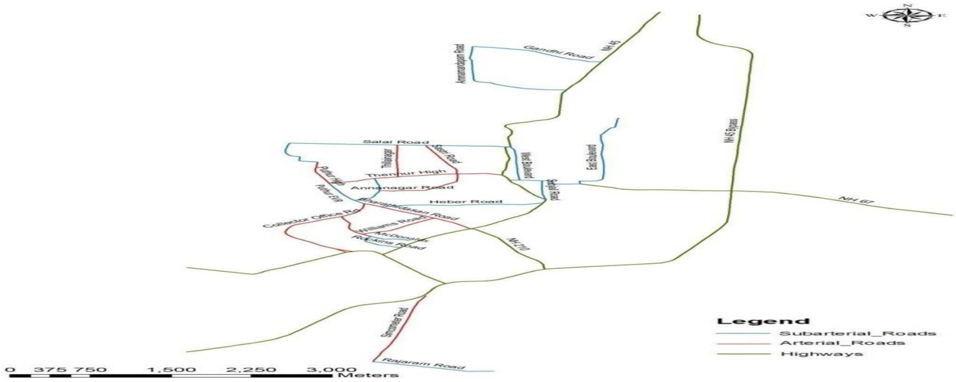

FIGURE 1 Road network map.

Traffic Volume Count Analysis

The recommended PCU factors for volume count analysis for different types of vehicles on the Urbanroads as per IRC 93-1985. Recommended PCU Factors are illustrated in Table 1.

TABLE 1 Recommended PCU Factors for Various vehicle types in urban roads.

Vehicle Type	PCU Value
Car	1
Bus and Truck	3
Auto Rickshaw	1
Two-Wheeler	0.5
Cycle	0.5
Others	8

Traffic Volume Data

Traffic volume studies are conducted to determine the number, movements and classification of roadway vehicles at a given location. These data can help identify critical flow time periods, determine the influence of large vehicles or pedestrians on vehicular traffic flow, or document traffic volume trends. The detailed field survey program is prepared to obtain the volume count at intersections. The counts were done on normal working days and fair weather conditions. Traffic volume data at each of the intersection has been taken and a comparative study over years has been done as shown in Figure 2.

Location: Puthur Four Road
From:Bishop road

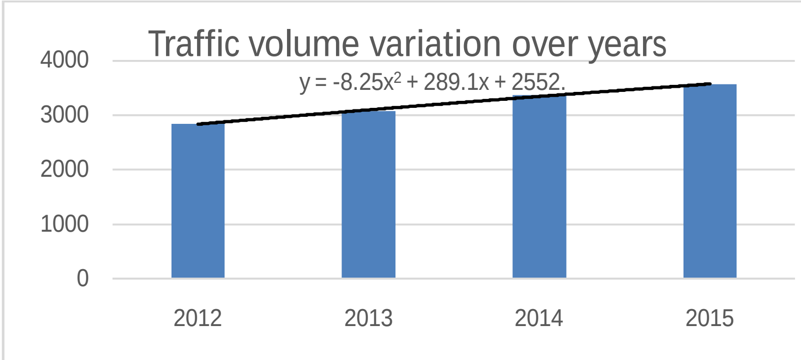

FIGURE 2 Traffic volume variation over years at Puthur four road from Bishop Road.

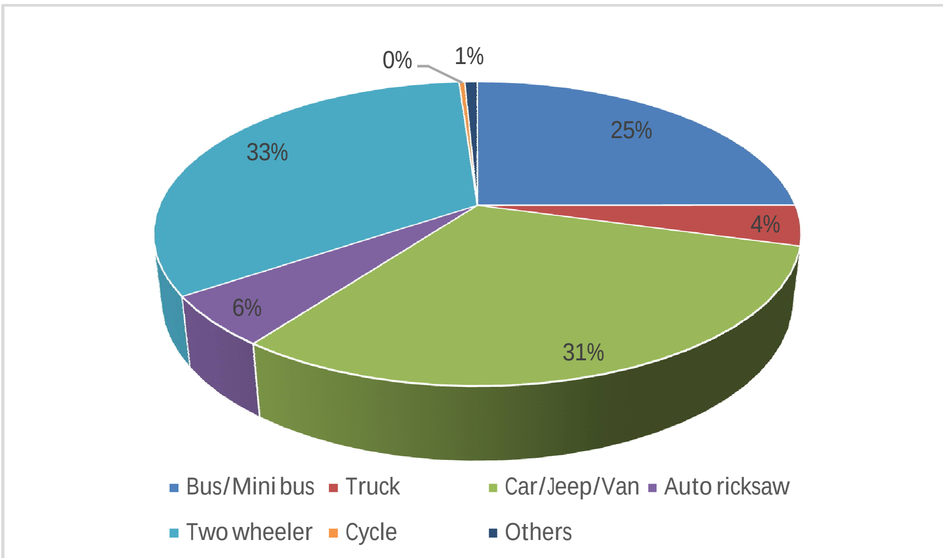

FIGURE3 Traffic volume composition at HPO on Pudukottai to Bharathdasan Road.

Network Modelling in VISTRO

The network layout for the study area was created using the PTV VISTRO software. The intersections were created using the road geometrics and the interconnecting roads were drawn by using links. Cartosat 2011 image was used a base map to create the network to the scale.

Network Optimization Process

The created model is then subjected for optimization which is further described below. Following Figure 4 represents the optimization of the network with desirable results which makes feasibility work better than the existing signal timing. The network is checked for 5 scenarios namely:

1. Morning off peak (6:00-7:30Hrs)
2. Morning Peak (7:30-11:30Hrs)
3. Midday Off Peak (11:30-15:00Hrs)

4. Evening off Peak (15:00-16:30Hrs)
5. Evening Peak (16:30-20:00Hrs)

Flowchart for Network Optimization

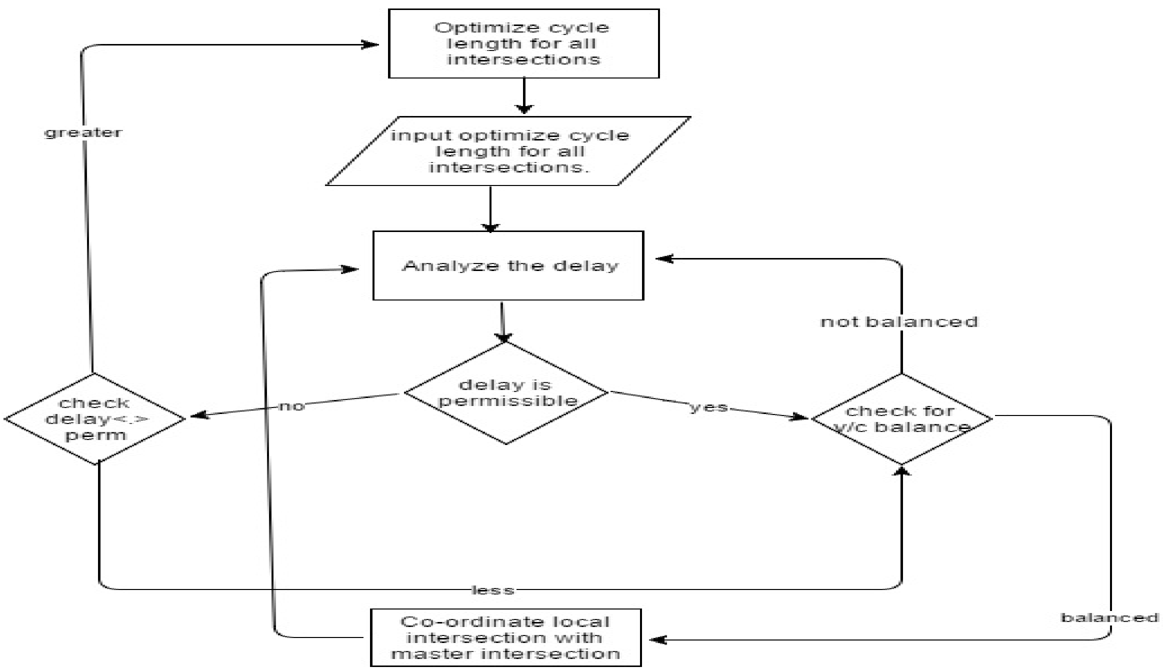

FIGURE 4 Network Optimization Process.

Results

Results obtained are compared between the actuation type of signals as well as with existing conditions. Results corresponding to Cycle Length, Delay, LoS were calculated using HCM 2010 and being tabularized for comparative studies.

Cycle Length

TABLE2 Cycle lengths for Morning Peak.

Intersections Name	Fixed Cycle Length(s)	Semi Actuated Cycle Length(s)	Fully Actuated CycleLength(s)
HPO	90	80	80
American Hospital	90	80	80
Puthur four road	90	80	80
War Memorial	90	80	80
Thennur High	90	80	80
Dominos	90	80	80
Karur By Pass	90	80	80
Church	90	80	80
Main Guard Gate	90	80	80

Scenario Analysis

Scenario 1: Morning Off Peak

TABLE3 Intersections summary for Morning Off Peak.

HPO			AMERICAN HOSPITAL			PUTHUR FOUR ROAD		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
NEB THRU			SEB LEFT	NWB THRU	SEB LEFT	NEB THRU	SWB THRU	WB LEFT
0.222			0.244			0.318		
23.6	23.3	23.3	33.4	32.6	29.1	33.1	31.8	31.8
C			C			C		
WAR MEMORIAL			THENNUR HIGH			DOMINOS		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
NB LEFT			SB RIGHT			NB RIGHT		
0.181			0.256			0.183		
18.8	14.7	14	29.4	20.7	19.9	19.9	17.9	15.4
C	B	C	C			C		
KARUR BYPASS			CHURCH			MAIN GUARD GATE		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
WB RIGHT			NB RIGHT	SEB THRU	NB RIGHT	SB THRU		
0.223			0.149			0.198		
23	24.6	22.7	15.5	15.5	15.5	19.5	19.5	17.7
C			C			C		

Scenario 2: Morning Peak

TABLE4 Intersections summary for Morning Peak.

HPO			AMERICAN HOSPITAL			PUTHUR FOUR ROAD		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
NWB RIGHT			NB RIGHT	NWB THRU		NWB RIGHT	SWB THRU	NEB THRU
0.869			1.27			0.86		
54.2	53.9	42.9	56.6	55.7	51.5	54.7	54.4	51.5
D			E		D	D		
WAR MEMORIAL			THENNUR HIGH			DOMINOS		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
NEB RIGHT			WB THRU	SB RIGHT		EB RIGHT		
1.17			0.798			1.2		
42.8	42.3	38	50.5	44.1	44.1	51.3	50.7	46.2
D			D			D		
KARUR BYPASS			CHURCH			MAIN GUARD GATE		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
SB THRU			SEB THRU	SEB THRU	NB RIGHT	SB THRU		
1.206			0.89			1.23		
58.8	54.7	54.7	52.9	43.8	42.9	41 .3	41.3	41 .3
E	D		D			D		

Scenario 3: Evening Peak

TABLE 5 Intersections summary for Evening Peak.

HPO			AMERICAN HOSPITAL			PUTHUR FOUR ROAD		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
NEB RIGHT	NWB RIGHT	SWB THRU	NB RIGHT	NWB THRU	NEBR2	WB LEFT		NB RIGHT
0.938			1.399			0.729		
55.3	52.9	51.6	67.9	60.7	60.1	57	54.3	53.1
E	D		E			E	D	
WAR MEMORIAL			THENNUR HIGH			DOMINOS		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
NB LEFT	NEB RIGHT	NB LEFT	SB RIGHT	WB THRU	SB LEFT	NB RIGHT	EB RIGHT	NB RIGHT
0.89			1.13			1.06		
50.8	45.4	43.2	61.1	58.8	55.6	69.4	66.3	65.6
D			E			E		
KARUR BYPASS			CHURCH			MAIN GUARD GATE		
FIXED	SEMI	FULLY	FIXED	SEMI	FULLY	FIXED	SEMI	FULLY
SB RIGHT	NB THRU	SB RIGHT	EB THRU	NB RIGHT		SB THRU	EB LEFT	
1.36			0.94			1.21		
74.6	71.5	69.2	57.9	53.7	50.5	59.1	55.6	52.7
E			E	D		E		D

DISCUSSION

The above tables give us an idea about Intersections V/C, Delay, Worst movement and LOS. Based on above results it is observed that as the traffic volume changes the LOS also changes for an intersection and worst movement is that where the delay is higher when compared to the other directions at an intersection and the delay summarized is the weighted average delay of all the lane groups, the route that should be optimized has least delay when compared to other movements. As the advantage of Actuated signal is that if the delay and queue length for stretch increases that should be prioritized and given equal importance by adjusting timing conditions as and on necessary. From the tables, it is seen that the delay is being reduced for actuation type signal. Comparative to fixed signals actuation type signal perform better when both cycle time and delay are considered. When fully actuated is not performing then we can utilise semi actuated type. In all the different scenarios considered fully actuated signal has been performing well in compare to other two types.

Delay comparison

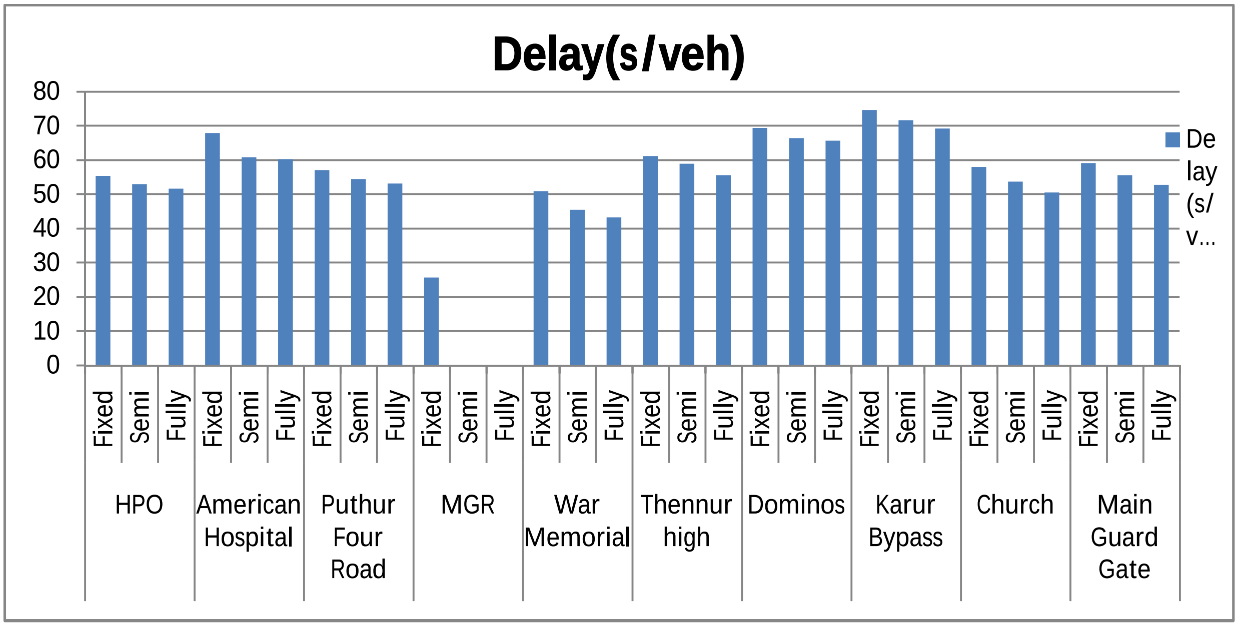

FIGURE 5 Delays during Morning peak

Delay during Evening Peak

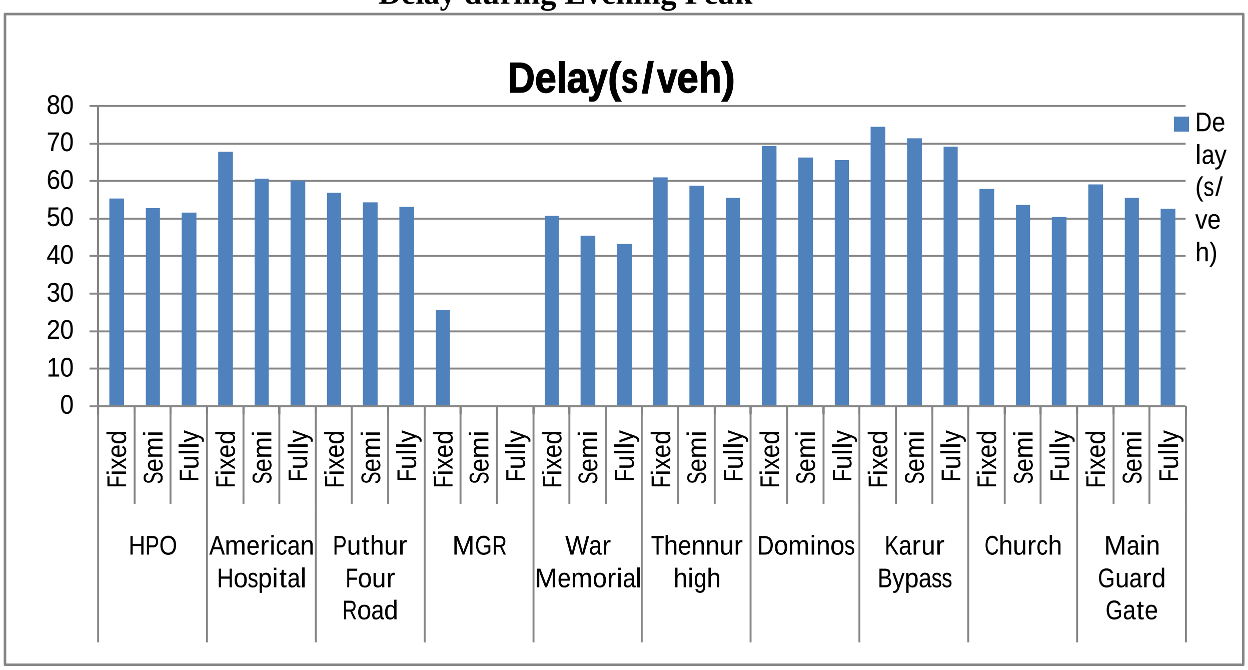

FIGURE 6 Delay during Evening Peak

CONCLUSIONS

Major composition of the traffic on the selected intersections is contributed by two-wheeler falling in the range of 53-71 %. Cars and two wheelers together add up to 78-85 % of the traffic in the city. In addition, non-motorized traffic inclusive of cycles and cycle rickshaws formed nearly 5-12 % of total traffic carrying on the intersections. Cycle times obtained gives an indication of various cases from which it can be inferred that more cycle times has been given in fixed time in different scenarios. The delay has been compared only for the scenarios Morning Peak and Evening Peak because the delay in other scenarios is smaller compared to the above mentioned. From the above tables, it is inferred that delay corresponding to actuated signal timing is lower than existing and fixed signal times. The delay mentioned was corresponding to the worst movement in actuated signals, but there was a reduction of 30% in coordinated movement compared to other signal types. The delays obtained from the results show that the fully actuated has performed well in five scenarios. Semi actuated can also be utilized when the traffic demand is increasing at a pace and varying with huge frequency over a period. From the results, it was observed that at an intersection in compare to the other techniques fully actuated timing has a better performance. The average queue lengths by the network optimization in each of these cases has been varying in different wings of the approaches and was found to be better in semi actuated and fully actuated.

FUTURE SCOPE OF WORK

ATSC is modelled for an entire City and performance in real-time is to be checked. Cost Estimation of the Technology is to be carried out for proposal. If cost exceeds limit any equipment like ANPR with coding can be inputted to have economical solution. Research for new model for heterogeneous traffic is being carried out.

REFERENCES

1. Benhamza, K. and H. Seridi. Adaptive Traffic Signal Control in Multiple Intersection Network, Journal of Intelligent and Fuzzy Systems, IEEE, 6, 2015, pp.2557-2567.
2. Cheng, S.T., P.L. Jian, G.J. Horng and K.C. Wang. The Adaptive Road Routing Recommendation for Traffic Congestion Avoidance in Smart City, Wireless Pers Communication, IJSER, 77, 2013, pp 225-246.
3. Heydecker, B.G., Chen Cai and C.K. Wong. Adaptive dynamic control for road traffic signals, IEEE International Conference on Networking, 7, 2007, pp 193-198.
4. Li-Der, C. and C.L. David. A Passenger based Adaptive Traffic Signal Control Mechanism in Intelligent Transportation Systems, 12th International conference on ITS Telecommunications, 12, 2012, pp.408-411.
5. Minal, K., Avzekar and M. Amruta. Adaptive Traffic Signal Control with VANET, IJSER, 2, 2014, pp.30-32.
6. Mirchandani, P.B. and N.Zou. Queuing Models for Analysis of Traffic Adaptive Signal Control, IEEE transactions on Intelligent Transport System, 8, 2007, pp.50-59.

7. Patel, A., T.V. Mathew and J. Venkateswaran. Real-time Adaptive Signal Controller for Non-Lane Following Heterogeneous Road Traffic, 'COMSNETS,' ITS Workshop, IEEE, 24, 2016, pp.1-6.
8. Sadguna, N. and T.V. Mathew. Vehicle Actuated Control for Heterogeneous Traffic Using Stop Line Detection, European Transport, IEEE, 57, 2015, pp.1-6.
9. Zhang, J., G. Tan, N. Ding and M. Liu. Adaptive Traffic Signal Control based on path priority, Applied Mechanics and Materials, IJSER, 72, 2015, pp.675-682.