Analytic research on traffic signal timing synchronization using MATLAB

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***Abstract*—Over the last decade, large cities have experienced haphazard industrialization and country-wide urbanization. As a result, the urban population must travel longer distances in the shortest amount of time. To manage travel demand, the intersection should provide the least amount of barrier to traffic flow in order to reduce travel time. These days, efforts are being made all over the world to safeguard the environment and save the planet. In this research, an attempt is made to investigate numerous crossings in order to reduce delays at these intersections and, as a result, enhance the level of service. Traffic signals can be synced such that a vehicle leaving from one end of the street and proceeding at a predetermined speed can reach the opposite end without stopping at a red light. Existing traffic has been estimated at each intersection, and then signal designs have been created. Optimized signal has been synchronized and assessed the benefits to improve the level of service at junctions and to minimize delay.**

***IndexTerms*— Signal timing, Synchronization, Delay**

I. INTRODUCTION:

The study stretch selected along the major intersection (SHARDA CHOWK TO TELIBANDHA- 3.13KM) 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 method is used for the optimization of traffic timings thus more efficient signal timings can be achieved. The journey time is then calculated by floating car method to calculate the required journey speed through which synchronization can be done.

II. LITERETURE REVIEW :

TOPIC	Publishing year	STUDY AREA	OBJECTIVE	CONCLUSION
Gaurav Dane and H.S. Goliya (Associate professor in SGSITS **"Synchronization of Traffic Signals "A Case Study- Mr-10 Road, Indore"**	2013	Mr-10 Road, Indore	In this paper an attempt has been made to study the various intersections, so as to minimize the delays at these intersections and consequently improve the level of service.	Saving 390 kl petrol, 517 kl diesel per annum, CO2 emission estimated to be reduced by 2.29 million kg per annum.
David Shinar, MukiBourla, and Liat Kaufman, Ben Gurion University of the Negev, Beer-Sheva, Israel **"Synchronization of Traffic Signals as a Means of Reducing Red-Light Running"**	2004	12 major intersections in the city of Tel Aviv	The goal of this study was to determine if traffic signals that are synchronized along routes are associated with fewer red-light violations than traffic signals that are not synchronized.	Reduction in rate of Red light running. Decrease in aggression and frustration of users leading to RLR.
Shambhavi S (PES College of Engineering) and Pruthvi Raj U.A (Dayanand Sagar College of Engineering) **"Traffic Signal Synchronization- A Case Study: Bengaluru Ring Road"**	2018	Bengaluru Ring Road	The study is concerned with reducing delay by providing seamless travel to the vehicles along the arterial road.	Saving of 57.5 crore per annum in fuels Significant reduction in journey time by Synchronization

PayalMankar and MR Vyavahare **"Synchronization of traffic signals system for Nagpur city"**	2019	Intersection of Laxmi - Jhansi rani Nagar	The study is concerned with reducing delay by providing seamless travel to the vehicles along the arterial road.	Reduction in red light timing & fuel consumption with increase in speed and saturation flow
Amit Mishra &Tejas Joshi (Nirma University) **"Synchronization of Traffic Light System for Maximizing Efficiency along Helmet Circle, Sal Junction and Mam Nagar"**	2016	Sal Junction and Mam Nagar	The aim of this study is to reduce stops and delays experienced by motorists. Synchronizing traffic signals ensures a better flow of traffic and minimizes gas consumption and pollutant emissions.	Analysis showed major differences in the cycle time of each and every intersection.
M.A. Ahmad Rafidi , A.H. Abdul Hamid **"Synchronization of Traffic Light Systems for Maximum Efficiency along Jalan Bukit Gambier, Penang, Malaysia"**	2014	Jalan Bukit Gambier 4.6km long	The outcomes of this study support the hypothesis that retiming traffic lights to create a synchronized traffic light system for main roads will greatly improve traffic flow.	Continuity in traffic flow by reducing stop & slowing down near junctions.
Ishant Sharma and Dr. Pardeep K Gupta(Punjab Engineering University) **"Study of Automatic Traffic Signal System for Chandigarh"**	2015	Madhya Marg, Chandigarh	The paper deals with the feasibility of provision of inductive loop detection based traffic signals in place of existing pre-timed traffic signals by comparing their performance, suitability and economics.	It can be concluded that the by replacing the pre timed traffic signals with the automatic traffic signals, capacity is being increased and LOS is also being improved
HS goliya and Nitin Kumar Jain (S.G.S.I.T.S., Indore) **"Synchronization of traffic signal a case study eastern ring road Indore"**	2012	Eastern ring road, Indore	Traffic signals can be synchronized so that a vehicle starting at one end of the Street and traveling at Preassigned speed can go to the other end without stopping for a red light.	241l of petrol & 340l of diesel is saved. CO2 emission of 1.5 million kg/annum is reduced.
Zhongtai Jiang et al **"Integrating traffic signal optimization with vehicle microscopic control to reduce energy consumption in a connected and automated vehicles environment "**	2022	Emerging of connected and automated vehicles (CAVs) technologies	This study describes an integrated traffic control system for optimizing traffic signals and controlling CAVs at an isolated signalized crossroads in order to minimize fuel consumption and increase transportation sustainability.	Depending on the demand scenario, the decreased traffic delay, energy consumption, and pollution emission can be as much as 33.51-44.25%, 18.44-22.14%, and 13.36-55.20%, respectively.
Dallas Leitner et al **"Recent advances in traffic signal performance evaluation"**	2022	• A comprehensive review on recent works related to traffic signal performance evaluation is conducted.	This paper's assessment looks at the advancements in traffic signal performance evaluation. We establish the need for the evaluations, investigate the process of continual improvement of traffic signal performance through the use of the evaluations, and then investigate numerous approaches in a variety of research initiatives.	This study aims to give a complete analysis of the state-of-the-art to aid researchers, traffic authorities, and commercial organisations who strive to enhance traffic signal safety and efficiency through performance evaluations.

		• Various data sources and performance measures are discussed.		
Weiming Zhao et al **"A platoon based cooperative eco-driving model for mixed automated and human-driven vehicles at a signalised intersection"**	2018	• An eco-driving model for mixed traffic flow including automated vehicles and human driven vehicles. • Platoon based cooperation between automated vehicles and human driven vehicles. • Dynamic platoon splitting and merging method in terms of cooperation. • Cooperation behaviour significantly smooth the traffic flow and reduce the travel time.	In this study, we look at the design of a real-time cooperative eco-driving strategy for a group of cars that includes both automated and human-driven vehicles (HVs). The platoon's lead cars can receive signal phase and timing information via vehicle-to-infrastructure (V2I) communication, as well as the traffic conditions of both the preceding and current vehicles via vehicle-to-vehicle (V2V) communication.	Our model reveals that collaboration between AVs and HVs can further smooth out the latter's trajectory and lower the overall fuel consumption of the traffic system, especially given the low penetration of AVs. It is worth noting that the proposed model does not sacrifice traffic efficiency or driving comfort in order to achieve the eco-driving approach.
Yu du et al **"Dynamic capacity estimation of mixed traffic flows with application in adaptive traffic signal control"**	2022	Connected and Automated Vehicle (CAV) technology	Intersection control is critical in determining traffic efficiency inside cities. CAV technology provides regular traffic information exchange over vehicular networks, which appears to be a potential solution to minimize vehicle trip time and boost junction capacity.	A mechanism for modifying the maximum-pressure input value is also suggested. To evaluate the suggested technique locally, an isolated junction scenario was initially generated. A multi-intersection network experiment was also carried out to validate the proposed MPMF method's network-level performance. Comparing the new MPMF approach to the

				traditional max-pressure control method and the existing fixed time control method demonstrates that the MPMF can effectively enhance junction performance and is suited for the multi-intersection road network.

III. STUDY SPECIFICATIONS & APPROACH FOR SYNCHRONIZATION:

The study area consists of major intersections of Raipur city accommodating in the total length of 3.13 km. The study area comprises of 6 intersections namely Sharda Chowk, Jaistambh Chowk, Kutchery Chowk, Ghadi Chowk, Bhagat Singh Chowk and Telibandha Chowk. Each intersections have a four phase signalized traffic system. The reason behind selecting these intersections is as these intersections possess a large traffic volume of Raipur city.

Fig. 1 Locations

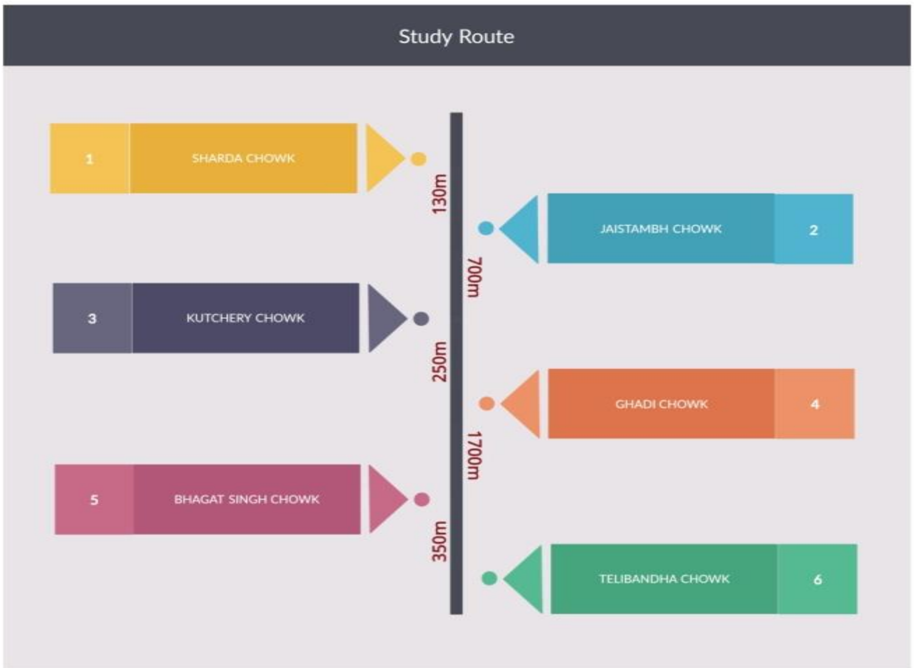

Fig.2 Study route

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. Traffic volume has been recorded during their peak hours (10:00 AM to 12:00 AM and 6:00 PM to 8:00 PM) for 4 days which consists 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 IRC. After computing the normal flow rate, these values were converted to PCU per hour.

Saturation flow rates are estimated for each flow direction from 20 minutes of recording during a green time and average data is calculated by averaging morning and evening data. Cycle lengths are then estimated for each intersection by Webster's method and green time is also then calculated for each phase.

Journey time is then estimated by conducting the floating car method. 6 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 travelling within the intersections.

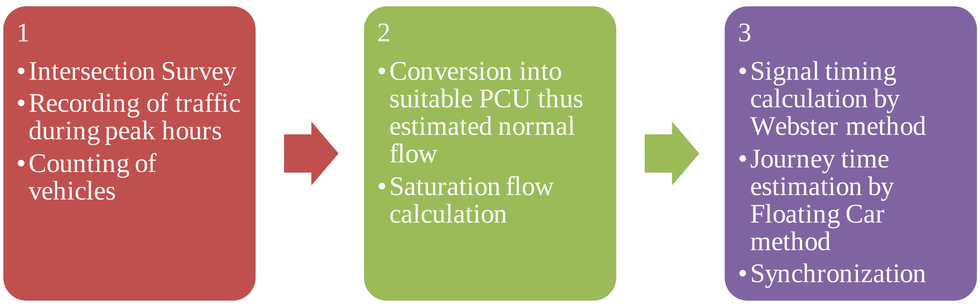

fig.3 flow chart

3.2 Design Calculation Utilized for Traffic Signal
The optimum signal cycle is given by relation:

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

Where, L= total lost time per cycle, sec = 2n+R
n= number of phases
R= all-red time or red-amber time

$$Y = y_1 + y_2$$

Here,
y1 = q1/s1 and y2 = q2/s2

Then, $G1 = \frac{y_1}{Y}(\mathbf{C_o} - \mathbf{L})$ and $G2 = \frac{y_2}{Y}(\mathbf{C_o} - \mathbf{L})$

IV. DATA CALCULATION:

following are the data of traffic signal timing from each intersection

Table 4.1 Traffic design data of Sharda Chowk

SHARDA CHOWK								
Intersection	Green (sec.)	Amber (sec.)	Red (sec.)	Current Cycle Length		Road Width		Type of signal system
Sharda Chowk to Tatyapara Chowk	43	3	104	150 seconds		3.75m		Fixed Time
Sharda Chowk to Jaistambh Chowk	43	3	104					
Sharda Chowk to Banjari Chowk	36	3	111					
Sharda Chowk to Gurunanak Chowk	19	3	128					
Normal flow(PCU/hr)	Saturation flow (PCU/hr)	Flow ratio	L=2*n+all red time	Cycle length	g	Amber	Green	Red
			2*4+(2*4)				A=3,l=2	
1307	5651.21	0.23	16	120	32	3	31	86
1737.2	6362.8	0.27	16	120	38	3	37	80
500.2	3850	0.13	16	120	19	3	18	99
261.2	2173.81	0.12	16	120	17	3	16	101

Table 4.2 Traffic design data of Jaistambh Chowk

JAISTAMBH CHOWK								
Intersection	Green (sec.)	Amber (sec.)	Red (sec.)	Current Cycle Length		Road Width		Type of signal system
Jaistambh to sharda	37	5	108	150 seconds		3.75m		Fixed Time
Jaistambh Chowk to Kutchery Chowk	37	5	108					
Jaistambh Chowk to Gol Bazar	25	5	120					
Jaistambh Chowk to Moudhapara	22	5	123					
Normal flow(PCU/hr)	Saturation flow (PCU/hr)	Flow ratio	L=2*n+all red time	Cycle length	g	Amber	Green	Red
1764.9	8042.7	0.22	16	100	27	3	26	71
1346.8	7145.85	0.19	16	100	23	3	22	75
979.9	5463.8	0.18	16	100	22	3	21	76
1000.5	8678.72	0.12	16	100	15	3	14	83

Table 4.3 Traffic design data of Kutchery Chowk

KUTCHERY CHOWK								
Intersection	Green (sec.)	Amber (sec.)	Red (sec.)	Current Cycle Length		Road Width		Type of signal system
Kutchery Chowk to Jaistambh Chowk	22	8	90	120 seconds		6m		Vehicle Actuated Controls (VAC)
Kutchery Chowk to Ghadi Chowk	19	8	93					
Kutchery Chowk to Moti Bagh	27	8	85					
Kutchery Chowk to Mekahara	17	8	95					
Normal flow	Saturation flow (PCU/hr)	Flow ratio	L=2*n+all red time	Cycle length	g	Amber	Green	Red
1068.15	5086.43	0.21	16	110	27	3	26	81
966.5	5685.29	0.17	16	110	22	3	21	86
814.5	4072.5	0.2	16	110	26	3	25	82
860.35	5735.67	0.15	16	110	20	3	19	88

Table 4.4 Traffic design data of Ghadi Chowk

GHADI CHOWK								
Intersection	Green (sec.)	Amber (sec.)	Red (sec.)	Current Cycle Length		Road Width		Type of signal system
Ghadi Chowk to Kutchery Chowk	27	5	78	110 seconds		6m		Vehicle Actuated Controls (VAC)
Ghadi Chowk to Bhagat Singh Chowk	30	5	75					
Ghadi Chowk to Raj Bhavan	7	5	98					
Ghadi Chowk to Civil Court	12	5	93					
Normal flow(PCU/hr)	Saturation flow (PCU/hr)	Flow ratio	L=2*n+all red time	Cycle length	g	Amber	Green	Red
615.4	2930.48	0.21	16	100	25	3	24	73
746	3390.91	0.22	16	100	27	3	26	71
237.2	1976.67	0.12	16	100	15	3	14	83
314.9	2099.33	0.15	16	100	18	3	17	80

Table 4.5 Traffic design data of Bhagat Singh Chowk

BHAGAT SINGH CHOWK								
Intersection	Green (sec.)	Amber (sec.)	Red (sec.)	Current Cycle Length		Road Width		Type of signal system
Bhagat Singh Chowk to Ghadi Chowk	19	3	98	120 seconds		6m		Vehicle Actuated Controls (VAC)
Bhagat Singh Chowk to Telibandha Chowk	35	3	82					
Bhagat Singh Chowk to C M House	23	3	94					
Bhagat Singh Chowk to BTI Ground	22	3	95					
Normal flow(PCU/hr)	Saturation flow (PCU/hr)	Flow ratio	L=2*n+all red time	Cycle length	g	Amber	Green	Red
918.7	3674.8	0.25	16	120	35	3	34	83
897.45	5609.06	0.16	16	120	22	3	21	96
1073.35	8256.54	0.13	16	120	18	3	17	100
812.6	3869.52	0.21	16	120	29	3	28	89

Table 4.6 Traffic design data of Telibandha Chowk

TELIBANDHA CHOWK								
Intersection	Green (sec.)	Amber (sec.)	Red (sec.)	Current Cycle Length		Road Width		Type of signal system
Telibandha Chowk to Bhagat Singh Chowk	44	5	88	137 seconds		6m		Fixed Time
Telibandha Chowk to Gurudwara	28	5	104					
Telibandha Chowk to Canal Linking Road	28	5	104					
Telibandha Chowk to Katora Talab	20	5	112					
Normal flow(PCU/hr)	Saturation flow (PCU/hr)	Flow ratio	L=2*n+all red time	Cycle length	g	Amber	Green	Red
1335.8	4947.41	0.27	16	120	38	3	37	80
624.85	4463.21	0.14	16	120	20	3	19	98
1071.3	8927.5	0.12	16	120	17	3	16	101
1092.55	4966.14	0.22	16	120	31	3	30	87

Flow data converted into Passenger Car Unit (PCU)

Pedestrian timings:

Since pedestrian movement has been majorly obtained at Sharda Chowk and Jaistambh Chowk thus pedestrian green times has to be designed for these two intersections. The widths of these junctions are 7.5m.

Pedestrian green = 7.5/1.2 + 7 = 13.25 sec say 14 sec.
Therefore, pedestrian green time for pedestrian movement of 14 seconds is provided.

V. PHASE DIAGRAM :

In the phase diagram the timing of each signal colour will be present into the graphical form.

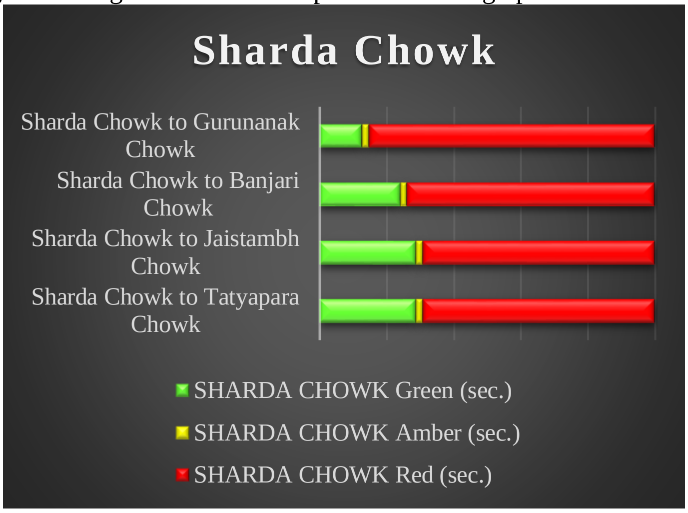

Fig. 4.1 Sharda Chowk Phase diagram

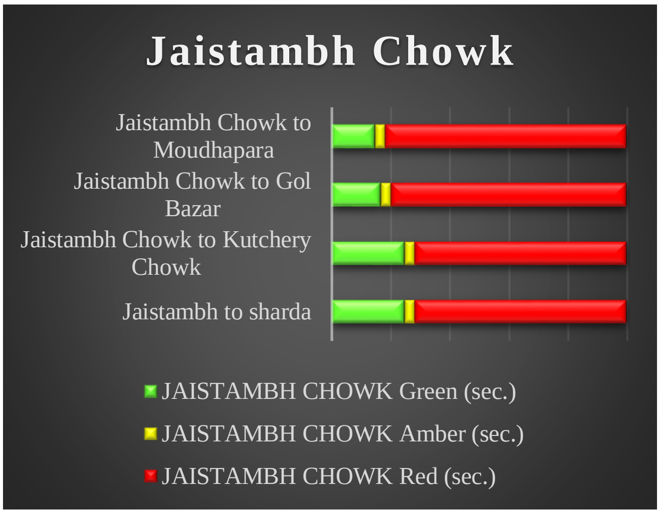

Fig. 4.2 Jaistambh Chowk Phase diagram

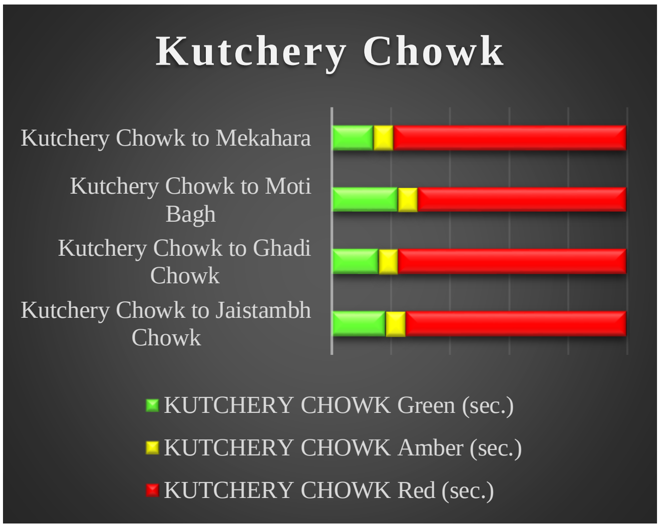

Fig. 4.3 Kutchery Chowk Phase diagram

Fig. 4.4 Ghadi Chowk Phase diagram

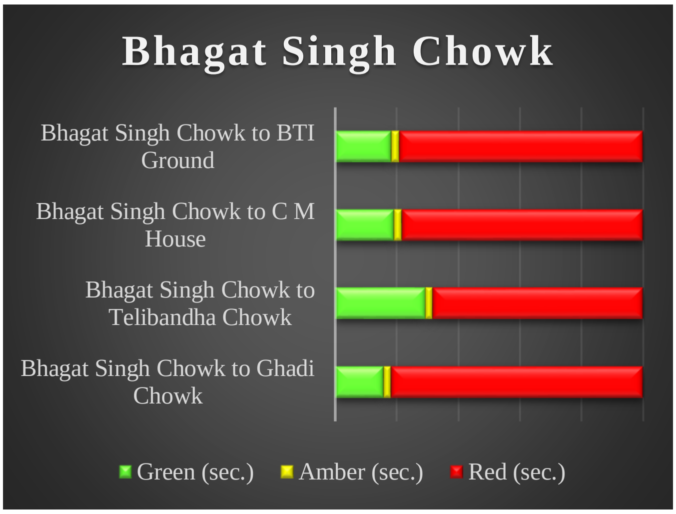

Fig. 4.5 Bhagat Singh Chowk Phase diagram

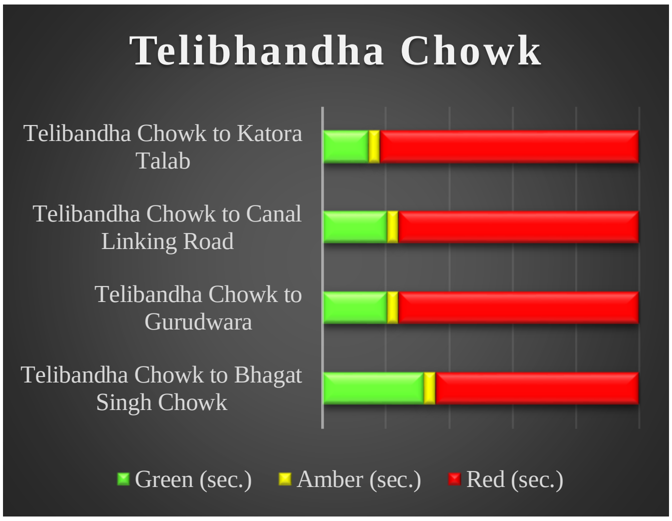

Fig. 4.6 Telibandha Chowk Phase diagram

VI. SYNCHRONIZATION OF TRAFFIC SIGNAL TIMINGS:

After designing appropriate signal timings for each junction under consideration, they must be synchronized to achieve maximum trip efficiency by eliminating delay. Because it is almost difficult to synchronise traffic from all approaches to the junctions, synchronization is performed primarily on all main routes of the junctions to achieve optimum efficiency on synchronization. The synchronization allows traffic on main routes to flow without stopping at study intersections owing to Red signal encounters.. All cars travelling along key roads are instructed to travel at a certain pace, and junction signal timings are changed such that none of the vehicles on main roads of the research stretch experience the Red signal, allowing seamless transit of vehicles along the study stretch.

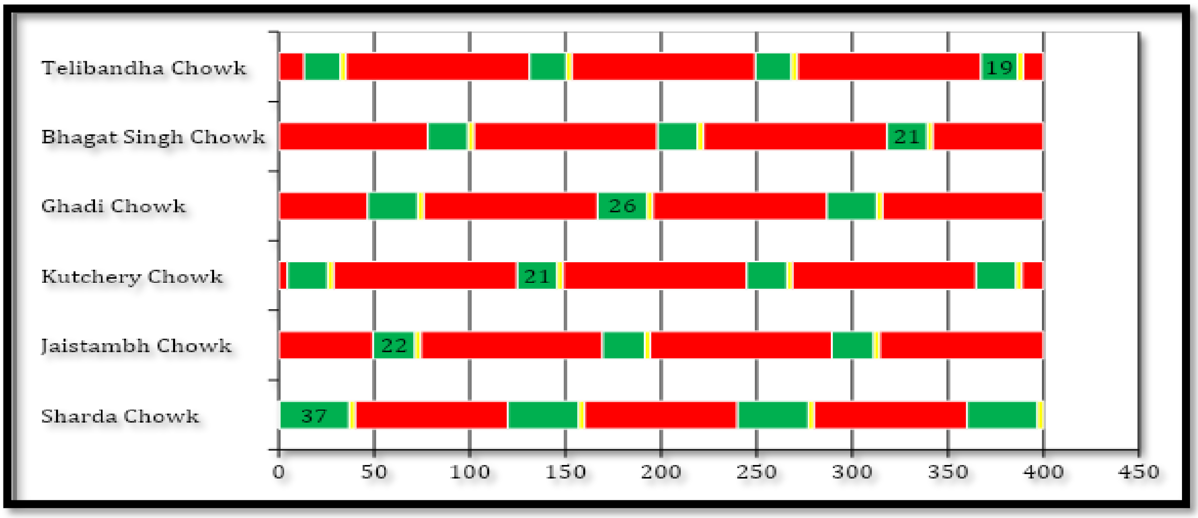

Fig. 4.8 Synchronization chart of the signal timings

VII. EVALUATION BY FLOATING CAR METHOD:

In order to the evaluate the effectiveness of the project existing Journey speed, Running speed and Delays at the study stretch is examined by floating car method during the peak hour of traffic flow were journey time, number of vehicle met with opposite direction and number of vehicles overtaking and overtaken by the test vehicle are noted and analysed as below.

ny = Average no of vehicles overtaking the test vehicle minus the no of vehicles overtaken when the test is in the direction of q
na = Average no of vehicles counted in the direction of the stream when the test vehicle travels in the opposite direction
tw = Average journey time, in minute when the test vehicle is travelling with the stream q
ta = Average journey time, in minute when test vehicle is running against the stream q
q = Average volume= (na + ny)/(ta + tw)
t = Average journey time= tw - (ny/q)
Journey speed = Journey length/Journey time

Table 4.7 Along Sharda to Telibandha

Average no of vehicles overtaking the test vehicle	14
Average no of vehicles overtaken by the test vehicle	15.33
n_y	-1.33
n_a	161.67
t_w	5.13 min
t_a	6.37 min
Average volume q	13.94 veh/min
Journey length	3.13 km
Average journey time, t	5.22 min
Average journey speed	36 kmph
Average delay	1.4 min
Average running time = Average journey time - Average delay	3.82 min
Average running speed	50 kmph

Table 4.8 Along Telibandha to Sharda

Average no of vehicles overtaking the test vehicle	23
Average no of vehicles overtaken by the test vehicle	23
n_y	0
n_a	186
t_w	6.37 min
t_a	5.13 min
Average volume q	16.17 veh/min
Journey length	3.13 km
Average journey time, t	6.37 min
Average journey speed	29.5 kmph
Average delay	1.74 min
Average running time = Average journey time - Average delay	4.63 min
Average running speed	41 kmph

As a result, the trip speed from Sharda to Telibandha and Telibandha to Sharda is 36 kmph and 29.5 kmph, respectively, with an acceptable delay of 1.4 minutes and 1.74 minutes. After synchronisation, the travel speed rises by about 39% from Sharda to Telibandha and 39% from Telibandha to Sharda, with no vehicle stops at any point throughout the study length. Since the synchronisation has been completed, the static delay caused by encountering the Red time signal is ideally zero. The synchronisation is done at 50 kmph for more efficient flow and a shorter trip duration. The table below displays the time necessary to go between each junction when traffic flows at the design speed of 50 mph.

Table 4.10.3 Time required between two Intersection

Intersection	Distance, km	Time, sec
Sharda Chowk		
	0.13	9.36
Jaistambh Chowk		
	0.7	50.4
Kutchery Chowk		
	0.25	18
Ghadi Chowk		
	1.7	122.4
Bhagat Singh Chowk		
	0.35	25.2
Telibandha Chowk		

VIII. MATLAB SIMULATION:

MATLAB is a programming environment designed primarily for engineers and scientists to research and develop systems and products that will alter the world. At the core of MATLAB is the MATLAB language, a matrix-based language that provides for the most natural description of computer mathematics.Simulink is a block diagram environment for creating multidomain models, simulating them before deploying them, and deploying them without writing code.

- **Block Diagram:**

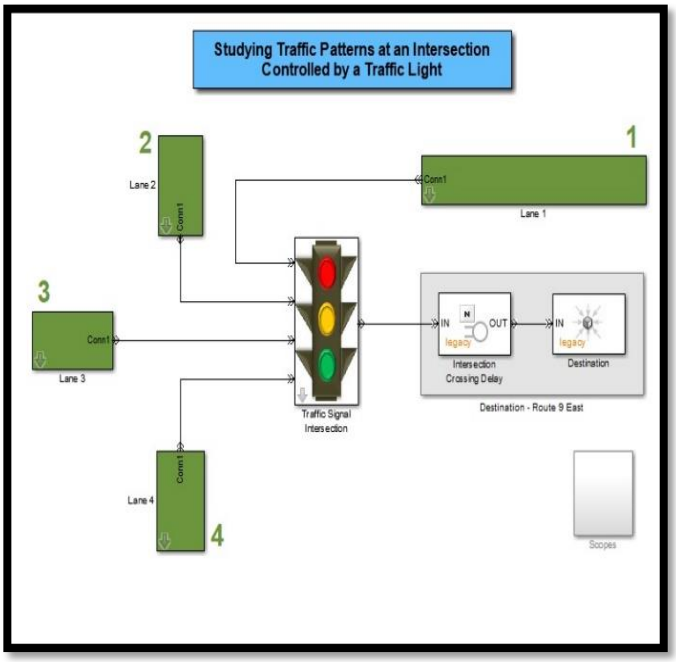

Fig. 8.1 Traffic patterns at an intersection

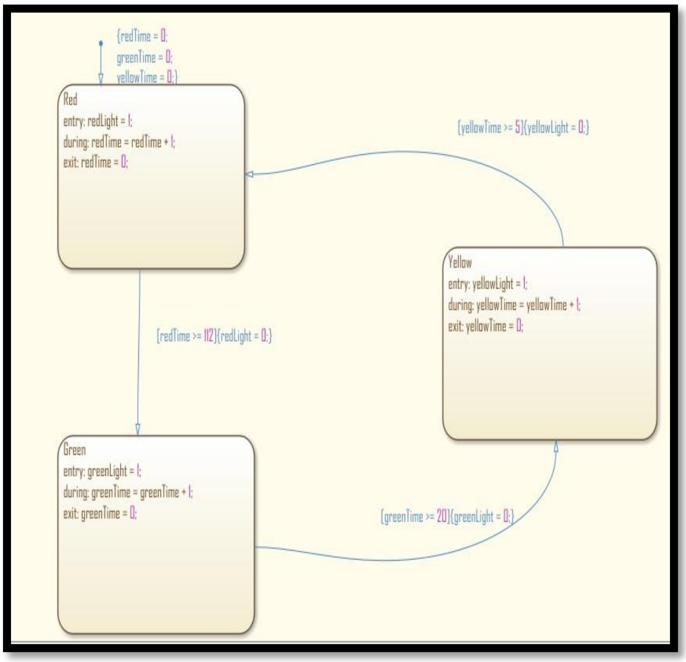

Fig. 8.2 Date input block

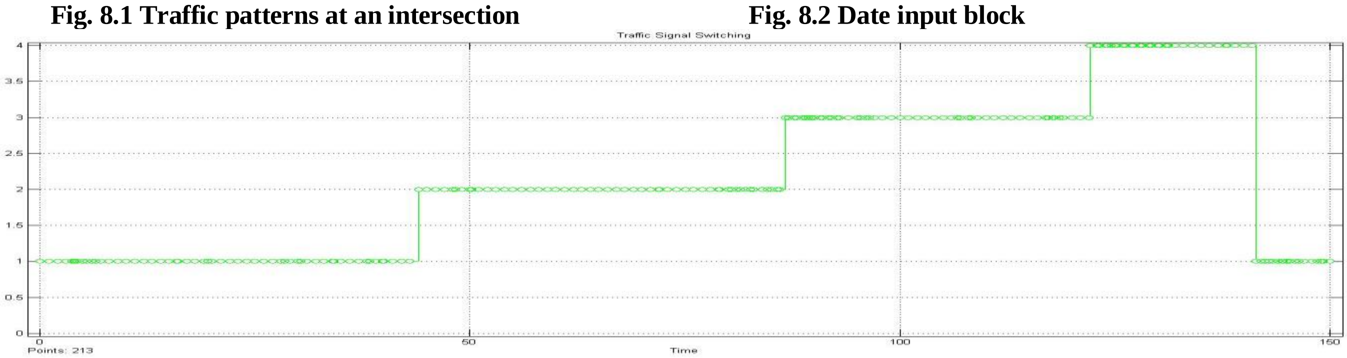

Fig 8.3 Traffic signal switching between the phases of Sharda chowk

Fig 8.4 Traffic signal switching between the phases of jaistambh chowk

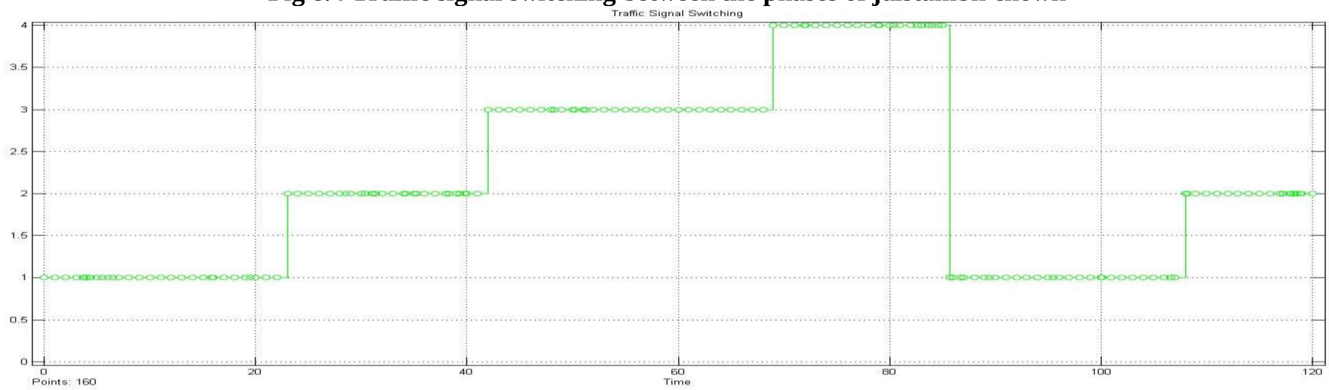

Fig 8.5 Traffic signal switching between the phases of Kutchery Chowk

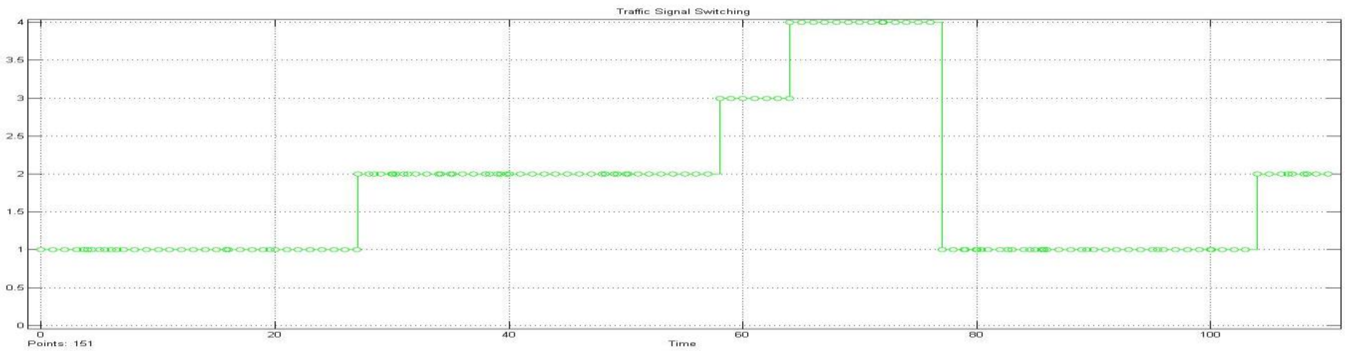

Fig 8.6 Traffic signal switching between the phases of Ghadi Chowk

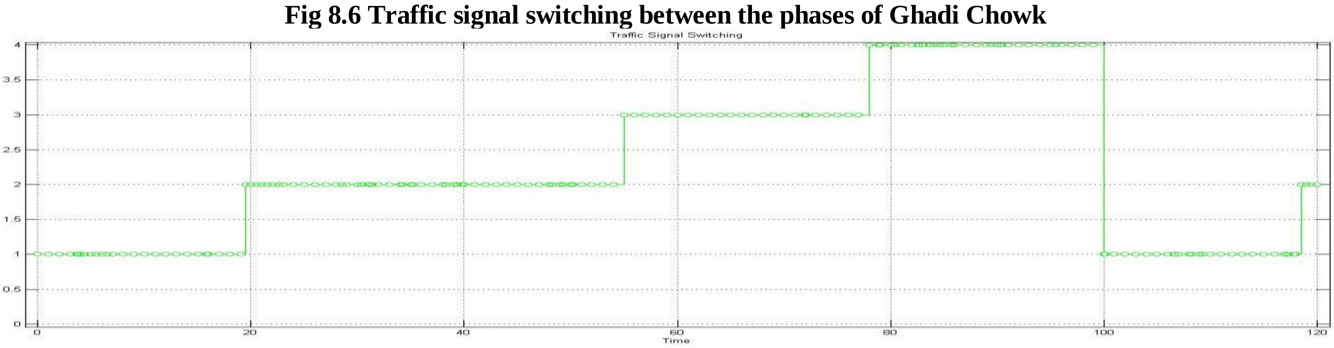

Fig 8.7 Traffic signal switching between the phases of Bhagat Singh Chowk

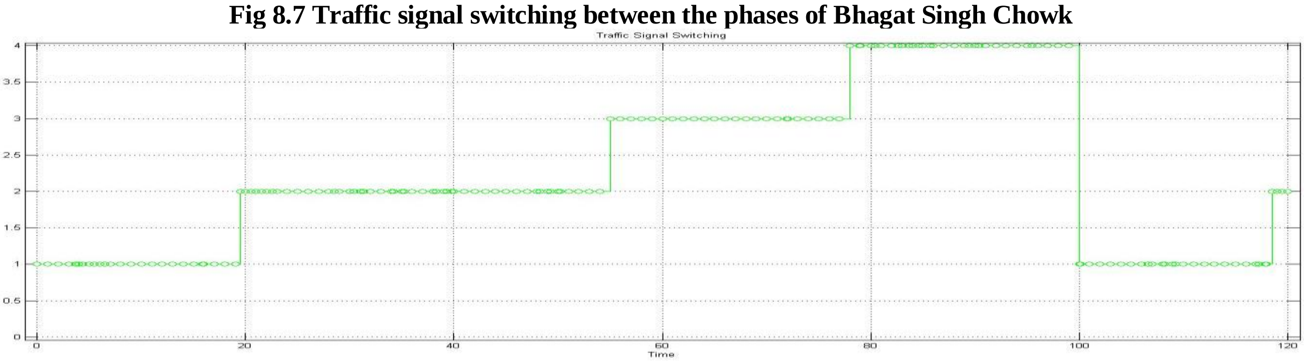

Fig 8.8 Traffic signal switching between the phases of Telibandha Chowk

IX. CONCLUSION :

- Webster's technique optimizes signal timings, resulting in shorter cycle durations and fewer stoppages.
- Why Low red time stoppages result in less mental irritation and a lower probability of red light running.
- By synchronizing the route signal timings, travel time is decreased.
- When travelling at the design speed of 50 kmph, the timings at each of the six junctions are synchronized.
- A 39% improvement in travel speed is recorded once synchronization eliminates waits at crossings.
- There will be no idling of automobiles since there will be no delay. As a result, the idle fuel consumption of traffic flow is minimized, resulting in cost savings for transportation users.
- Because there is no idling, there are fewer gas emissions, demonstrating synchronisation to be an ecologically friendly strategy.
- There would be no traffic congestion even at the narrow junctions of Sharda Chowk and Jaistambh Chowk.
- The necessity for pedestrian timings was identified at Sharda Chowk and Jaistambh Chowk, for which a 14-second green pedestrian time was given.

X. FUTURE SCOPE:

- The study length chosen provides transportation for a vast community in Raipur, making effective signal design a must.
- The synchronisation of these significant crossroads will benefit road users not only in terms of time and money, but also in terms of safety and avoidance of traffic rule infractions.
- The designation of signals leads in reduced congestion at junctions and a lower accident rate since the smooth flow of traffic is maintained.
- Drivers will be less annoyed as a consequence of fewer stops, resulting in fewer red light infractions.
- Changing the stopping and accelerating of cars repeatedly leads in a large amount of fuel consumption and therefore increased pollution; this problem will also be mitigated to a larger extent if fewer stops are made.

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