

Synchronization of Optimized Traffic Signals Designed by Webster Method Along Six Intersections of Raipur City from Sharda Chowk to Telibandha Chowk



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Abstract Over the last decade, large cities have experienced haphazard industrialization and country-wide urbanization. As a outcome, the urban population must travel long distances in the shortest amount of time. To manage travel demand, the intersection should provide the least amount of barrier to traffic flow to reduce travel time. These days, efforts are being made all over the world to safeguard the environment and save the planet. An attempt is made to investigate numerous crossings to reduce delays at these studied intersections. The areas considered for the study consists of Raipur's city busiest intersections, i.e., Sharda Chowk to Telibandha Chowk. In the initial phase, gathering data collected from different intersections analyzing the cycle length, signal type by using the Webster method. The second phase of work is based on accurate green timing for pedestrians. The third phase of work is done with the floating car method for synchronization of the traffic signal at each intersection. It was concluded that synchronization results in cost and time-efficient traffic movement for the road users giving lesser travel durations and low chances of collision thus ensuring smooth traffic operation.

Keywords Synchronization · Webster method · Floating car method · Pedestrian timing

1 Introduction

The study route selected along the major intersection (Sharda Chowk to Telibandha—3.13 km) serves the huge traffic community in Raipur city making the need for proper signal design a mandatory need. The synchronization of these major intersections of the city will be benefited not only by time and money but also in terms of safety and violation against traffic rules. Thus, synchronization of traffic signal timing at the selected study stretch will allow the smooth functioning of traffic flow. Webster

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method [1] is used for the optimization of traffic timings; thus, more efficient signal timings can be achieved. The journey time is then calculated by the floating car method to calculate the required journey speed through which synchronization can be done. Kushwah et al. [2] examined traffic signal coordination at Bhopal. The time-based coordination is established for current traffic by offsetting signal time for particular junctions where actuated signal controller mechanism deals with the demand of traffic flow and timings are set out. Rafidi and Hamid [3] studied the synchronization of traffic systems for better performance along Penang, Malaysia. However, the vehicle density as well as traffic timings is recorded out in order to plan proper reconsideration of timing along the considered road track. Raifidi and Hamid [3] studied about synchronization of a signal system for better performance along Penga Road, Malaysia. However, the density of vehicles and traffic timings were recorded out to plan proper reconsidered timing of traffic lights for the Penga road. Goliya and Jain [4] investigated a case study for the ring road, Indore for which data collection is done with the Webster method, and synchronization has been carried out for nine intersections to minimize the traffic delay.

Raj [5] studied four junctions at Outer Ring Road of the most fast-growing city Bengaluru, namely Kamakya Intersection, Kathriguppe intersection, Janathba-zar junction, and Hoskerehalli crossing located in Banashankari. The traffic volume counts for the weekdays were recorded on each approach lane, and signal times were synchronized with Webster's method [1]. The author concluded that after synchronization almost a 50% increase in traveling speed was seen due to lack of red time. Jilani et al. [6] synchronized the signals at Helmet Circle, Sal Junction and Mam Nagar, Ahmedabad, from different observations made through video survey and field survey during the process. Since, after the designing of cycle lengths, major differences were seen so to remove the whole bias; the average of the cycle length was taken thus reducing the distortion arriving due to congestion. Gaurav and Goliya [7] have worked on synchronized the optimized signals to improve the level of service at intersections on MR-10 Road. Twelve intersections on a stretch of 8.4 km were studied and designed. It was concluded that 13.71 kmph speed increased from Radisson Square to Lavkush Square and 12.71 kmph speed increased from Lavkush Square to Raddisson Square after the synchronization. Also, CO₂ emission is estimated to reduce by 2.29 million kg per annum. Vinod Kumar and Pavithra [8] studied the signal design at West Church Circle and Gandhi Road Circle, Tirupati, by IRC method and optimized by Webster's method [1] to help in reducing the accident rates at the intersections due to congestion and conflict between vehicles. The comparison of green times by IRC method and trial cycle method was presented.

Sanket and Davara [9] examined the signal time of the KKV junction, Rajkot, to lower the cycle length of signal and the time of each approach. The video recording approach for volume counting and the Webster method [1] for signal optimization has been implemented. The cycle length of KKV intersection is reduced from 250 to 157 s. Roshandeh et al. [10] examined the methodology data on the Chicago area for travel demand, designs, and signal timings for main intersections. Easa and Cheng [11] established a probabilistic method for pedestrian's characteristics to collect data

for 14 intersections. Pimentel et al. [12] applied to a pedestrian using data collected by a pedestrian as input to the model, and a sudden increase in density is observed.

Hamilton [13] deals with the promotion of transportation reliability and timing for the signal which balances overcrowding. Sharma et al. [14] studied to analyze red-light violation under traffic conditions due to timer. Gaurav and Goliya [7] synchronized the transitions between Devesh Naka intersection to Rajeev Gandhi intersection, Eastern Ring Road, Indore, which is about 14.6 km long and comprises 11 transitions. The results include saving of 241 kl petrol and 340 kl diesel per annum and reduction of CO₂ emission by 1.50 million kg per annum. Yun and Park [15] study the development of stochastic optimization for actuated traffic signal by implementing an algorithm with better schemes.

2 Objective for Synchronization of Traffic Signal

The involvement of proper signal timings, a continuation of signals, conveniences for both bicyclist and side walkers in pedestrian, good lightings in crossings and better drainage system impart overall progress in a journey with signalizing. For proper signalizing, the Webster method is applied to reduce delay in seamless traveling along with the pedestrians. This research work will provide cost and time-efficient traffic movement for the road users giving lesser travel durations and low chances of collision thus ensuring smooth traffic operation. The first phase of the study is gathering of data from the intersection for understanding the type of signal system at each and signal cycle length by the Webster method. The second phase of work is based on accurate timing for pedestrians. The third phase of work is done with a floating method for synchronization of the traffic signal at each intersection.

3 Study Specifications and Approach for Synchronization of Traffic Signal

The study area consists of major intersections of Raipur city accommodating a total length of 3.13 km. The study area comprises of six intersections, namely Sharda Chowk, Jaistambh Chowk, Kutchery Chowk, Ghadi Chowk, Bhagat Singh Chowk, and Telibandha Chowk. Each intersection has a four-phase signalized traffic system. The reason behind selecting these intersections is as these intersections possess a large traffic volume of Raipur city (Figs. 1 and 2).

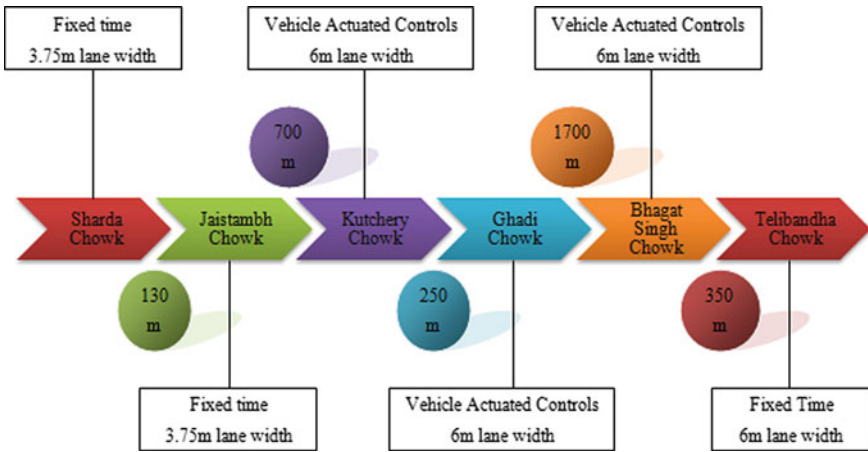


Fig. 1 Sequence of intersections surveyed and their details

3.1 Traffic Survey Procedure and Approach for Data Collection and Designing

The study consists of the collection of preliminary data and traffic survey analysis for six intersections, i.e., Sharda Chowk (SC) having 4 approaches which are Tatyapara Chowk (TPC), Jaistambh Chowk (JC), Banjari Chowk (BC) and Gurunanak Chowk (GNC). Similarly, for JC, i.e., SC, Kutchery Chowk (KC), Gol Bazar (GB), and Moudhapara (MP). Four approaches of KC are JC, Ghadi Chowk (GC), Moti Bagh (MB), and Mekahara (MH). For GC, the approaches are KC, Bhagat Singh Chowk (BSC), Raj Bhavan (RB), and Civil Court (CC). The approaches of BSC are GC, Telibandha Chowk (TBC), CM House (CMH), BTI ground (BTIG). Last TBC has 4 approaches, i.e., BSC, Gurudwara (GW), Canal linking road (CLR), Katora Talab (KT). Traffic volume has been recorded during their peak hours (10:00–12:00 am and 6:00–8:00 pm) for 4 days which consist of 2 weekdays and 2 weekends at each intersection. The type of traffic, i.e., whether the vehicles are light or heavy commercial, decides the type of PCU values to be adopted as per the road congress. After computing the normal flow rate, these values were converted to PCU per hour (Fig. 3).

Saturation flow rates are estimated for each flow direction from 20 min of recording during a green time, and average data are calculated by averaging morning and evening data. Cycle lengths are then estimated for each intersection by Webster’s method [1], and green time is also then calculated for each phase. Journey time is then estimated by conducting the floating car method. Six trips were made throughout the study stretch with 3–3 trips in each direction (Sharda Chowk to Telibandha Chowk—Telibandha Chowk to Sharda Chowk). The synchronization was then done for each intersection signal after the calculation of journey speed and time needed for traveling within the intersections (Tables 1 and 2) (Fig. 4).

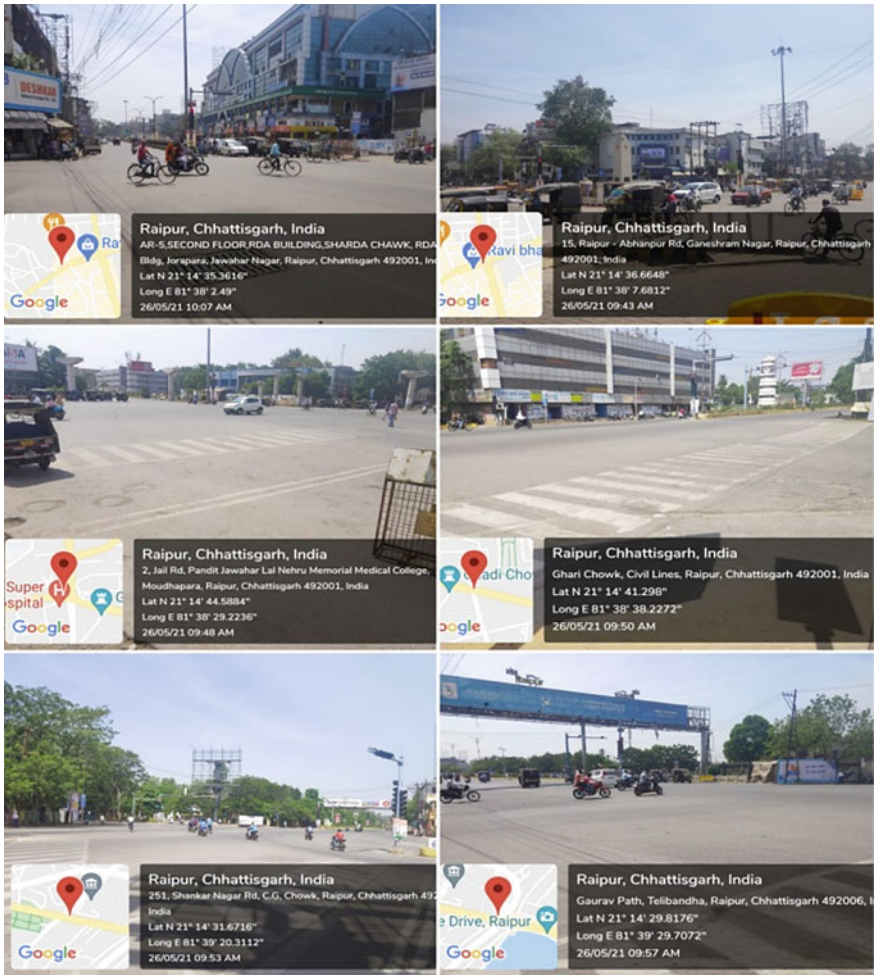


Fig. 2 Geo-tagged locations of studied intersection

Fig. 3 General sequence for synchronization of traffic signal

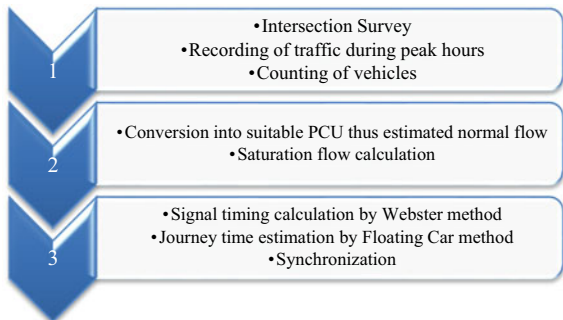


Table 1 Traffic survey data for all locations

Intersections	Green (sec.)	Amber (sec.)	Red (sec.)	Current cycle length (s)	Road width (m)	Type of signal system
SC to TPC	43	3	104	150	3.75	Fixed time
SC to JC	43	3	104			
SC to BC	36	3	111			
SC to GNC	19	3	128			
JC to SC	37	5	108	150	3.75	Fixed time
JC to KC	37	5	108			
JC to GB	25	5	120			
JC to MP	22	5	123			
KC to JC	22	8	90	120	6	VAC
KC to GC	19	8	93			
KC to MB	27	8	85			
KC to MH	17	8	95			
GC to KC	27	5	78	110	6	VAC
GC to BSC	30	5	75			
GC to RB	7	5	98			
GC to CC	12	5	93			
BSC to GC	19	3	98	120	6	VAC
BSC to TBC	35	3	82			
BSC to CMH	23	3	94			
BSC to BTIG	22	3	95			
TBC to BSC	44	5	88	137	6	Fixed time
TBC to GW	28	5	104			
TBC to CLR	28	5	104			
TBC to KT	20	5	112			

3.2 Design Calculation Utilized for Traffic Signal

The optimum signal cycle is given by the relation:

$$C_o = \frac{1.5 L + 5}{1 - Y} \tag{1}$$

where

L = total lost time per cycle, sec = $2n + R$

n = number of phases and R = all-red time or red-amber time

Table 2 Traffic design data for all locations

Intersections	Normal flow (PCU/hr)	Saturation flow (PCU/hr)	2 * n + all-red time	Cycle length	g	Amber	Green	Red
SC to TPC	1307	5651.21	16	120	32	3	31	86
SC to JC	1737.2	6362.8	16	120	38	3	37	80
SC to BC	500.2	3850	16	120	19	3	18	99
SC to GNC	261.2	2173.81	16	120	17	3	16	101
JC to SC	1764.9	8042.7	16	100	27	3	26	71
JC to KC	1346.8	7145.85	16	100	23	3	22	75
JC to GB	979.9	5463.8	16	100	22	3	21	76
JC to MP	1000.5	8678.72	16	100	15	3	14	83
KC to JC	1068.15	5086.43	16	110	27	3	26	81
KC to GC	966.5	5685.29	16	110	22	3	21	86
KC to MB	814.5	4072.50	16	110	26	3	25	82
KC to MH	860.35	5735.67	16	110	20	3	19	88
GC to KC	615.4	2930.48	16	100	25	3	24	73
GC to BSC	746	3390.91	16	100	27	3	26	71
GC to RB	237.2	1976.67	16	100	15	3	14	83
GC to CC	314.9	2099.33	16	100	18	3	17	80
BSC to GC	918.7	3674.80	16	120	35	3	34	83
BSC to TBC	897.45	5609.06	16	120	22	3	21	96
BSC to CMH	1073.35	8256.54	16	120	18	3	17	100
BSC to BTIG	812.6	3869.52	16	120	29	3	28	89
TBC to BSC	1335.8	4947.41	16	120	38	3	37	80
TBC to GW	624.85	4463.21	16	120	20	3	19	98
TBC to CLR	1071.3	8927.50	16	120	17	3	16	101
TBC to KT	1092.55	4966.14	16	120	31	3	30	87

Here,

$$Y = y_1 + y_2 \quad (2)$$

$$y_1 = \frac{q_1}{s_1} \quad (3)$$

$$y_2 = \frac{q_2}{s_2} \quad (4)$$

$$G_1 = \frac{y_1}{Y}(C_o - L) \quad (5)$$

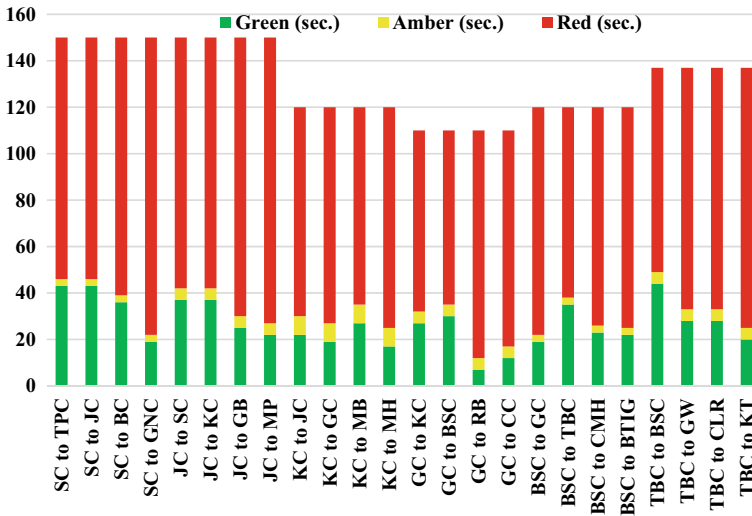


Fig. 4 Traffic signal based on survey data

$$G_2 = \frac{v_2}{Y} (C_0 - L) \tag{6}$$

4 Evaluating the Pedestrian Timings for the Study Area

The pedestrian movement has been majorly obtained at Sharda Chowk and Jaistambh Chowk; thus, pedestrian green times have to be designed for these two intersections. The widths of these junctions are 7.5 m. The guidelines for recommendations followed for pedestrian’s timings are from IRC 93:1985 [16]. The pedestrian green time allocated for intersections is $(7.5/1.2 + 7)$ equal to 13.25 s say 14 s. Therefore, pedestrian green time for pedestrian movement of 14 s is provided (Fig. 5).

Here, all the vehicles traveling along major roads are asked to travel at preassigned speed, and signal timings of junctions are adjusted in such a way that none of the vehicles on major roads of the study stretch experience the red signal and thus allow seamless travel of vehicles along the study stretch (Fig. 6).

5 Evaluation by Floating Car Method

To evaluate the effectiveness of the project, existing journey speed, running speed, and delays at the study stretch are examined by floating car method during the peak

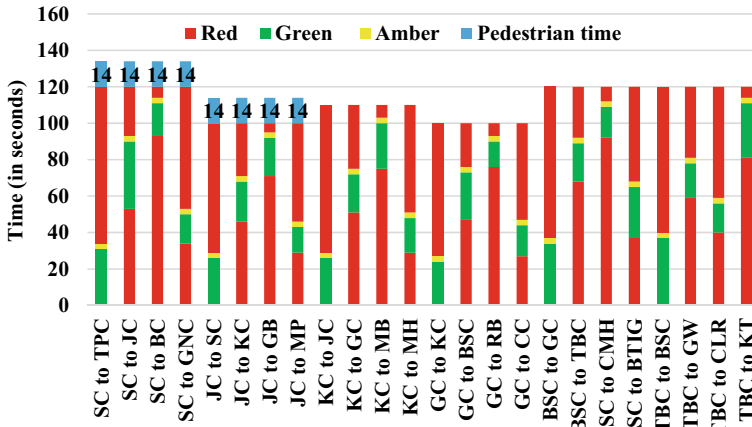


Fig. 5 Design traffic signal for intersections

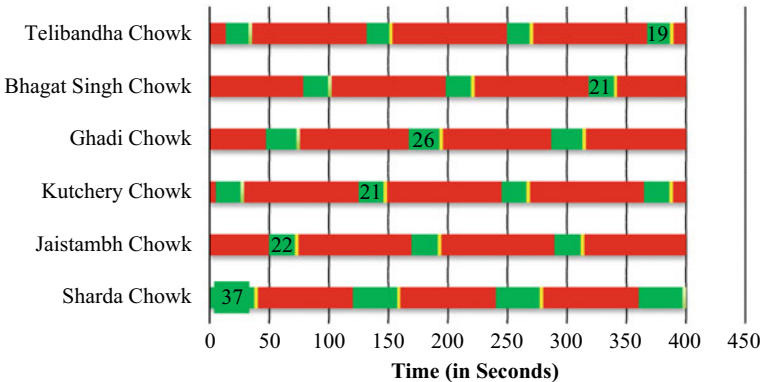


Fig. 6 Synchronization of the signal timings

hour of traffic flow where no. of vehicles met with opposite direction and no. of vehicles overtaking and overtaken by the test vehicle are noted and analyzed in which notations used are n_y = average no. of vehicles overtaking the test vehicle minus the no. of vehicles overtaken when the test is in the direction of the stream, n_a = average no of vehicles in the direction of the stream when the test vehicle travels in the opposite direction, t_w = average journey time, in minutes when the test vehicle is traveling with the stream, t_a = average journey time, in minutes when the test vehicle is running against the stream, and q = Average volume = $(n_a + n_y)/(t_a + t_w)$, t = average journey time = $t_w - (n_y/q)$ (Table 3).

Therefore, journey speed = journey length/journey time.

Table 3 Different responses obtained by the floating car method

Particulars	Along Sharda to Telibandha	Along Telibandha to Sharda
Average no. of vehicles overtaking the test vehicle	14	23
Average no. of vehicles overtaken by the test vehicle	15.33	23
n_y	-1.33	0
n_a	161.67	186
t_w	5.13 min	6.37 min
t_a	6.37 min	5.13 min
Average volume q	13.94 veh/min	16.17 veh/min
Journey length	3.13 km	3.13 km
Average journey time, t	5.22 min	6.37 min
Average journey speed	36 kmph	29.5 kmph
Average delay	1.4 min	1.74 min
Average running time = Average journey time—Average delay	3.82 min	4.63 min
Average running speed	50 kmph	41 kmph

Therefore, journey speed from Sharda Chowk to Telibandha Chowk and Telibandha Chowk to Sharda Chowk is found to be 36 kmph and 29.5 kmph, respectively, with a suitable delay of 1.4 min and 1.74 min. After the synchronization has been done, journey speed increases by about 39% for Sharda Chowk to Telibandha Chowk and 39% for Telibandha Chowk to Sharda Chowk with no stoppage of vehicles at any part of the study stretch. Since the synchronization has been done, the static delay caused due to encountering the red time signal is ideally zero. The synchronization is done for 50 kmph for much efficient flow and more reduction in the journey time. The below table shows the time required to travel between each of the intersections when traffic moves with the design speed of 50 kmph (Table 4).

6 Conclusions

- The optimized signal timings by Webster's method provide lesser cycle lengths thus giving lesser stoppages.
- Low red time stoppages provide lesser chances of mental frustration and a low risk of red-light running.
- Journey time is reduced by synchronizing the route signal timings. Journey time is reduced from 5.22 to 3.82 min when traveling from SC to TBC and from 6.37 to 4.63 min when traveling from TBC to SC.

Table 4 Time required between two intersections

Intersection	Distance (km)	Time (s)
Sharda Chowk (SC)		
	0.13	9.36
Jaistambh Chowk (JC)		
	0.7	50.4
Kutchery Chowk (JC)		
	0.25	18
Ghadi Chowk (GC)		
	1.7	112.4
Bhagat Singh Chowk (BSC)		
	0.35	25.2
Telibandha Chowk (TC)		
Total	3.13	225.36

- Keeping the design speed of 50 kmph, the timings are synchronized at each of the six intersections.
- About a 39% increase in journey speed is observed after the removal of delays at intersections due to synchronization.
- Since there is no delay, thus, there will be no idling of vehicles. Due to this, the idle fuel consumption of traffic flow is reduced leading to the economy for the transport users.
- No idling also results in lesser gas emissions thus proving synchronization as an environmentally beneficial method.
- No traffic congestion will be encountered even for the low width intersections, i.e., Sharda Chowk and Jaistambh Chowk.
- The need for pedestrian timings was observed at Sharda Chowk and Jaistambh Chowk for which after evaluating 14 s green-pedestrian time was allotted.

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