Comparative study of traffic signals with and without signal coordination of various intersection

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Abstract - *This study focuses on quantifying the congestion at intersection. For obtained congestion this study updates the signal timing in order to exalt the intersection capacity, abate delays and enhance comprehensive efficiency of traffic. As signal coordination is the most effective method to pass maximum number of vehicles from any route. The previous signal coordination was done by thumb rule or theoretical manner. For more realistic performance of traffic signals microscopic, time and behavior-based software should be used to coordinate the signals.*

Key Words: Signal Optimization, bandwidth, TRANSYT7F, VISSIM SCAPI

1.INTRODUCTION

Mobility of people and goods from their point of origin to their point of destination is what is meant by transportation. Due to the massive population expansion in cities and the rise in automobile ownership, urban mobility is becoming more complicated every day. Increased vehicular density on urban roads necessitates effective traffic control measures, especially at intersections where heterogeneity and turning movements lead to problems with time pollution, traffic jams, mobility delays, and environmental pollution, among other things, when operating and maintaining each individual vehicle's costs are taken into account. Increased fuel consumption is a result of the time pollution caused by the enormous expansion in the number of vehicles on the road. (1,2)

Signals are one way of traffic regulation provision of it deals with leg wise traffic movement. Traffic signal with prevailing conditions helps to control the network in practical and economical way. Traffic flow at signalized intersections is filtered by fixed time signal system (halting a vehicle during red phase) leaving delay in travel time. Coordination of signals is the most practical solution to solve all the problems with signalized crossings within an urban road network. The main goal of signal coordination is to maximize vehicle flow across junctions in a predictable amount of time with a minimum amount of stops and accidents while maintaining a high level of speed. It abates alteration of speed with furnishing an unruffled maneuvering of traffic, resulting in intensify the capacity, diminution in fuel consumption along with pollution, this tumbles out comprehensive operation and maintenance cost. (1,2,3)

In India, traffic is heterogeneous form and during peak hours approaches to intersections are dense, so it is herculean to manure with no effort. A metropolitan city like Mumbai has many heavy traffic corridors leaving dilemma during maneuvering. The local administration and government body had made efforts to mitigate the congestion by enhancing urban transport system. The base line of this study is to linking of signals with abating travel time, to quantify the delay as well as fuel consumption with respect to the volume. Extensive research work had been carried out to quantify the congestion at intersection for obtained congestion this study updates the signal timing in order to exalt the intersection capacity, abate delays, enhance comprehensive efficiency of traffic. (3)

2. LITERATURE REVIEW

Arash M. Roshandeh, (2014), proposed a strategy for minimizing overall vehicle and pedestrian delays each cycle by adjusting green splits for each signalised intersection in the urban street network without altering the current cycle length and signal coordination. (4)

Zichuan Li (2011), had worked on Modelling Arterial Signal optimisation and provided an arterial signal optimisation model that could take junction lane group queue blockage into account when conditions were oversaturated. The suggested model uses the cell transmission idea to capture traffic dynamics. (5)

Diao Pengdi, (2012), Considered to be the bottleneck for transportation capacity, intersections are also frequently the scene of accidents and traffic congestion. Engineering study on traffic control was heavily focused on the scientific management and control of the intersection. (6)

Aleksandar Z, (2008had proposed microsimulation techniques that mimic the random character of traffic to model it. A variety of traffic demand and control scenarios were examined. Their findings demonstrated that when macroscopically improved signal timings were put through a thorough review using microsimulation. (7,8)

Xianfeng Yang, (2014), studied the theory of interval analysis and developed a set of demand intervals to depict the variations in demand. An optimisation approach based on demand interval patterns was suggested. (9)

Mahmood Mahmoodi Nesheli, (2009), this study establishes the traffic signal coordination layout for four adjacent crossings that are separated by 780 meters. Using a video camera, data on vehicle movement was gathered during morning and evening rush hours when traffic was heavy. An evaluation simulation model called TRANSYT7F was used to assess the potential coordination of signalized junctions. The findings demonstrate that after coordination, delays, travel times, and queues are reduced. (10)

Rui Yue, Guang chuan Yang (2022), An elliptical approach is presented in this study to balance the control delays between a major street and a minor street. The process is to use the e-service strategy in the small street's signal controller in addition to optimizing the big street's splits. Results indicate that the coordination effect on the major street may be obtained and protected with an acceptable delay to smaller street traffic when adequate splits are used. (11)

Jiao Yao, Qingyun Tang (2021), The traditional fundamental green wave bandwidth model was adjusted by the researchers in this study so that a separate turning green wave band was made available for the flow of traffic from sub-arterials merging into an arterial and that this variable green wave band could be more adaptable to support the commuting traffic. A multi-route signal coordination control model was developed with this as the goal function; this model is a mixed integer linear programming problem with the overall ideal coordination rate of inbound, outbound, and turning movement. (12)

Changjiang Zheng, Genghua Ma (2012), In order to address the issue with pedestrian Mid-Block Street Crossings, this article investigates the signal coordination control mechanism between Mid-Block Street Crossing and Intersections. The study suggests using the graph "distance-flow rate-time" as a tool for creating a coordination control system model that is for various traffic control conditions. (13)

Yan Li, Lijie Yu, Siran Tao, and Kuanmin Chen (2013), A multi-objective coordination approach for traffic signal control is suggested in order to increase the effectiveness of traffic signal management at solitary intersections under oversaturated conditions. The traffic signal control's optimization goals under oversaturated conditions are throughput maximum and minimum average queue ratio. The convergence and optimization findings were assessed in a simulation environment using VISSIM SCAPI under varied traffic circumstances. The simulation results showed that the suggested algorithm's signal timing scheme is quite effective in controlling traffic at overcrowded intersections. (14)

Lin Du and Yun Zhang (2014), In this research, a dissipative-based control technique for online traffic signalization is proposed by treating the intersection as a positive switched system. An LP problem-based design approach is proposed that satisfies the positivity, dissipative, and control requirements. We now have a fresh perspective on simulating junctions thanks to the positive switched system approach; our upcoming work will involve bringing other cutting-edge control schemes from the positive switched system to the intersection system. (15)

Li Wang, Xiao-ming Liu, Zhi-jian Wang (2013), For the purpose of optimising the control structure of the traffic system, the network analysis approach was used in these two areas. Simulation results demonstrate that the suggested network analysis approach can significantly enhance the effectiveness of the operation of the traffic control system. (16)

Xiaojian Hu, Jian Lu (2014), The long green and long red (LGLR) traffic signal coordination approach is the one the study suggests for coordinating local traffic signals. The goal of the strategy is to maximize the effectiveness of traffic flows at signalized intersections in the congested HGRN while controlling the formation and dispersal of lineups. The simulation is run to compare the model's performance to that of other models, and it is clear that the LGLR model performs better overall and in terms of delay, number of stops, queue length, and performance in the saturated HGRN. (17)

3. DESIGN AND IMPLEMENTATION

Speed is the prime factor for the design of any control system in transportation as relates to safety, comfort, time, convenience, and economy. It is more important to determine the speed distribution of traffic flow maneuvering in a particular stream. The spot speed study was performed to evaluate the percentiles speed of vehicles.

The percentile speed distribution before Kala Nagar Junction is shown following figures.

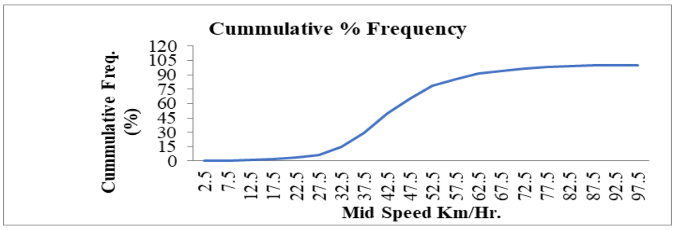

Chart 1. Cumulative Frequency – Mid-Speed relationship

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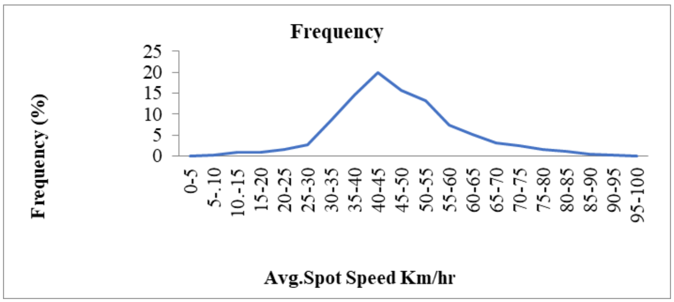

Chart2. Variation of speed w.r.t. frequency

From above relationship the percentile speed and maximum frequency is evaluated as follows: -

- 15th Percentile speed – 32.5 Km/hr
- 85th Percentile speed - 57.5 Km/hr
- Maximum Frequency of vehicle – 19.83 %

3.1 Design of signal

All the signals are designed based on field data and using Webster's method. All the signals are designed as fixed time signals. One of the supreme factors for design of signal is to determine the cycle time.

Table 1. Sample calculation for signal design at Kala Nagar Junction:

Traffic direction	North Bound	South Bound	West Bound	East Bound
Volume (q) (veh/hr)	767	1078	1875	1628
Lane Width (w) (m)	8	8	12	12

Saturation Flow(s) = 525 x lane width (veh/hr)

Saturation flow at N-S bound: -

$s = 525 * 8$ = 4200 veh/hr -------- (1)

Saturation flow at E-W bound: -

$s = 525 * 12$ = 6300 veh/hr ------- (2)

Ratio of volume to saturation flow various bounds: -

North Bound

$$y_1 = \frac{q}{s} = \frac{767}{4200} = 0.182$$

South Bound

$$y_2 = \frac{q}{s} = \frac{1078}{4200} = 0.256$$

West Bound

$$y_3 = \frac{q}{s} = \frac{1875}{6300} = 0.297$$

East Bound

$$y_3 = \frac{q}{s} = \frac{1628}{6300} = 0.258$$

0.256+0.297 = 0.553

The cycle length of signal as per Webster's Formula: -

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

L= Total lost time in each cycle (sec).

C_o = Optimal cycle length (sec).

Y= Volume to saturation flow ratio for critical bound.

$$C_o = \frac{1.5 * 16 + 5}{1 - 0.553} = 64.87 = 65\ (sec)$$

While considering pedestrian flow, and considering higher value we can adopt cycle length as **76 sec.**

Green phase at each bound: -

- $G_{NB} = \frac{0.182}{0.553} * 76 = 14$ sec
- $G_{SB} = \frac{0.256}{0.553} * 76 = 20\ sec$
- $G_{WB} = \frac{0.297}{0.553} * 76 = 23$ sec
- $G_{SB} = \frac{0.258}{0.553} * 76 = 19\ sec$

Table 2. Signal Design details at Kala Nagar Junction

Approach	N	S	W	E
Approach Width	8	8	12	12
Volume (veh/hr)	765	1078	1875	1628
Green Phase (sec)	14	20	23	19
Green Time (sec)	11	17	20	16
Amber time (sec)	3	3	3	3
Red Time (sec)	62	56	63	57
V/C ratio (X_c)	0.988	0.97	0.98	1.03

Table 3. Details of design of signals of all signals: -

			Green Phase (sec)				Red Phase (Sec)			
Sr. No.	Name of Intersections	Cycle Length	N	S	W	E	N	S	W	E
1	Kala Nagar	76	11	17	20	16	62	56	63	57
2	Family Court	105	30	21	22	21	72	81	80	81
3	Bharat Nagar	105	27	23	24	19	75	79	78	83
4	Diamond Market	105	21	29	25	22	86	78	82	85
5	MTNL Sq. BKC	105	22	25	24	22	80	77	78	80

3.2 Signal Coordination

Based on the field observed data and signal design details, the coordination of signals is performed theoretically. Route: - From Kala Nagar to MTNL Sq. BKC

Considering average spot speed = 42.5 kmph

Table 4. Phase time, Offset and Distances

Intersection	Green time (sec)	Amber time (sec)	Red Time (sec)	Offset	Distance
Family Court	22	3	80	30	1600
Bharat Nagar	24	3	78	69	2200
Diamond Market Sq.	25	3	82	18	2800
MTNL Sq. BKC	24	3	78	96	3600

1) Time required for Vehicle leaving form Kala Nagar and arrive at Family Court Sq. is

$$T0= \frac{1600}{11.8} = 135 \text{ sec}$$

$$\left|\frac{135-30}{105}\right| = 0 \ll 25 \; sec$$

Vehicles will reach the beginning of green time in next cycle.

2) Time required for Vehicle leaving form Kala Nagar and arrives at Bharat Nagar is

$$T1 = \frac{2200}{11.8} = 187 \text{ sec}$$

$$\left|\frac{187-62}{105}\right| = 20 \ll 27 \; sec$$

27-20= 7 sec Vehicles leaving after 7 sec get stopped at Bharat Nagar. So, the residual time added to offset to increase the through bandwidth. The new offset = 62+7= 69 sec.

$$\left|\frac{187-69}{105}\right| = 3 \ll 25 \; sec$$

Vehicle will enter 3 sec after starting of green time.

3) Time required for Vehicle leaving form Kala Nagar and arrives at Diamond Market is

$$T2= \frac{2800}{11.8} = 238 \; sec$$

$$\left|\frac{238-18}{105}\right| = 0 \ll 28 \; sec$$

Vehicles will reach the beginning of green time in next cycle.

4) Time required for Vehicle leaving form Kala Nagar and arrives at MTNL square BKC is

$$T2= \frac{3600}{11.8} = 306 \; sec$$

$$\left|\frac{306-96}{105}\right| = 0 \ll 24 \; sec$$

Vehicles will reach the beginning of green time in next cycle.

4. RESULTS

The comparison of various parameters with and without coordination is shown in this chapter. The results are evaluated after the simulation of the network in Vissim.

The graphical representation of results is shown as follows.

i. Comparison of delay before and after signal coordination at each square is shown in the following chart.

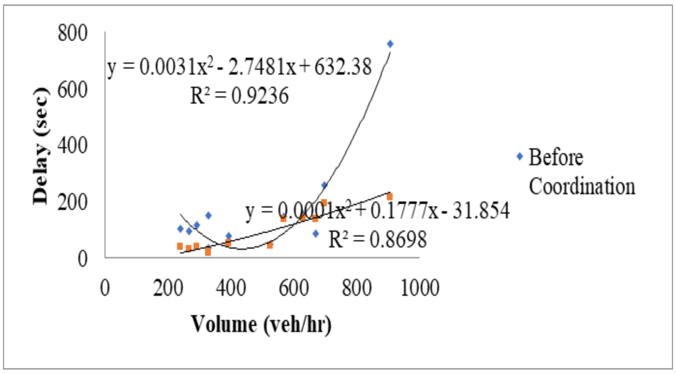

Chart 3. Delay variation at Kala Nagar

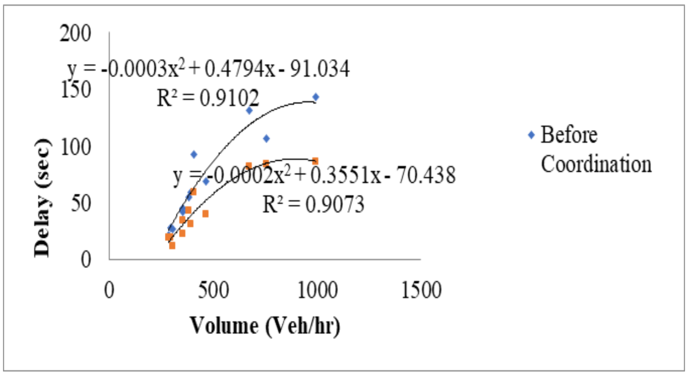

Chart 4. Delay variation at Family Court

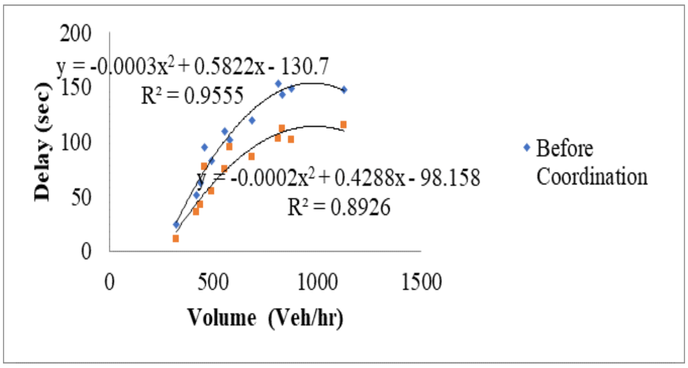

Chart 5. Delay variation at Bharat Nagar.

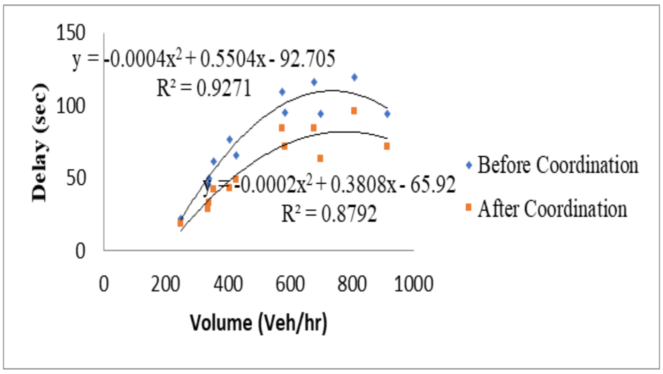

Chart 6. Delay variation at Diamond Market.

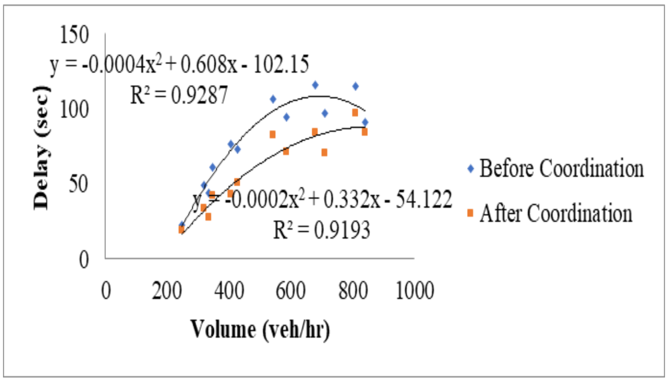

Chart 7. Delay variation at MTNL Sq. BKC

4.1 Queue length Estimation

The queue length is estimated considering the average volume of traffic at every bound at each intersection.

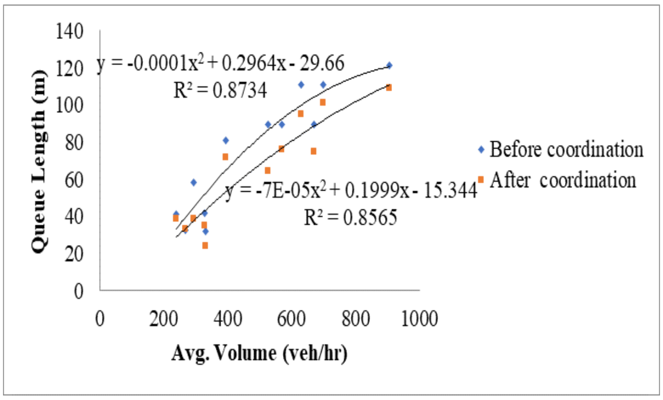

Chart 8. Variation of Queue Length w.r.t. Avg. Volume

4.2. Fuel Consumption

Fuel consumption is evaluated from different directions of traffic flow. The comparison of average fuel consumption before and after signal coordination is shown in the following charts.

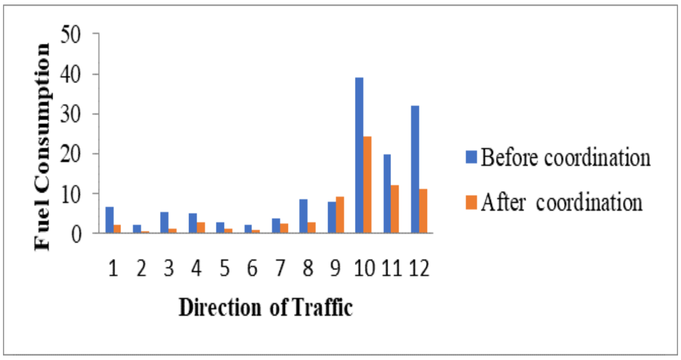

Chart 9. shows the average fuel consumption in various traffic flow directions.

4.3 Emissions

Average emissions of CO and NoX are evaluated from different directions of the traffic flow. The comparison of emissions before and after coordination is shown in the following chart.

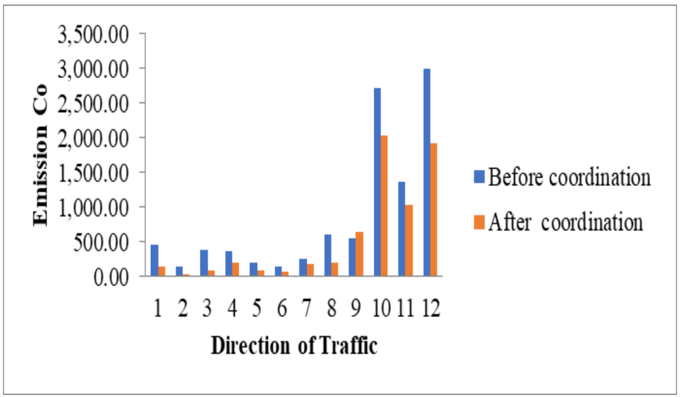

Chart 10. Average emission of CO in different direction of traffic flow

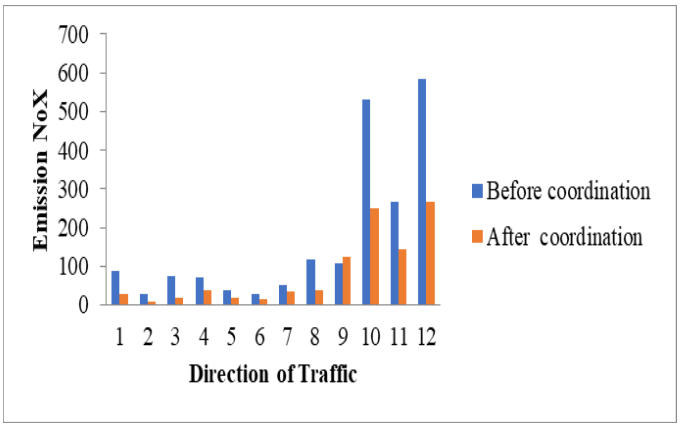

Chart 11. Average emission of NoX in different direction of traffic flow

5. CONCLUSION

Signal coordination is evaluated for all five intersections between Kala Nagar and MTNL Sq. BKC using a signal timing approach based on data analysis for selected routes.

- 32% reduction in vehicular delay is observed when comparing the findings before and after coordination. The delay in east- west bound is more as compared to bound south-north.
- There is a 17% drop in the length of the queue, which results in shorter vehicle travel times.
- The amount of time a vehicle takes to go forward in the queue is cut by 17%.
- Fuel usage is down 27%, and emissions of NoX and CO are down 28% and 27%, respectively. This is a key element in lowering both environmental pollution and fuel costs.
- It can be deduced from graphs of fuel consumption and emissions that the East-West bound has a greater impact than the South-North bound.

Results in the simulation run demonstrate that signal coordination plays a cardinal role in abating congestion, reduction in travel time, and fuel consumption. Routes with coordinated signals change the speed of vehicles.

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