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Evaluation of Traffic Signal at an Intersection in an Indian City

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Abstract: In the present day scenario the traffic is growing enormously due to the rapid growth in urbanization and industrialization. This growth in traffic leads to several problems such as congestion, environmental and noise pollution and also causes severe accidents. These problems are more profound, especially at intersections. Hence there is a need for traffic control devices such as road markings, traffic signs, and signals to alleviate these problems and to insure highway safety. It is seen that delays and stops can be reduced considerably when signal timings are properly designed and maintained.

This study evaluates the existing signals at an intersection in a medium city like Warangal for the measured turning movements and vehicular delays. For this purpose, field surveys such as volume count with turning movements, physical inventory, and delay studies have been conducted at the selected intersection. Saturation flow curves developed for Indian conditions have been incorporated in the analysis. Signal time settings and delays were computed by adopting Webster method and comparative analysis was carried out. Further, the delay values obtained through Webster delay equation are compared with field-measured values.

1. Introduction

Road Networks are meant for providing safe, efficient, and effective operation of vehicular and pedestrian traffic. In recent years the problem of traffic congestion and delays at signalized urban intersections are becoming global problems with tremendous socio-economic impact. The main reasons identified for this problem are rapid growth of traffic as compared to the system capacity. This increase in vehicular traffic began to hamper the safe and efficient movement of traffic. To alleviate these problems intersection evaluation, i.e., assessing performance is necessary from time to time with respect to the growth of traffic.

The average delay incurred by vehicles at signalized intersections is commonly used as a measure for quantifying intersection performance in both design and evaluation procedures. The delay at pre-timed traffic signal may be due to improper cycle time and phase splits, and optimum of them is arrived at after careful consideration of traffic variables and the road parameters.

In traffic engineering practice, for each stream a signal cycle is usually divided into alternative periods called red and effective green times for that stream. It is assumed that in the red times, traffic in the stream cannot pass the signal, and in the effective green periods, it passes the signal at a uniform rate called the saturation flow. The value for saturation flow may be measured or estimated by using the relevant physical layout information for the stream (e.g. Width of the corresponding approach, number of lanes,

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gradient ets). The calculation of fixed-time signal timings, i.e., the cycle time and green times and arriving at optimum cycle time yields satisfactory operating conditions. As the traffic growing rapidly the cycle time and green should be optimum for the existing traffic volume to reduce delay and make working of the intersection more efficient.

2. Various Methods of Signal Design and Optimization Cycle Lengths

Several methods used to design the cycle time of fixed time individual intersections are presented below.

2.1. Texas A and M Method (Drew, 1968)

This method for signal settings is also referred to as the failure rate method. This was developed by the staff members of Texas Transportation Institute. It relates signalized intersection LOS to failure rate and average individual delay. It is based on evidence that peak period traffic flow approaching a signalized intersection is accurately defined by the Poisson probability distribution.

$$C = 3600\phi(K\text{-}D) / 3600 - D(EV) \quad (1)$$

Where C=minimum cycle length, Φ= number of phases, K= K1+K2 (starting delay plus time necessary for last vehicle to cross the intersection), D= average minimum headway and EV= sum of hourly critical lane values for all phases.

2.2. British TRRL Method (Webster[8], 1966)

Webster dealt with the random nature of traffic flow and developed equations from which the average delay per vehicle can be computed as a function of the cycle length, which is green, the approach volume or actual flow per lane, and the degree of saturation. In addition Webster model computes the approximate cycle length that minimizes the total intersection delay.

$$C_o = 1.5L+5 / 1\text{-}Y \quad (2)$$

$$G_i = y_i(C_o - L)/ Y \quad (3)$$

Where L : lost time per cycle, Y: sum of critical flow/ saturation flow and G_i: effective green time of the i th phase.

2.3. Australian Road Capacity Method (ARRB[4], 1968)

The Australian road research board has sponsored research, which is necessary for development of capacity guide and it has formulated equations by which the optimum cycle length and average delay can be calculated.

$$C = L+2.2 \sqrt{L/S} / 1-Y \tag{4}$$
$$d= (C-g)\, 2\, E(Z) / 2C(1-Y)g + (C-g) \tag{5}$$
$$E(Z) = \exp(-1.33\phi) / 2(1-X) \tag{6}$$
$$\Phi= (1-X)Sg / X \tag{7}$$

Where $X= qC/Sg$ = degree of saturation,
$E(Z)$= average number of vehicles left in the queue when the signals change to red.

2.4. HCM 2000 Method

This manual was designed by the Transportation Research Board. The signalized intersection analysis procedure in HCM 2000, remains largely unchanged from the 1997 Highway Capacity Manual update, but includes some corrections, clarifications, and minor adjustments. The signal timing plan in this method is estimated in five sub-steps: phasing plan development, computation of critical sum, estimation of total lost time, cycle length estimation, and effective green time estimation.

3. Selection of the Method

Although a large number of methods such as discussed above are available for the design of traffic signals at intersections containing only fast moving traffic, there appears to be not much literature on the design aspect for mixed traffic flow. A few signal designs adopted at different cities in India has followed the British TRRL method i.e., Webster's analysis. This method needs limited data and presents dependable results for most of the intersections. Another advantage with this system of design is that it takes care of percentage composition of other vehicles also. This is achieved by means of assigning EPCU's to various types of vehicles. Keeping all these in view, it has decided to use British TRRL method, the Webster's analysis as the suitable approach for design of signal at the selected intersection. Signal design was also carried out by adopting the saturation flow curves developed for Indian conditions.

Delays were calculated for both the cases and a comparative evaluation is made between the measured field delays and the delays obtained from delay models.

Table 1. Equivalent Passenger Car Units for Various Vehicles

Type of vehicle	E.P.C.U
Heavy or medium goods vehicle	1.75
Light Goods Vehicle	1.00
Bus	2.25
Motor Cycles, Mopeds, Scooters	0.33
Pedal Cycle	0.20
Cycle Rickshaw	0.75

4. Methodology

Stepwise analysis describing the determination of various elements that decide signal design by Webster's approach is as follows:

4.1. Phasing

The phasing depends mainly on the number of roads entering the junction and amount of turning movements. The number of phases more than two is restricted, wherever possible, since each additional phase lengthens the overall cycle length, there by increasing delay. The effect of left turning traffic will be accounted for its constituents more than 10% of traffic, by counting each left turn vehicle as equivalent to 1.25 straight ahead vehicles. If exclusive right turning lanes are not provided, then the effect of right turning traffic will be accounted by counting each right turning vehicle as equivalent to 1.75 straight ahead vehicle.

4.2 Determination of Optimum Cycle Time

One of the most important steps in designing a fixed time signal system is to determine the cycle time. Main consideration in selecting the cycle time should be that least delay is caused to the traffic passing through the intersection. In selecting cycle time another factor is the proportion of the time lost to the cycle time. If it is high, it results in an inefficient signal operation, and lengthy delays. On the other hand, if the cycle time is large, lost time will be small and the signal operation will be more efficient. At the same time if the cycle time is too large, a good proportion of green time will be used by unsaturated flow of traffic, which again leads to inefficiency. Therefore, for each traffic flow volume, there is an optimum cycle time, which results in the minimum delay to the vehicles.

4.3. Calculation of Green Time

For the intersections to operate with minimum overall delay, the effective green times must be divided between the number of phases in proportion to their Y values. If (C_o-L) is the total effective green time in the cycle, then the proportion of green time for each phase is given by the equation 3.

4.4. Discussion on Saturation Flow Curves[6]

Saturation flow is the flow, which would be obtained if there was a continuous queue of vehicles and they are given 100 percent green time. When the green period commences, a certain time elapses while vehicles are accelerating to normal speed, but after a few seconds the queue discharges at a more or less constant rate, called saturation flow.

6. Data Analysis

6.1. Calculation of Peak Flows

In order to find out the peak hour flow of the intersection, traffic volumes, which are leaving and entering the intersection area, were summed up for every hour duration. The particular hour, which is having the maximum flow, is identified as'peak hour flow. The morning peak hour at the selected intersection was observed between 10:00A.M to 11:00A.M and evening peak hour was 6:00P.M to 7:00P.M

Table 2. Peak Hour Flow on All Approaches Observed during Morning Peak Hour in PCU

Traffic from	To		
	Left	through	right
Kazipet	64	1250	95
Kumar palli	62	92	91
Warangal	126	461	33
Bus stand	330	20	215

6.2. Observed Delays

The approach wise calculations were done to find the total delay per cycle and average delay per stopped vehicle. All the vehicles recorded as stopped during any interval considered to have suffered delay equal to that interval irrespective of the exact point of time at which they have joined the queue. Therefore, the total delay during the cycle is obtained by multiplying the total vehicles recorded in each interval with the duration of that interval and adding the values so obtained.

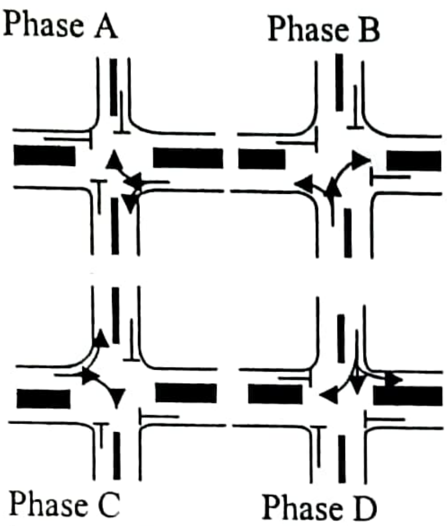
The average delays observed in the field for the existing signal settings as shown in Figure 1 are presented in Table 3.

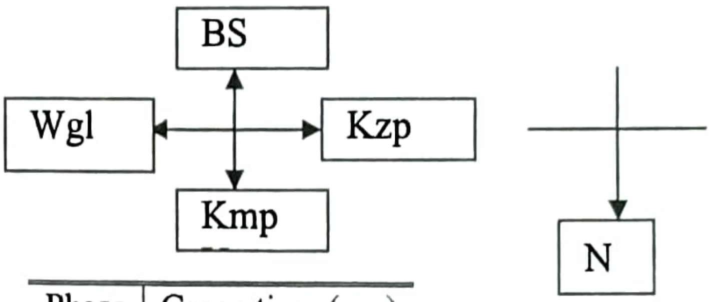
Table 3. Observed Delays during Morning Peak Hour

Traffic approaching from	Observed delay per vehicle (seconds)
Kazipet	44
Kumar palli	49
Warangal	55
Bus stand	38

6.3 Suggested Phase Diagrams and Delay Computations

Five alternative phase diagrams are proposed. For each phase diagram, cycle time and effective green times were computed using Webster method and with the saturation curve proposed in Webster method itself. These computations are presented in Table 4.





Phase	Green time (sec)
A	33
B	13
C	23
D	35

Figure 1. Existing Signal Time Settings

Table 4. Webster Method of Design for Various Phase Movements

Alternative	phase	traffic approaching from	optimum cycle time(sec)	green time (sec)	Amber (sec)	red time (sec)
1	1	west	120	36	4	80
	2	north	120	20	4	96
	3	east	120	16	4	100
	4	south	120	39	4	77
2	1	W-N, W-E, E-W, &E-S	44	16	2	26
	2	N-S, N-E, S-N, &S-W	44	10	2	32
	3	W-S &E-N	44	10	2	32
	4	S-E &N-W	44	10	2	32
3	1	west & east	57	22	4	30
	2	N-S, N-E, S-N, &S-W	57	13	4	39
	3	S-E &N-W	57	11	4	41
4	1	west	85	29	4	51
	2	east	85	13	4	67
	3	north & south	85	31	4	49
5	1	west & east	46	18	4	24
	2	North & south	46	19	5	22

Average delays computed using Webster delay equation are presented in Table 6.
By comparing the calculated delays with observed delays it was observed that the delays for all the alternatives of design are less than those of observed delays. It can also be observed that delays are increasing as the number of phases increases.

Saturation curves developed by NIT Warangal were used to get saturation flows at this intersection. These saturation flows were used in computation of cycle lengths and phase timings using Webster method for all the alternative phase diagrams. The results are presented in Table 5. Average vehicular delays were also computed and presented in Table 6.

Table 5. Webster Method of Design Using Saturation Flow curves For Various Phases

Alternative	Phase	traffic approaching from	optimum cycle time(sec)	green time (sec)	Amber (sec)	red time (sec)
1	1	west	48	10	2	36
	2	north	48	10	2	36
	3	east	48	10	2	36
	4	south	48	10	2	36
2	1	W-N, W-E, E-W, &E-S	48	10	2	36
	2	N-S, N-E, S-N, &S-W	48	10	2	36
	3	W-S &E-N	48	10	2	36
	4	S-E &N-W	48	10	2	36
3	1	west & east	43	11	4	28
	2	N-S, N-E, S-N, &S-W	43	10	4	29
	3	S-E &N-W	43	10	4	29
4	1	west	42	10	4	28
	2	east	42	10	4	28
	3	north & south	42	10	4	28
5	1	west & east	30	10	4	16
	2	north & south	30	10	5	15

Table 6. Calculated Delays

Alternative	Traffic Approaching from	Webster	Webster using saturation curves	Alternative	Traffic Approaching from	Webster	Webster using saturation curves
1	Kazipet	41	18	4	Kazipet	16	14
	Kumar palli	50	16		Kumar palli	21	13
	Warangal	52	16		Warangal	13	13
	Bus stand	40	16		Bus stand	22	14
2	Kazipet	15	17	5	Kazipet	12	8
	Kumar palli	14	15		Kumar palli	10	8
	Warangal	15	16		Warangal	10	7
	Bus stand	16	15		Bus stand	12	7
3	Kazipet	26	14				
	Kumar palli	21	13				
	Warangal	35	13				
	Bus stand	26	14				

7. Summary and Conclusions

Intersection delays can be reduced considerably when signal timings are properly designed and maintained. To achieve safe and efficient movement of vehicles there is a need for evaluation of the existing signals at intersections. Hence evaluation of traffic signals at an intersection is carried out in the present paper.

Static and dynamic characteristics such as size, shape, acceleration and deceleration characteristics etc, have larger variation in mixed traffic conditions, which result in complex interaction between the vehicles. The approaches having higher composition of scooters, cycles, cycle rickshaws, etc, have found to give rise to higher saturation flow values owing to their small size, easy maneuverability. Saturation flow curves were developed for higher composition of 2/3 wheeler slow and fast moving vehicles by NIT-Warangal. In this study, traffic signals were designed by both Webster and Webster using Indian saturation flow curves. Delays were calculated for both the cases for different phase movements. When these delays were compared with those of field delays, it was observed that delays are minimal when signals are designed by incorporating saturation flow curves in the Webster method. It was also observed that that too many phases cause more delays. From the results it was observed that delays were minimum for2-phasesignaldesign.

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