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Traffic Signal Coordination by Alternate Progressive System and Simultaneous System on Selected Stretch of Ahmedabad

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Abstract - *During the past decade most of the cities have undergone chaotic growth of Industrialization and urbanization of country. Consequently, the urban population has to travel bigger distances within least probable time. To accomplish travel demand the intersection should be given least resistance to traffic flow so that the travel time can be lessened. In this study an attempt has been made to reduce the travel time, stopped delay and queue length by coordination of signalized intersection both ways without the detectors by optimizing the signal timing and the offset.*
C.G Road is considered one of the most important roads in Ahmedabad. The three signalized intersections namely Parimal cross road, Panchvati cross road and Tanishq cross road on the corridor were selected. The Alternate Progressive System and Simultaneous System are considered for the study. At each considered intersection present signal timing, classified volume count, stopped delay, queue length and optimum cycle length were measured. By considering both the system it has been found that Simultaneous System is more effective.

Key Words: Signalised Intersection, Traffic Signal Coordination, Traffic Signal Design, Stopped Delay, Alternate Progressive System, Simultaneous System

1. INTRODUCTION

The world is facing traffic congestion which is a global issue. The growth of vehicles has increased due to urbanization and industrialization. Increase in traffic volume has caused problems in traffic operations like accidents, delay, congestion, fuel consumption, pollution, etc. specially at intersections. Therefore, it is required to signalize the intersections in urban areas for better regulation and control. There are limitations of traffic control devices where the traffic signal reaches its limit. Where there is high traffic volume for longer time, the signals repeatedly apply common control strategies. Only signalizing intersection is not enough, it is essential to optimize the cycle time and provide proper phase to reduce the conflict points and delay by ensuring safety. Coordinated signals have reduced delay time. Coupling the signals using an offset is traffic signal coordination. Offset indicates the how green phases of different signals are shifted to each other. When vehicles travel without being obstructed by red signal is most important objective known as "green wave". To ensure the traffic moves easily and safely is the normal function of coordination. This can be achieved by different control systems, which ranges from simple clockwise mechanism to complex computerized control and coordination systems.

1.1 Traffic Signal Coordination

Signal coordination is done when they are closely spaced to enable vehicle in one predominant direction to get continuous green. This will reduce the delay and travel time in one direction and increases throughout. There are three methods of coordination.

I. Simultaneous System
II. Alternate or Limited Progressive System
III. Simple Progressive System

I. Simultaneous system

Under this system, all the signals along a given street always display the same indication to the same traffic stream at the same time. The division of the cycle time is the same at all intersections. A master controller is employed to keep the series of signals in step.

II. Alternate or limited progressive system

Under this system, consecutive signal installations along a given road show contrary indications at the same time. This permits the vehicle to travel one block in half the cycle time. This system operates efficiency where the blocks are of equal lengths. It also brings about a certain measure of speed control since speeding drivers are stopped at each signal.

III. Simple progressive system

With this system, the various signals along a street display green aspect in accordance with a time schedule to permit, as nearly as possible, continuous operation of platoons of vehicles along the street at a planned rate of motion, which may vary in different parts of the system. The offset at each installation is determined so as to secure the best continuous movement of platoons in both directions. These offsets are fixed and cannot be altered at different periods of the day.

2. STUDY AREA

For proposed study of two-way coordination of traffic signals, a continuous stretch is essential having closely situated signalize intersections. It has been found that Chimanlal Girdharlal Road is highly suffering from traffic problems such as excessive delay, queue length, high travel time, etc. due to very high commercial development along the stretch which intersect the North and South bound traffic catering roads. The considered road is located in commercial area. In the selected corridor, two intersections are four armed and one intersection is five armed.

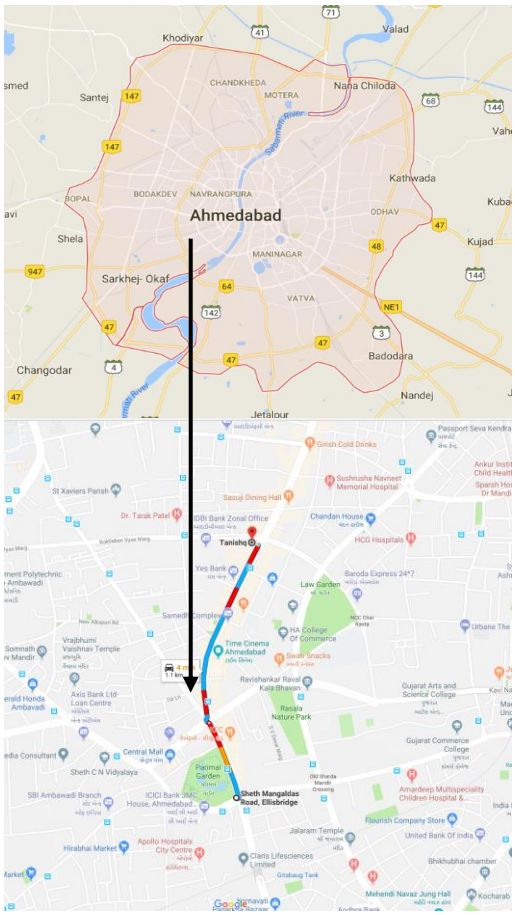

Fig -1: Study Area

2.1 Corridor Configuration

Stretch of 1.15 km along with three intersections named Parimal cross road, Panchvati cross road, Tanishq Intersection have been selected. The distance between Parimal and Panchvati intersection is 350 meters and the distance between Panchvati and Tanishq intersection is 800 meters.

3. DATA COLLECTION

For coordination of traffic signal various traffic surveys were performed like Classified Volume, Spot Speed, Stopped Delay, Travel Time, Queue Length, Offset, Optimum Cycle Time, etc. Manual as well as videography procedure is used for the data collection.

3.1 Intersection Inventory

At the considered three intersections the numbers of lanes, width of the road, median width, existing cycle time are measured which are shown in Table 1.

Table -1: Intersection inventory at all three intersections

Inventory at Parimal Intersection								
	North		South		East		West	
	L	R	L	R	L	R	L	R
No. of lanes	3	2	3	3	2	3	2	3
Width (m)	10.8	8	11.5	11.7	8.8	11.5	7	11
Median (m)	0.9		0.9		0.5		0.5	
Green Time (s)	25		35		30		40	
Red Time (s)	115		105		110		100	
Amber (s)	2		2		2		2	

Inventory at Tanishq Intersection								
	North		South		East		West	
	L	R	L	R	L	R	L	R
No. of lanes	2	2	2	2	2	3	2	3
Width (m)	7.5	8	7.8	8.2	8.3	9.5	8.5	9.2
Median (m)	0.95		0.95		1		1	
Green Time (s)	25		25		26		23	
Red Time (s)	95		95		94		97	
Amber (s)	2		2		2		2	

Inventory at Panchvati Intersection										
	North		South		East		West		North-West	
	L	R	L	R	L	R	L	R	L	R
No. of lanes	2	2	2	2	3	3	3	3	2	2
Width (m)	7	8	8	8	10	11	11	11	7	7
Median (m)	1		1		0.5		0.5		0.5	
Green Time (s)	30		28		40		40		26	
Red Time (s)	153		155		143		143		157	
Amber (s)	2		2		2		2		2	

3.2 Pilot Survey

Traffic volume count survey was conducted manually on C. G. Road in Ahmedabad at Girish intersection for 10 hours from 8:00 AM to 6 PM. At all the four approaches the left

turning, straight movement and right turning vehicles were counted. The hourly variation of traffic volume is obtained from this survey is shown in Chart-1.

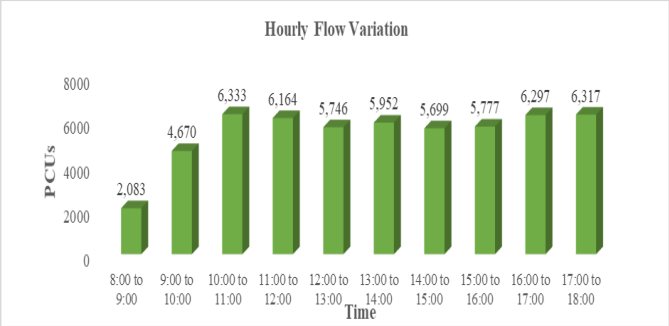

Chart -1: Hourly Variation of Traffic Volume

From the Chart-1 the peak hour is from 10:00 AM to 11:00 AM during which the PCU are 6633 PCUs/Hour. For the further study the traffic video recording is done for 10:00 AM to 11:00 AM at considered intersections.

4. DATA ANALYSIS

From the conducted traffic video recordings at considered intersections Traffic Volume, Stopped Delay, Queue Length are measured and at the midblock, the Spot Speed Study is carried out to find out the Space Mean Speed, Travel Time and Offset.

4.1 Traffic Volume

Traffic volume is the numbers of vehicles passing through a point on a road during a specified time. Earlier study indicates that PCU for a vehicle is not static, but it varies with the level of interaction between vehicles (P. Preethi). The Dynamic PCU values for Indian situation based on area occupancy method are used for the present study. The maximum peak hour flow occurs at the Parimal intersection which is 4846 PCUs/Hour. The peak hour flow at Panchvati and Tanishq intersection are 4553 PCUs/Hour and 3418 PCUs/Hour respectively.

Table - 2: Peak Hour Flow at Considered Intersections

Parimal intersection		**Panchvati intersection**		**Tanishq intersection**	
Approach	Traffic in PCU/hr	Approach	Traffic in PCU/hr	Approach	Traffic in PCU/hr
Panchvati (N)	776	Tanishq (N)	604	Girish (N)	735
Parimal (E)	1055	Gulbai Tekra (N-W)	594	Law Garden (E)	887
Polytechnic (W)	1348	Parimal (S)	835	Panchvati (S)	770
Paldi (S)	1667	Law Garden (E)	1309	Gulbai Tekra (W)	1025
		Ambawadi (W)	1211		
Total	4846	Total	4553	Total	3418

The vehicle composition at each intersection is shown in Table 4. There are maximum numbers of two wheelers having composition more than 62 %. Then after the 4 has vehicle composition more than 16 %. The three wheelers i.e. autorickshaw has a vehicle composition more than 12 %.

Table - 3: Vehicle Composition at Considered Intersections

	Parimal intersection	**Panchvati intersection**	**Tanishq intersection**
Class of Vehicles	%Composition	%Composition	%Composition
Scooter/Bike (2W)	65.48	62.97	62.82
Autorickshaw(3W)	13.41	12.98	14.5
Car/Van/Jeep	16.66	19.34	19.48
Bus	0.52	0.83	0.28
Bicycle	2.57	3.32	2.44
LCV	1.34	0.56	0.49

4.2 Spot Speed Study

Spot speed of each class of vehicle whose composition is high viz. are two wheelers, three wheelers and four wheelers were measured at mid blocks for each approach. Spot speed was carried out during peak hour having sample size of 70-75 for each class of vehicles.

Table - 4: Spot Speed Study Results

Approach	Category	No. of Samples	Space mean speed
Parimal Cross Road to Panchvati Cross Road	2W	75	38.46
	3W	75	29.61
	4W	75	36.66
	Average		34.46
Panchvati Cross Road to Parimal Cross Road	2W	70	42.01
	3W	70	35.13
	4W	70	41.27
	Average		39.21
Panchvati Cross Road to Tanishq Cross Road	2W	70	31.93
	3W	70	28.37
	4W	70	32.72
	Average		30.88
Tanishq Cross Road to Panchvati Cross Road	2W	75	31.82
	3W	75	28.93
	4W	75	30.48
	Average		30.37

4.3 Offset

The offset is defined as the difference between the starts of green time at the successive upstream and downstream signal. The offset at downstream is provided is equal to travel time from upstream to downstream intersection. The offsets are calculated using equation 1 and the results are shown in Table 5.

$$offset = \frac{D}{V} \times 3600 \quad \text{.....Eq. (1)}$$

Table - 5: Offset Between Consecutive Intersections

Offset Detail	Direction	Offset in Seconds
Offset for Panchvati Intersection with respect to Parimal Intersection	South to North	37
Offset for Tanishq Intersection with respect to Panchvati Intersection		93
Offset for Parimal Intersection with respect to Panchvati Intersection	North to South	32
Offset for Panchvati Intersection with respect to Tanishq Intersection		95

4.4 Stopped Delay

Stopped delay is defined as the average delay of all stopped vehicles on approach during red time. A stopped delay was measured in peak hour and only for through traffic. Stopped delay was measured in 15 seconds intervals. Total stopped delay for major approach on each considered intersection are shown in Table 6.

Table - 6: Average Stopped Delay

Intersection	Approach	Average Stopped delay
Parimal Intersection	From Panchvati	49.36
	From Paldi	51.97
Panchvati Intersection	From Tanishq	74.03
	From Parimal	74.96
Tanishq Intersection	From Girish	45.55
	From Panchvati	44.22

4.5 Queue Length

Queue length is found out for each intersection on considered approaches viz. North and South. The maximum queue length for each cycle is calculated from the recorded traffic videos. The average queue length at Parimal intersection is 37 and 54 m on north and south approach, at Panchvati intersection is 54 and 51 m on north and south approach, at Tanishq intersection is 44 and 43 m on north and south approach.

Table - 7: Queue Length

Approach	Average Queue Length (m)
Parimal North approach	37
Parimal South approach	54
Panchvati North approach	54
Panchvati South approach	51
Tanishq North approach	44
Tanishq South approach	43

4.6 Optimum Cycle Length

Webster's method is used to determine the optimum cycle length. Main attention in selecting the cycle time should be that the minimum delay is caused to the traffic passing through the intersection. Optimum cycle time can be obtained by equation 2.

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

Saturation flow can be measure by following model developed by N. G. Raval (2012) for heterogeneous traffic conditions of Ahmedabad city.

$$S = 626W + 268 \quad \text{.....Eq. (3)}$$

Table - 8: Optimum Cycle Length

Approach	Green time in second	Amber time in second	Total cycle time in second
Parimal Intersection			
From Panchvati (N)	19	2	150
From Parimal (S)	37	2	
From Polytechnic (W)	48	2	
From Paldi (E)	30	2	
Panchvati Intersection			
From Tanishq (N)	24	3	165
From Gulbai Tekra (N-W)	24	3	
From Parimal (S)	30	3	
From Law Garden (E)	35	3	
From Ambawadi (W)	32	3	
Tanishq Intersection			
From Girish (N)	15	2	82
From Law Garden (E)	17	2	
From Panchvati (S)	15	2	
From Gulbai Tekra (W)	19	2	

5. TRAFFIC SIGNAL COORDINATION BY ALTERNATE PROGRESSIVE SYSTEM

In Alternate Progressive System contrary indicators are provided at consecutive intersections.

5.1 One-way Signal Coordination by Alternate Progressive System

- Considering Existing Cycle Time

Alternate Progressive System is that in which at consecutive intersections opposite indicators are provided. In the first option the existing cycle times are considered. The cycle times are not changed. The movement is considered in the direction from Parimal intersection to Tanishq intersection i.e. from south to north direction. The time space diagram is shown in Figure 2 left for the same. For Tanishq intersection to Parimal intersection i.e. North to South direction the signal coordination for existing cycle time by Alternate Progressive System is shown in Figure 2 right.

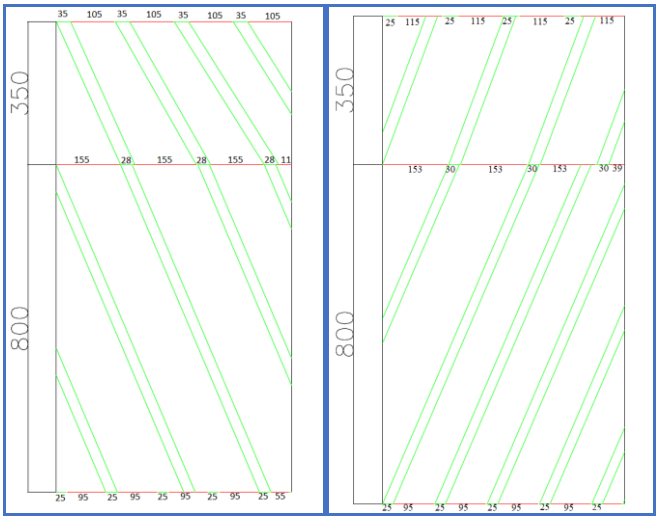

Fig -2: Time-Space Diagram for One-Way Coordination using existing cycle length by Alternate Progressive System

-Considering Optimum Cycle Time

The optimum cycle lengths are considered. The movement is considered in the direction from Parimal intersection to Tanishq intersection i.e. from south to north direction. At the Parimal intersection the Green indicator starts at the same time at Panchvati intersection the Red indicator starts and at the Tanishq intersection the Green indicator starts. The time space diagram is shown in Figure 3 left for the same. For Tanishq intersection to Parimal intersection i.e. North to South direction the signal coordination for optimum cycle time by Alternate Progressive System is shown in Figure 3 right.

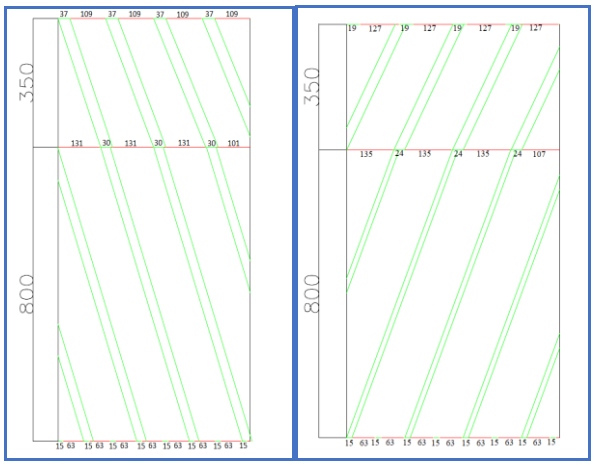

Fig -3: Time-Space Diagram for One-Way Coordination using optimum cycle length by Alternate Progressive System

5.2 Two-way Signal Coordination by Alternate Progressive System

The two-way coordination by Alternate Progressive System is achieved by considering the both direction movements and optimum cycle time as shown in Figure 4.

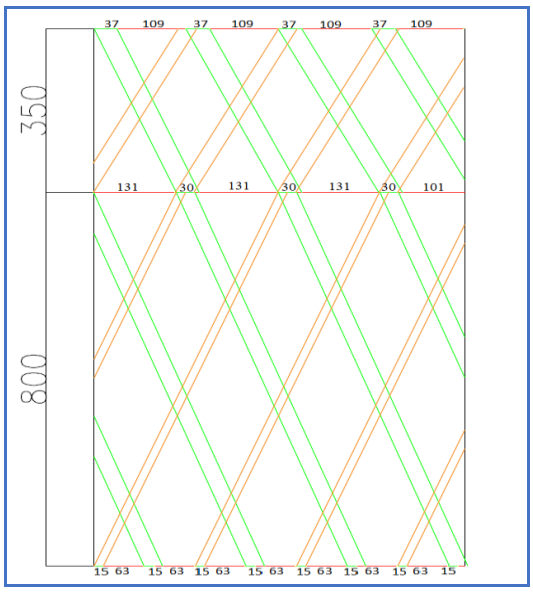

Fig -4: Time-Space Diagram for Two-Way Coordination using optimum cycle length by Alternate Progressive System

6. TRAFFIC SIGNAL COORDINATION BY SIMULTANEOUS SYSTEM

In Simultaneous System consecutive intersections show same indicators and having same cycle length.

6.1 One-way Signal Coordination by Simultaneous System

- Considering Existing Cycle Time

Simultaneous System is that in which at consecutive intersections are provided with the same cycle time and indicators. In the first option the existing cycle times are considered. The cycle time of Parimal intersection is considered as it is the middle cycle length between Panchvati intersection and Tanishq intersection. The cycle times are not changed. The movement is considered in the direction from Parimal intersection to Tanishq intersection i.e. from south direction to north direction. The time space diagram is shown in Figure 5 left for the same. For Tanishq intersection to Parimal intersection i.e. North direction to South direction the signal coordination for existing cycle time by Simultaneous System is shown in Figure 5 right.

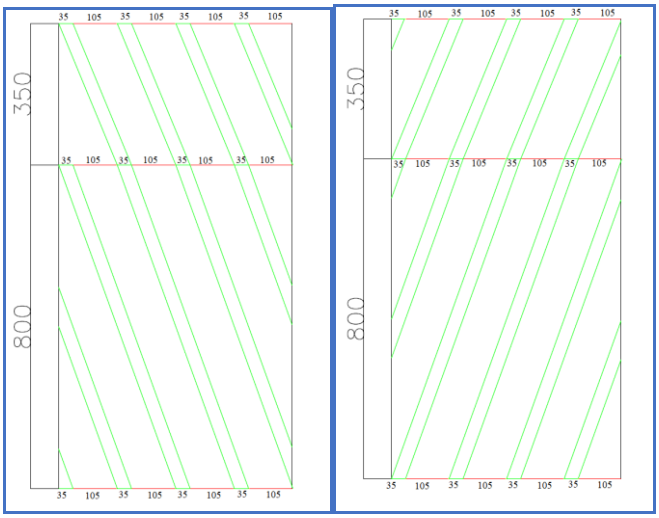

Fig -5: Time-Space Diagram for One-Way Coordination using existing cycle length by Simultaneous System

- Considering Optimum Cycle time

The optimum cycle lengths are considered. The movement is considered in the direction from Parimal intersection to Tanishq intersection i.e. from south direction to north direction. When at the Parimal intersection the Green indicator starts at the same time at Panchvati intersection and at the Tanishq intersection the Green indicator starts. The time space diagram is shown in Figure 6 left for the same. For Tanishq intersection to Parimal intersection i.e. North direction to South direction the signal coordination for optimum cycle time by Simultaneous System is shown in Figure 6 right.

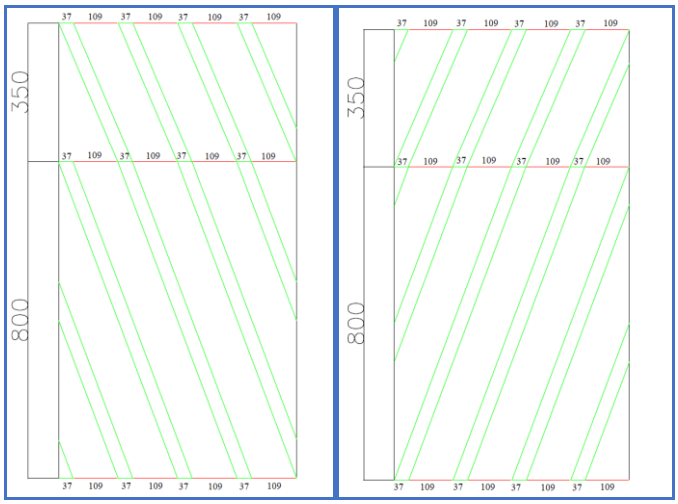

Fig -6: Time-Space Diagram for One-Way Coordination using Optimum cycle length by Simultaneous System

6.2 Two-way Signal Coordination by Simultaneous System

The two-way coordination by Simultaneous System is achieved by considering the both direction movements and optimum cycle time as shown in Figure 7.

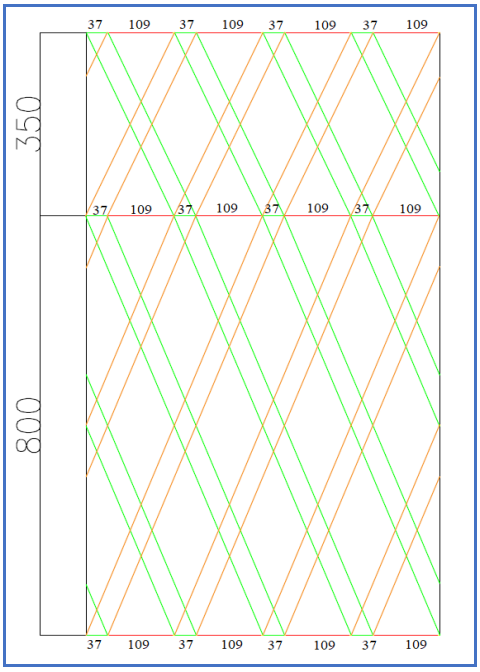

Fig -7: Time-Space Diagram for Two-Way Coordination using optimum cycle length by Simultaneous System

7. CONCLUSIONS

- ✓ The traffic movements in both the directions are high specially from South to North direction so the signal coordination from only one direction is not enough and two-way signal coordination is required on the corridor to provide unstopped through traffic movement.
- ✓ The existing signal cycle lengths (Parimal intersection 142 seconds. Panchvati intersection 185 seconds, Tanishq intersection 122 seconds) are inappropriate and connected with inadequate phase connection at consecutive intersections. This signal cycle lengths have been optimized (Parimal intersection 150 seconds. Panchvati intersection 165 seconds, Tanishq intersection 82 seconds).
- ✓ The Simultaneous System of coordination is more effective as compared to Alternate Progressive System.

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