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Traffic Signal Coordination by Simple Progressive System on Selected Stretch of Ahmedabad

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Abstract— ***The urban road network in Ahmedabad is 2600 km and it is mostly improbable to grow in near future, but the numbers of vehicle registration have enlarged by 24.59 Lakhs in last decade. As a result of this the traffic problems like delay, congestion, air pollution, fuel consumption are augmented and the signalized intersection are the utmost vital element. This paper signifies a technique of coordination for fixed time signals. It is essential to diminish delay at signalized intersections situated on stretch where through traffic movement is foremost. Signal coordination can be done by using the detectors at the intersections which uses real time data, but it is expensive. So, in this study an attempt is 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 was selected. The Dynamic PCU values reflects true nature of the vehicles, so in this study the Dynamic PCU values of vehicles were used. At each considered intersection present signal timing, geometric features, classified volume count, stopped delay, queue length spot speed study and optimum cycle length were measured.***

Keywords— Traffic Signal Coordination, Signal Design, Space Mean Speed, Time-Space Diagram, Stopped Delay, Offset, VISSIM Simulation

INTRODUCTION

Economic growth and social development are fastened by transport improvements due to improved accessibility and increased mobility to people, resources and markets. The world is facing traffic congestion, a global issue. The growth of vehicles has enlarged due to urbanization and industrialization. Upsurge in traffic volume has caused problems in traffic operations like accidents, delay, congestion, fuel consumption, pollution, etc. especially at intersections. Therefore, it is essential to signalize the intersections in urban areas for better regulation and control. There are boundaries of traffic control devices where the traffic signal reaches its edge. Where there is high traffic volume for lengthier time, the signals frequently apply common control strategies. Only signalizing intersection is not sufficient it is crucial to optimize the cycle time and provide suitable phase to lessen the conflict points and delay by confirming safety. Coordination of signals can be accomplished when the flow of traffic on a given direction of movement at one intersection is accommodated by a green time phase on its arrival at the next signalized intersection.

A. Objectives of study

- To reduce delay and to pass the traffic with minimum stoppages.
- To provide optimum cycle length and maximum flow through the intersection.
- To minimize the queue length on major road.

TRAFFIC SIGNAL COORDINATION

When the signals are closely placed, signal coordination is carried out to permit vehicles in major direction to get nonstop green. This will diminish the delay and travel time in one direction and upsurges through movement. It is essential to coordinate the green time so that vehicles can move efficiently through the set of signals. In some cases, two signals are located at very short distance that they have to be considered as one signal. In other cases, the signals are located at long distance that they may be considered independently. The geometric layout of the road system and the major traffic flow regulate the purpose of the signal system. It is essential to consider the type of system, whether one way or two ways arterial, type of road network, the volumes in both directions on roads, the activities to be proceeded, purpose of routes. All signals can't be easily coordinated. If an intersection which creates problems lies straight in the way of the strategy that must be planned for signal coordination, then two distinct systems, one on each side of this upsetting intersection can be taken for study. A serious intersection is one that can't handle the volumes distributed to it at any cycle length. There are mainly four types of traffic signal coordination system named as:

- Simultaneous System
- Alternate or Limited Progressive System
- Simple Progressive System
- Flexible Progressive System

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 and all the intersections are signalized. As per the standard code IRC:93-1985, the distance among successive intersections should be less than 1 km for coordination and this condition satisfies here.

Figure 1(A) Ahmedabad City Map

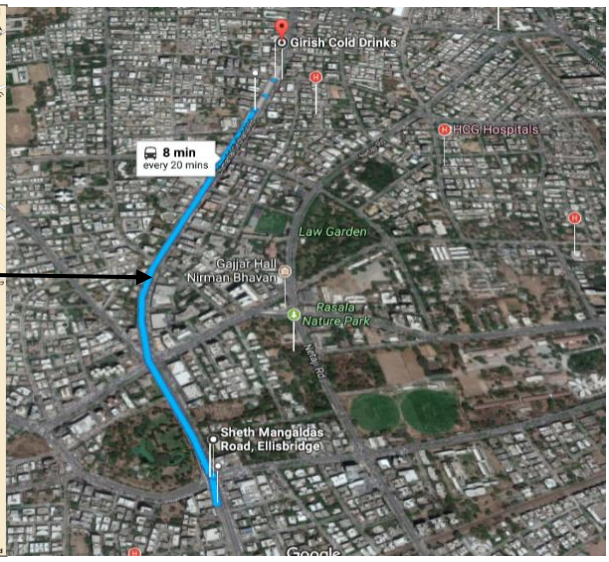

Figure 1(B) Selected Stretch of C.G Road

A. Geometry of Corridor

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.

DATA COLLECTION

For coordination of traffic signal various traffic surveys were performed like Classified Volume Count, 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.

A. 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									**Inventory at Tanishq Intersection**								
	North		South		East		West			North		South		East		West	
	L	R	L	R	L	R	L	R		L	R	L	R	L	R	L	R
No. of lanes	3	2	3	3	2	3	2	3	No. of lanes	2	2	2	2	2	3	2	3
Width (m)	10.8	8	11.5	11.7	8.8	11.5	7	11	Width (m)	7.5	8	7.8	8.2	8.3	9.5	8.5	9.2
Median (m)	0.9		0.9		0.5		0.5		Median (m)	0.95		0.95		1		1	
Green Time (s)	25		35		30		40		Green Time (s)	25		25		26		23	
Red Time (s)	115		105		110		100		Red Time (s)	95		95		94		97	
Amber (s)	2		2		2		2		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	8.5	7.8	8.3	10.5	11	10.7	11.5	7	7.5
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	

B. Peak Hour Determination

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 are counted. The hourly variation of traffic volume is obtained from this survey.

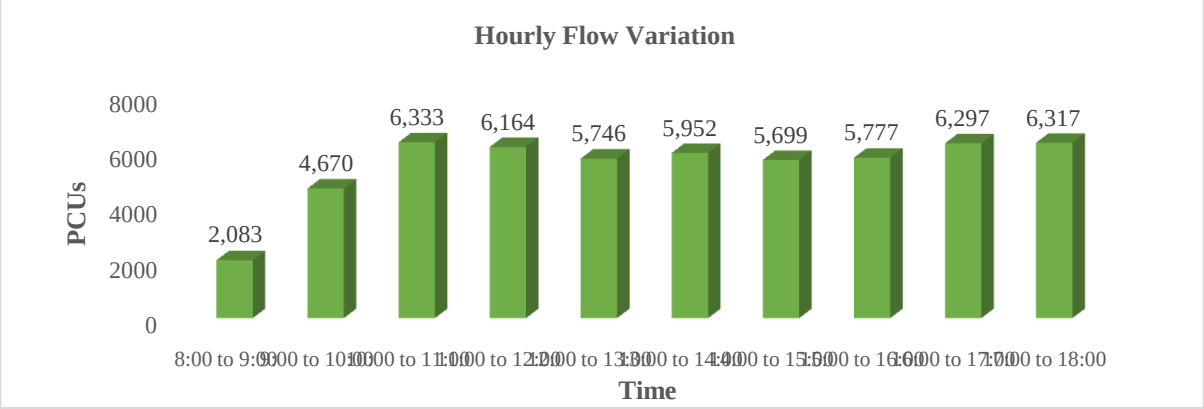

Figure 2 Hourly variation of traffic volume

From 10 hours survey it is observed that 2W, 3W and Cars consists of about 95% of the total traffic volume. From the figure 2 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.

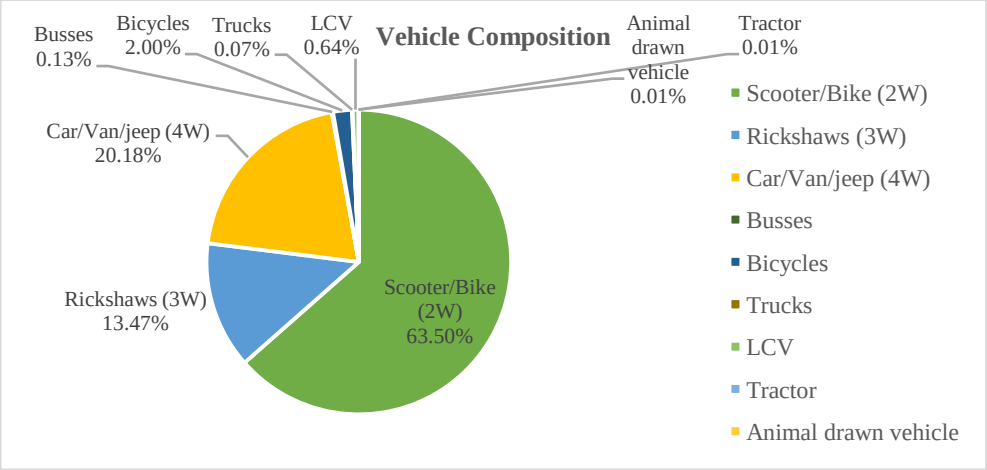

Figure 3 Vehicle Composition

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.

A. 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 car/van/jeep 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	Class of Vehicles	% Composition	Class of Vehicles	% Composition
Scooter/Bike (2W)	65.48	Scooter/Bike (2W)	62.97	Scooter/Bike (2W)	62.82
Autorickshaw(3W)	13.41	Autorickshaw(3W)	12.98	Autorickshaw(3W)	14.5
Car/Van/Jeep	16.66	Car/Van/Jeep	19.34	Car/Van/Jeep	19.48
Bus	0.52	Bus	0.83	Bus	0.28
Bicycle	2.57	Bicycle	3.32	Bicycle	2.44
LCV	1.34	LCV	0.56	LCV	0.49

B. Spot Speed Study

Spot speed of each class of vehicle whose composition is high viz. are two wheelers, three wheelers and four wheelers are measured at mid blocks for each approach. Spot speed is carried out during peak hour having sample size of 70-75 for each class of vehicles. Stop watch method is used to carry out the survey.

Table 4 Spot Speed Study Results

Approach	Category	No. of Samples	Time mean speed	Space mean speed
Parimal Cross Road to Panchvati Cross Road	2W	75	40.5	38.46
	3W	75	30.5	29.61
	4W	75	38.43	36.66
	Average		36.48	**34.46**
Panchvati Cross Road to Parimal Cross Road	2W	70	43.71	42.01
	3W	70	35.79	35.13
	4W	70	43.14	41.27
	Average		40.88	**39.21**
Panchvati Cross Road to Tanishq Cross Road	2W	70	33.43	31.93
	3W	70	29.57	28.37
	4W	70	33.79	32.72
	Average		32.26	**30.88**
Tanishq Cross Road to Panchvati Cross Road	2W	75	33.17	31.82
	3W	75	29.9	28.93
	4W	75	31.37	30.48
	Average		31.48	**30.37**

C. 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.

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

Table 5 Offsets Between Consecutive Intersections

Offset Detail	Direction	D (Kilometer)	V (KMPH)	Offset in Seconds= (D/V) * 3600
Offset for Panchvati Intersection with respect to Parimal Intersection	South to North	0.35	34.46	37
Offset for Tanishq Intersection with respect to Panchvati Intersection		0.8	30.88	93
Offset for Parimal Intersection with respect to Panchvati Intersection	North to South	0.35	39.21	32
Offset for Panchvati Intersection with respect to Tanishq Intersection		0.8	30.37	95

D. 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. A sample of stopped delay calculation is shown in table at bodyline intersection from Girish intersection for 5 cycles is shown in Table 6.

Table 6 Stopped Delay Calculation

Cycle No.	No. of Vehicles								
	0-15 s	16-30 s	31-45 s	46-60 s	61-75 s	76-90 s	91-105 s	106-115 s	Total
1	1	2	8	8	5	14	15	2	55
2	5	4	0	1	2	10	13	1	36
3	8	12	1	3	2	5	4	4	39
Waiting Time W_t	100	85	70	55	40	25	10	0	

Existing cycle time- 142 seconds

Existing green time- 25 seconds

Existing red time- 115 seconds

Waiting time W_t = Red time – Observed time Eq. (2)

= 115 - 15

= 100 seconds

Similarly, for other intervals W_t is 85, 70, 55, 40, 25, 10 and 0.

Now, total waiting time for 1st cycle is = (Wt) × (vehicles waiting in 0-15 sec) + (Wt) × (vehicles waiting in 16-30 sec) + (Wt) × (vehicles waiting in 31-45 sec) + (Wt) × (vehicles waiting in 46-60 sec) + (Wt) × (vehicles waiting in 61-75 sec) + (Wt) × (vehicles waiting in 76-90 sec) + (Wt) × (vehicles waiting in 91-105 sec) + (Wt) × (vehicles waiting in 105-115 sec). Eq. (3)

Total stopped delay = $\frac{Total\ waiting\ time}{Total\ vehicle\ stopped}$ Eq. (4)

Total stopped delay for major approach on each considered intersection are shown in Table 7.

Table 7 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

E. 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 8 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

F. Optimum Cycle Length

Webster's method is used to determine the optimum cycle length. it was studied in the road research laboratory (U.K.) by means of computer simulation of flow at the traffic signals. 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 5.

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

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

S = 626W + 268 Eq. (6)

Minimum inter green period (I) = 4 second, Amber period = 2 seconds for 4 phase and 3 seconds for 5 phase traffic signals., Lost time for phase = 2 seconds for each phase.

Table 9 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	

TRAFFIC SIGNAL COORDINATION BY SIMPLE PROGRESSIVE SYSTEM

The two-way signal coordination is done because of the high peak hour traffic on both directions on selected stretch. Delay and queue length on selected route is also high. There are two options possible which are:

A. One-way Signal Coordination by Simple Progressive System

– Considering Existing cycle time

In the first option the existing cycle times are considered. The cycle times are not changed and the offsets are provided. First the offsets are selected 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 4 (B)left side for the same. Now, the offsets are selected in the direction from Tanishq intersection to Parimal intersection i.e. from north direction to south direction. The time space diagram is shown in Figure 4 (B) for the same. The existing cycle time are not optimized and the coordination from downstream to upstream or from north to south direction cannot be achieved.

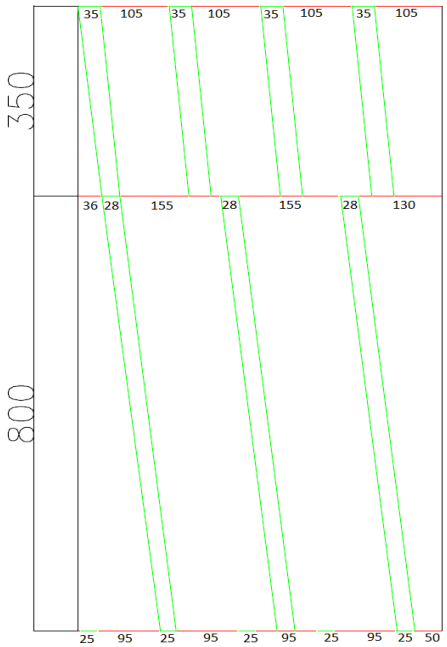

Figure 4 (A) Time-Space Diagram South-North Direction for One-Way Coordination using existing cycle length

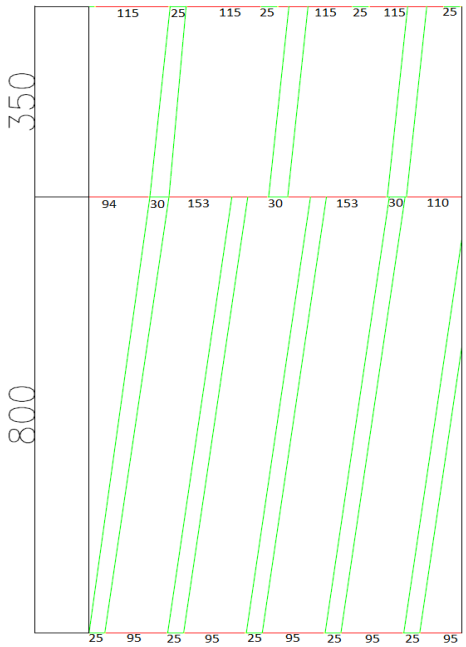

Figure 4 (B) Time-Space Diagram North-South Direction for One-Way Coordination using existing cycle length

– Considering Optimum Cycle Time

In the second option the optimum cycle lengths are considered. The cycle timings are changed and offsets are provided. First the offsets are selected 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 (A) for the same. Now, the offsets are selected in the direction from Tanishq intersection to Parimal intersection i.e. from north direction to south direction. The time space diagram is shown in Figure 5 (B)for the same.

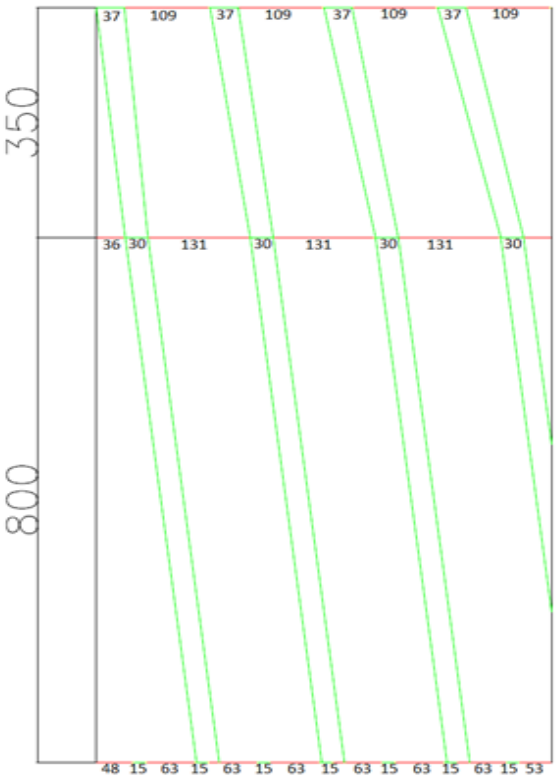

Figure 5 (A) Time-Space Diagram South-North Direction for One-Way Coordination using Optimum Cycle Length

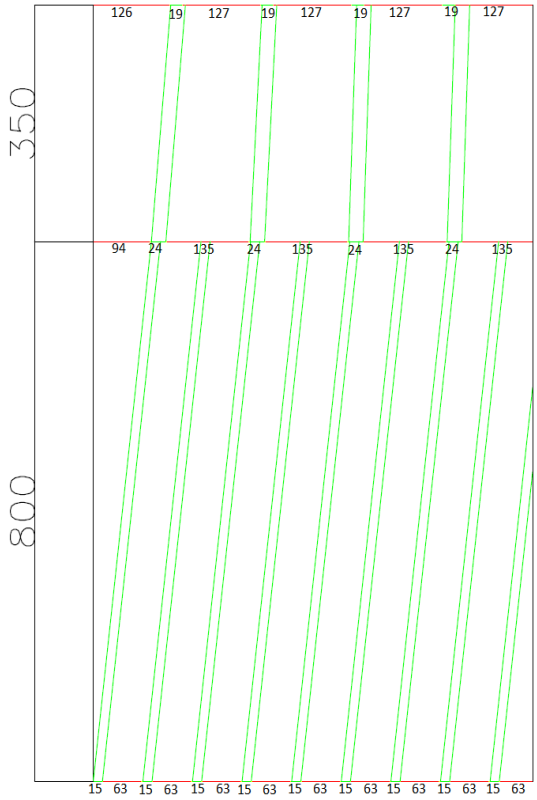

Figure 5 (B) Time-Space Diagram North-South Direction for One-Way Coordination using Optimum Cycle Length

B. Two-way Signal Coordination by Simple Progressive System for Optimum Cycle Time

If the coordination is done by considering the offset in the one direction, that makes the delay on opposite direction. For example, consider two intersections for coordination which are Parimal intersection and Panchvati intersection. The offset time for Parimal intersection with respect to Panchvati intersection is 32 seconds and the offset time for Panchvati intersection with respect to Parimal intersection is 38 seconds. If the coordination is done by taking 38 seconds offset there will be a delay of 10 seconds for vehicle coming from Panchvati intersection to Parimal intersection. If the coordination is done by taking 32 seconds offset, then there will be a 10 seconds delay for vehicle coming from Parimal intersection to Panchvati intersection. In this case the delay is divided in both the direction, so the offsets will be 32+5=37 seconds for Parimal intersection with respect to Panchvati intersection and 38+5= 43 seconds for Panchvati intersection with respect to Parimal intersection. Similarly, the offsets for Tanishq intersection with respect to Panchvati intersection is 94 seconds and that for Panchvati intersection with respect to Tanishq intersection is 96 seconds. The delay of 2 seconds is divided on both the directions, so the offsets will be 94+1=95 seconds for Tanishq intersection with respect to Panchvati intersection and 96+1= 97 seconds for Panchvati intersection with respect to Tanishq intersection.

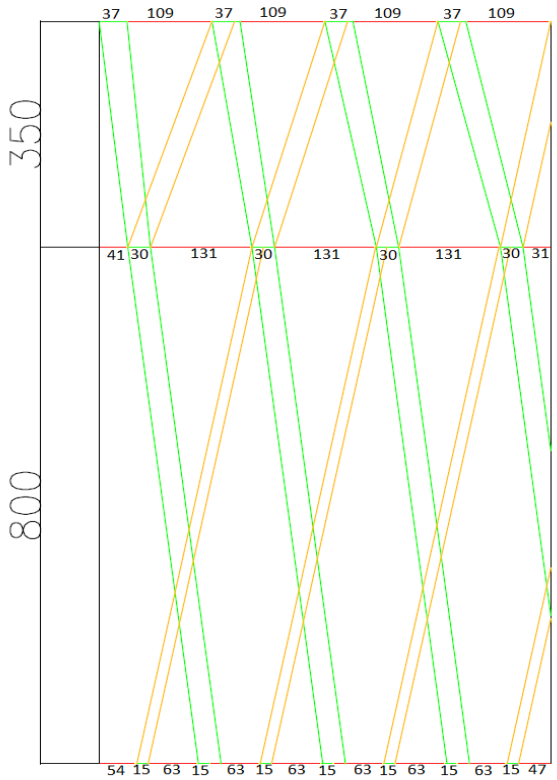

Figure 6 Two-way signal coordination using Simple Progressive System for Optimum Cycle Time

SIMULATION IN VISSIM

Simulation models play a significant role in the study and assessment of the road transport system and its components. Simulation models are intended to study the behavior of transportation systems and processes. One such software tool is VISSIM. VISSIM is an acronym of "Verkehr In Stadten – SIMulation". The model was developed at the University of Karlsruhe, Germany during the early 1970s. The collected data and analyzed data are used as input viz. in the VISSIM and the results are shown in Table 10.

Table 10 VISSIM Simulation Results

Intersection	Approach	Stopped Delay (seconds/vehicle)	Queue length (meters)
Parimal	Paldi to Panchvati (S)	26	55
	Panchvati to Paldi (N)	16	40
Panchvati	Parimal to Tanishq (S)	29	52
	Tanishq to Parimal (N)	6	35
Tanishq	Panchvati to Girish (S)	23	58
	Girish to Panchvati (N)	12	53

CONCLUSIONS

From this research work following concluding remarks are made:

- ✓ 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 Offset for Panchvati intersection with respect to Parimal intersection = 43 seconds, offset for Tanishq intersection with respect to Panchvati intersection = 95 seconds, offset for Parimal Intersection with respect to Panchvati intersection = 37 seconds, offset for Panchvati intersection with respect to Tanishq intersection = 97 seconds.
- ✓ For the Parimal intersection the stopped delay on south approach is reduced from 52 seconds to 26 seconds i.e. 50% and on north approach the delay reduction is from 49 seconds to 16 seconds i.e. 67%. For the Panchvati intersection the stopped delay on south approach is reduced from 75 seconds to 29 seconds i.e. 61% and on north approach the delay reduction is from 74 seconds to 6 seconds i.e. 92%. For the Tanishq intersection the stopped delay on south approach is reduced from 44 seconds to 23 seconds i.e. 48%and on north approach the delay reduction is from 46 seconds to 12 seconds i.e. 74%. Overall stopped delay from South direction to North direction is reduced from 171 seconds to 78 seconds i.e. 54% and that from North direction to South direction is reduced from 169 seconds to 34 seconds i.e. 80%.

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