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DEVELOPMENT OF DELAY EQUATIONS AT SIGNALIZED INTERSECTIONS IN HYDERABAD

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Abstract

Performance of any signalized intersection is evaluated in terms of level of service which is based on vehicle delay. The delay relates the time lost by the vehicles while crossing intersections. As the vehicle arrivals are random in nature and it is difficult to estimate correctly, the delay can be determined by different models viz., deterministic queuing, steady-state stochastic and time-dependent stochastic models. The assumptions made in these models make the delay estimation simpler or at least to a reasonable level of acceptance.

The present research is involved with development of vehicle delays at selected isolated intersection in Hyderabad. Detailed field studies have been conducted at an isolated signalized intersection in Hyderabad by video-graphic technique. The vehicles arrival rate, times lost in waiting in front of the stop line and departure rate are obtained from these videos. The developed delays models can be used for prediction delays at any other such isolated signalized intersection, with the similar traffic conditions.

Key Words: Isolated Signalized Intersections, Vehicle delays, Uniform, Random and Overflow delays.

1. INTRODUCTION

Signalized intersections are the important nodes within a system of any urban street network. To evaluate a signalized intersection for describing quality of traffic flow operations is a difficult task. Delay is a measure that most commonly and directly relates driver's experience as an unwanted/excess time consumed in traversing across an intersection. In addition, length of queue formed by the vehicles at an intersection at any time is an important useful measure, and is also critical in determining level of service of any signalized intersection. As the queue length increases, the system will begin to impede the discharge from an adjacent upstream intersection. Among these parameters, delay is the most frequently used measure of effectiveness of any signalized intersections. The estimation of delay is a complex issue due to random arrival of vehicles, time-lost due to stopping of vehicles, over saturated flow conditions that force to form queue. The total delay caused at signalized intersection can be termed as control-delay which comprises of the stopped-day and approach days. (Fig.01). the stopped-delay is the time lost in queue in front of the stop line. Approach-delay is the summation of delays caused due to deceleration and acceleration, just observed before and after the release by signal control. (Srinivasa kumar, 2018) [24].

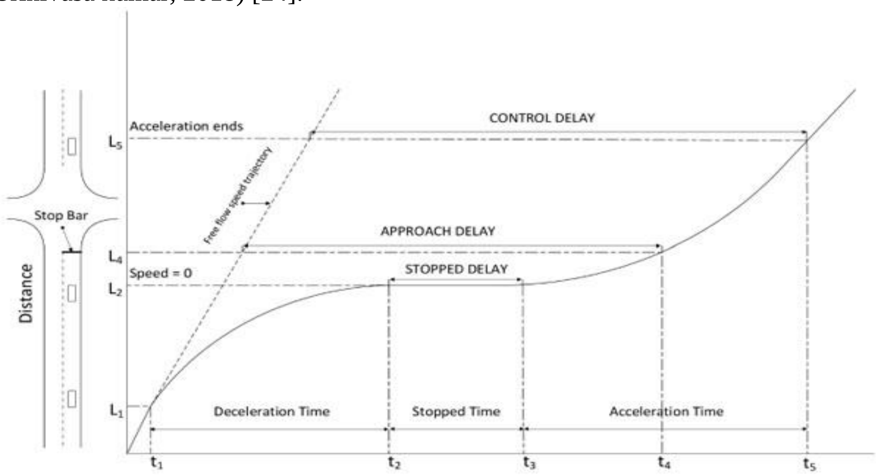

Figure 01: Traffic delays at isolated signal-controlled intersections

The overall delay can determined by the filed traffic data and it is time difference between the actual time taken to traverse through a signalized intersection and the time taken to traverse the same road segment at the desired cruising speed (Olszewski, 1993) [22].

Based on the above review on the types of delays observed at intersection, the following objectives are considered for the project:

The main objective of the study is to analyze the delay and queuing length occurring at the isolated signalized intersection in Hyderabad city and develop delay estimation equations.

Traffic surveys data includes collection of directional distribution of traffic volume, queue length data and the delays at the study location. Based on the analysis, a model has been proposed to be developed by using the observed delays.

2. REVIEW OF LITERAURE

Oversaturated conditions at fixed-time signalized intersection were primarily reported by Gazis and Potts (1963) [11] and Gazis (1964) [10]. Later, queue-length as a constraint of optimization was introduced in to Gazis (1964) [10] by Michalopoulos and Stephnopolos (1977) [21] with discrete algorithm based on numerical analysis.

The approximate delay formula at a fixed-time signal was developed by Webster (1958) [26].

Akcelik (1980) [2] proposed deterministic equation for determination of delay, stop rate and queue length for oversaturated conditions, using whiting/Kimber-Hollis co-ordinate transformation technique (Kimber and Hollis, 1979) [14].

Genetic Algorithm program based on optimization was developed by Park et al. (2000) [23] to solve the oversaturated condition. A mixed-integer linear program was proposed by Lieberman et al. (2000) [17] to obtain optimal queue lengths and signal timings.

Lo et al. (2001) [18] solved a network signal optimization problem as mix-integer-linear programming by using Cell Transmission Model as a traffic flow model. Lo and Chow (2004) [19] changed their previous study and developed Dynamic Intersection Signal Control Optimization.

In addition to the above models, signal coordination of urban road networks are also developed by different researchers by using software packages viz., TRANSYT-7F, SIGOP-II, SYNCHRO, SCOOT, and OPAC (Chen, 2007) [8].

3. METHODOLOGY

The overview of the methodology adopted in this research project is presented in Fig. 2. The Webster's formulas were used for determination of delay and the queue lengths on different approaches are determined by using the equations developed by Webster 1958 [26] and Webster and Cobber, 1966 [25].

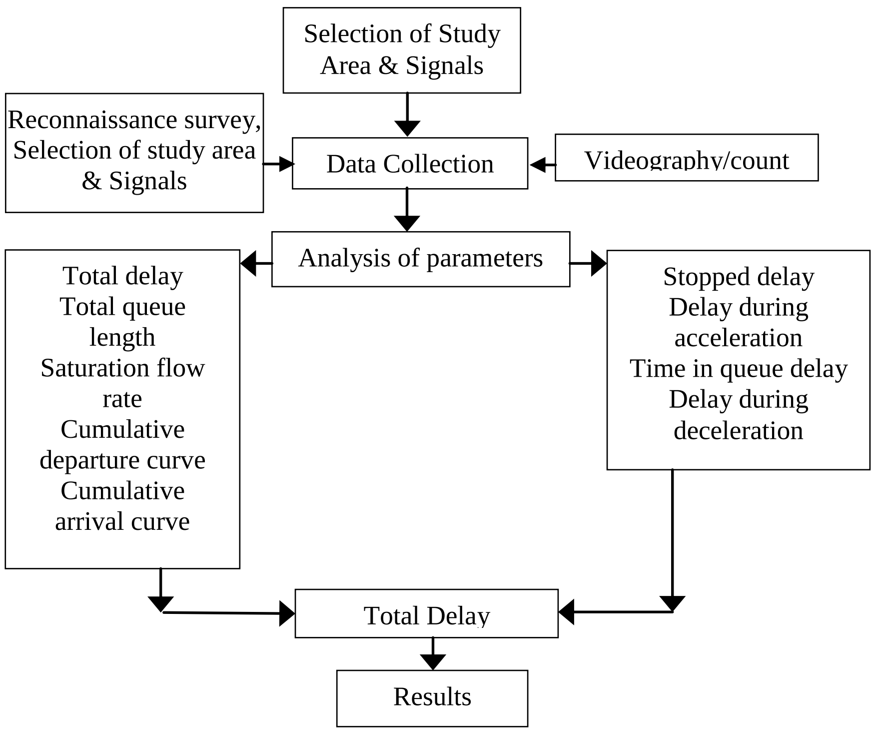

Figure 02: Flow chart of Methodology

4. DATA COLLECTION

A detailed field study has been conducted at the selected isolated signalized intersection in Hyderabad to collect data verifying the variable nature of arrival rate and queue discharge rate at this signalized intersection. The traffic data collected on the selected intersection i.e. at Amberpet Intersection during morning and evening peak hours of 9:30am to 10:30am and 6:00pm to 7:00pm, respectively. Arrivals and departures of the vehicles were recorded by manual counting based on mode type and grouped as four type's viz., buses, cars, bikes and autos. In addition to the arrivals and departures, the queue formed and cleared data has been recorded, for each cycle. The details of the data collected are presented below in Fig. 03:

Figure 03: Study Area at Amberpet Junction

The Existing Cycle lengths

The total cycle lengths including the details of green and red times for Amberpet Intersection are presented below in figure 04 respectively.

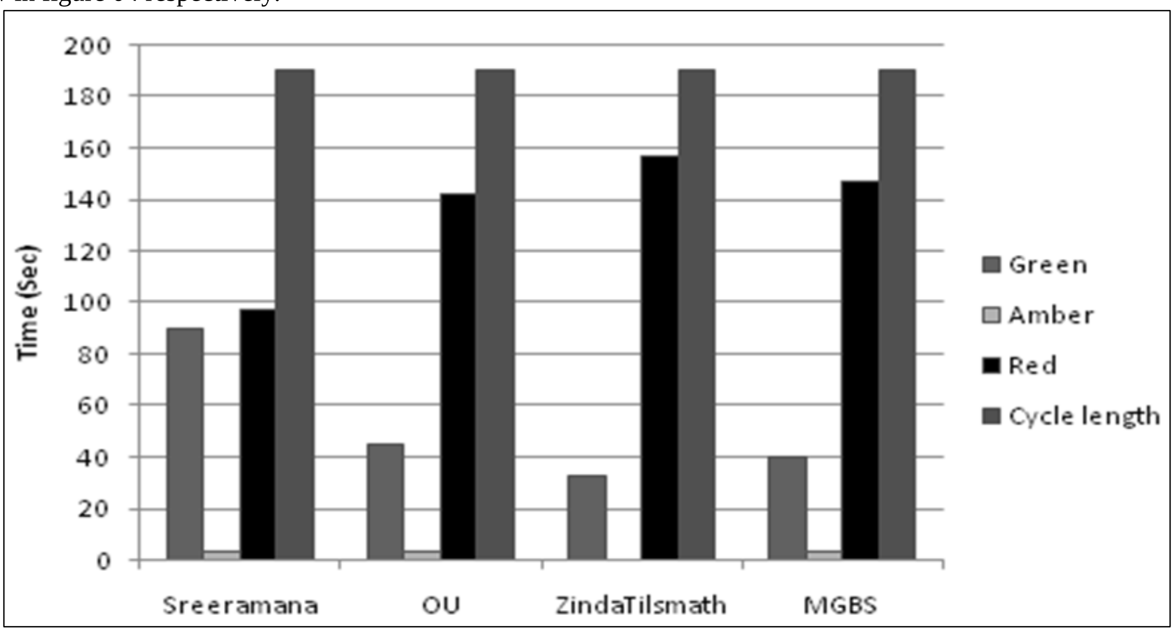

Figure 04: Cycle length at Amberpet Intersection

TRAFFIC COMPOSITION

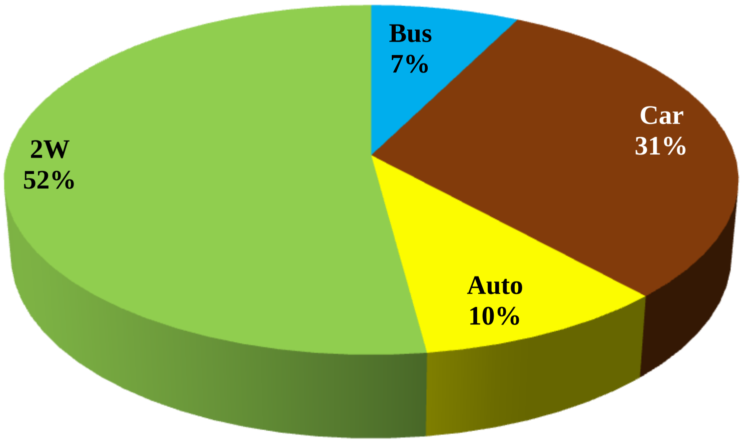

Figure 05: Vehicle Composition at Amberpet Junction

From the above figure 5, it can be noted that 52% vehicles are two wheelers and 31% vehicles are Cars.

5. ANALYSIS OF DELAYS

The sample delays analysis made for the Amberpet Road Intersection for a cycle is presented below:

Green time (g) = 33 sec; Red time (r) = 157 sec; Cycle length (Co) = 190 sec.

Arrivals for the first two cycles are 58.3 and 58 and having an initial queue of 72 vehicles in PCU.

Departures for the first two cycles are 56 and 56.6 with in green time.
Arrival rate (λ) = Arrivals/Cycle length = (58.3+72)/190 = 0.6857 veh/sec
Departure rate (μ) = Departures/Green time = 58/33 = 1.6968 veh/sec
ρ = λ/μ = 0.6857/1.6968 = 0.404
g/Co = 0.1736
Overflow condition found because ρ > g/Co.
We know, Total Delay (TOD) = Overflow Delay + Uniform Delay
$d_{overflow} = 0.5 \times ((T_2 + T_1) \times (\frac{\lambda}{cap} - 1))$
= 0.5*(190+380)*((0.6857/0.5277)-1) = 85.17secs
$d_{avg-uniform} = 0.5 \times r$=0.5*157=78.5secs
TOD = 56.43 + 48.5 = 163.67sec.
The above inputs and the area between the arrival and capacity curve also observed to be the same and presented in Fig.6.

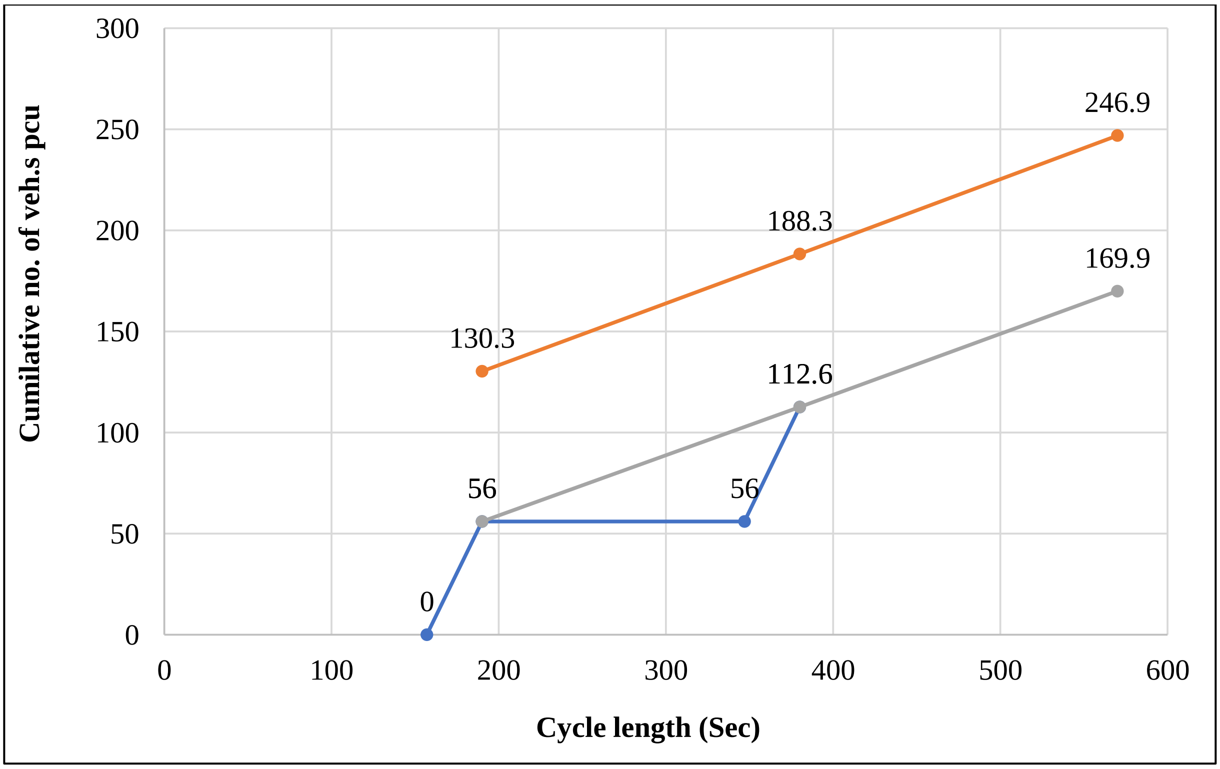

Figure 06: Cumulative flow of vehicles during a cycle at Amberpet Road Intersection

Area under the first cycle is =19327.1
N = no. of arrivals = λ × Co=130.28
Therefore delay from graph = Area obtained/N=19327.1/130.28=148.35secs.
Width of the road to be = (present width × avg arrivals)/(saturation flow)
= (2.0 × 2643.15)/(1050) = 4.7m
Width to be increased is =increased width-present width = 4.7 - 2.0 = 2.7 m.

Overflow delays are obtained at the junction Amberpet from the roads Sree Ramana Theatre and Zinda Tilismath and all other roads having uniform delays that are tabulated below.

Table 01: Delays at Amberpet Intersection

Approach Road	Avg. uniform delay(sec)	Avg. overflow delay(sec)	Avg. Total delay(sec)	Highest Queue formed (m)
SreeRamana road	47.5	35.21	82.71	98.24
Golnaka road	73.5	0	73.5	30.68
Shivam road	69.66	0	69.66	31.99
ZindaTilsmath road	78.5	94.23	172.73	84.85

6. DEVELOPMENT OF DELAY MODELS

1) At Amberpet Junction

A. Model 01

Delay Model 1 is developed considering Traffic Composition, Approach width and Red Time.

$$D = -2780.87 - 1.792B - 1.82A + 0.21TW + 275.23W + 15.43RT$$

Where,
D = Delay in sec/veh
RT = Red time in seconds;
W = Width of approach;
TW = Proportion of two-wheeler in percentage;
A = Proportion of auto rickshaw in percentage;
CAR = Proportion of car in percentage;
B = Proportion of Bus in percentage;

Table 02: Regression Statistics

Multiple R	0.94738308
R Square	0.897534701
Adjusted R Square	0.877097856
Standard Error	15.19600753
Observations	80

Table 03: ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	149680.4761	24946.74601	129.639143	7.15569E-37
Residual	74	17087.97972	230.9186448		
Total	80	166768.4558			

B. Model 02

Delay Model 2 is developed considering Red time and Road width

$$D = -2457.28 + 241.89W + 13.60\ RT$$

Where,
D = Delay in seconds/veh;
RT = Red time (seconds);
W = Width of road in m;

Table 04: Regression Statistics

Multiple R	0.894499
R Square	0.800129
Adjusted R Square	0.794937
Standard Error	20.80591
Observations	80

Table 05: ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	133436.2	66718.11	154.124	1.1992E-27
Residual	77	33332.23	432.8861		
Total	79	166768.5			

C. Model 03

Delay Model 3 is developed considering Green Ratio, Vehicle Composition and Road Width

$$D = 171.35 – 1.96B – 0.22CAR – 1.99A + 274.42W – 2923.6$$

Where,
D = Delay in seconds/veh;
GR = Green Ratio;
B = Proportion of Bus in percentage;
CAR= Proportion of car in percentage;
A = Proportion of auto rickshaw in percentage;
TW = Proportion of two-wheeler in percentage;
W = Width of road in m;

Table 06: Regression Statistics

Multiple R	0.94783
R Square	0.898383
Adjusted R Square	0.878003
Standard Error	15.133
Observations	80

Table 07: ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	149821.9	24970.31	130.8443	5.26E-37
Residual	74	16946.58	229.0078		
Total	80	166768.5			

7. CONCLUSIONS AND RECOMMENDATIONS

From the above analysis it was observed that the roads from Zinda Tilsmath and Sree Ramana theatre having overflow delay and the delay can be reduced by either by increasing the approach road width based on the saturation flow rate as 2.7 m and 0.89 m respectively, which are determined using the guidelines of HCM (2000) or providing a grade separated intersection.

The delays obtained in other roads of the Intersections of Amberpet road are having uniform delays but they have different level of service (Table 08).

Table 08: Level of Service for the analyzed roads at Amberpet Intersection

Sl. No.	Roads	Level of Service (LOS)
a	From Sree Ramana Theatre	F
b	From Golnaka Road	E
c	From Shivam Road	F
d	From Zinda Tilsmath Road	F

It has been observed that all the roads are experiencing least level of service (LOS-F), except Golnaka Road of Zinda Tilsmath Intersection as LOS of E.

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REFERENCES

1. Abu-Lebdeh G. and Benekohal R.F. (2000), “Genetic Algorithms for Traffic Signal Control and Queue Management of Oversaturated Two-way Arterials”, Transportation Research Record 1727, 61–67.
2. Akcelik, R. (1980). Time-Dependent Expression for Delay Stop Rate And Queue Length At Traffic Signals. Internal Report AIR 367-1. Australian Road Research Board, Vermont South, Australia.
3. Allsop, R.E. (1972), “Estimating The Traffic Capacity of a Signalized Road Junction”, Transportation Research, 6**,** 245-255.
4. Bell, M.G.H. (1992), “Future Directions in Traffic Signal Control”, Transportation Research. Part A. 26A, 303-313.
5. Benesch, A.A. (1915), “Regulating Street Traffic in Cleveland”, The American City, 182- 184.
6. Chang, T. H. and Lin J.T. (2000), “Optimal Signal timing for an Oversaturated Intersection”, Transportation Research Part B, 34 (6), 471-491.
7. Chaudhry M. S. (2013), “Capacity Analysis of Signalised Intersections: Effects of Green Time on Saturation Flow Rate”, Ph.D. thesis submitted to the University of Auckland.
8. Chen S. (2007), “Real-Time Traffic Signal Control for Over-Saturated Networks”, Ph.D. thesis submitted to the Graduate Faculty of Texas Tech University, December.
9. Dans, G. and Gazis D.C. (1976), “Optimal Control of Oversaturated Store-and Forward Transportation Networks”, Transportation Science 11 (1), 1-19.
10. Gazis, D. C. (1964) "Optimal Control of a System of Oversaturated Intersections" Operations Research 12, pp. 815-491.
11. Gazis D. C. and R.B. Potts (1963), "The Oversaturated Intersection" Proceedings from the Second International Symposium on the Theory of Traffic Flow, London, England, pp. 222-237.
12. Girianna M. and Benekohal R.F. (2004), “Using Genetic Algorithms to Design Signal Coordination for Oversaturated Networks”, Intelligent Transportation Systems, 8, 117–129.
13. HCM (2000), Highway Capacity Manual. Transportation Research Board. National Research Council,Washington, D.C.
14. Kimber, R. and Hollis, E. M. (1979), Traffic queues and delays at road junctions., TRRL Report, LR 909, Transport and Road Research Laboratory, Crowthorne, UK.
15. Kyte, M and Tribelhorn M. (2014), “Operation, Analysis and Design of Signalized Intersections”, A module for the Introductory Course in Transportation Engineering, University of Idaho, USA.
16. Li, H. and Prevedouros, P. D. (2004), “Traffic Adaptive Control for Oversaturated Isolated Intersections: Model Development and Simulation Testing”, Journal of Transportation Engineering, 130 (5), 594-601.

17. Lieberman E.B., Chang J. and Prassas E.S. (2000), "Formulation of Real-time Control Policy for Oversaturated Arterials", Transportation Research Record 1727, 77– 98.
18. Lo H. K. (2001), "A Cell-based Traffic Control Formulation: Strategies and Benefits of Dynamic Timing Plans", Transportation Science, 35(2), 148-164.
19. Lo H. K. and Chow A. H. (2004), "Control Strategies for Oversaturated Traffic", Journal of Transportation Engineering, 130 (4), 466-478.
20. Marsh, B.W. (1927), "Traffic Control", Annals of the American Academy of Political and Social Science, 133, 90-113.
21. Michalopoulos P.G. and Stephnopolos G. (1977), "Oversaturated Signal Systems with Queue Length Constraints –I Single Intersection", Transportation Research, 11, 413-421.
22. Olszewski, P. (1993), "Overall Delay, Stopped Delay and Stops at Signalized Intersection", Journal of Transportation Engineering, 119(6), pp.835-852, November/December.
23. Park B., Messer C.J. and Urbanik II., T. (2000), "Enhanced Genetic Algorithm for Signal-timing Optimization of Oversaturated Intersections", Transportation Research Record 1727, 32-41.
24. Srinivasa Kumar R. (2018), "Introduction to Traffic Engineering", Universities press, 2018.
25. Webster F.V. and Cobbe B.M. (1966), "Traffic Signals", Road Research Technical Paper, No. 56, Great Britain Road Research Laboratory, London.
26. Webster F.V. (1958), "Traffic Signal Settings", Road Research Technical Paper, No. 39, Great Britain Road Research Laboratory, London.