Determination of Most Favorable Signal Timings at Intersections Using Fuzzy Logic Method

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Abstract-*Increasing number of vehicles and shorter width of the roads at the intersection lead to traffic congestion in many cities which affects the efficiency, productivity and energy losses. In this paper, the conventional design of traffic signal at the intersection is adopted. The traffic signal timings for four phase of traffic flow at different time interval i.e. 9 to 12; 12 to 15; 15 to 18; and 18 to 21 hours are estimated. These traffic signal timings are simulated to get most favorable timings by fuzzy logic system using mat lab tools that will present the figures of all the fuzzy sets and membership functions.*

Keywords-Traffic control, Fuzzy logic, Vehicles, Roads, Intersection.

I. INTRODUCTION

Transportation has dependably been a critical part of human progress; however it is just in the second 50% of the most recent century that the marvel of movement clog has turned out to be dominating because of the fast increment in the quantity of vehicles and in the transportation request in for all intents and purposes all transportation modes. Traffic congestion shows up when excessively numerous vehicles attempt to utilize a typical transportation communications with constrained limit. In the top case, traffic congestion prompts queueing phenomena (and equivalent delays) while the infrastructure capability ("the server") is completely used. In the worst (and far added typical) case, traffic congestion prompts a corrupted utilization of the accessible infrastructure (condensed throughput), in this manner adding to an accelerated congestion enlarge, which prompts further infrastructure degradation, and so forth. Traffic congestion results in extra delays, reduced safety, and increased environmental pollution [1].

The observing and control of Road movement is turning into a noteworthy issue in numerous nations. The expanding number of vehicles and the lower period of expressways improvements have prompted traffic congestion issue [2]. There are many variables that prompt traffic congestion, for example, the number of vehicles on the streets, human behaviour, social behaviour, and activity light framework. One main consideration is because of the traffic lights framework that controls the activity at intersection. Traffic policeman are conveyed at traffic crossing point ordinary with a specific end goal to beat these congestion during peak hour, hence one of the underlying foundations of the issue is because of insufficient movement lights controllers. With viable control the convergence, it is trusted that the general limit and execution of urban movement system could be resolve. With the ever increasing number of vehicles on the road, the Monitoring authorities have to find new ways or measures of overcoming such a problem. Numerous solutions were proposed for traffic jam illumination. Most traditional activity traffic surveillance systems utilize intrusive sensors, including inductive loop detectors, micro-loop probes, and pneumatic road tubes. These sensors upset activity during establishment and repair, which prompts a high cost establishment and support

II. LITERATURE SURVEY

Nidhi Sharma, et. al. 2016, in this study they reviewed traffic signal management which depends on fuzzy logic to improve the traffic signal light control. The parameters and variables in traffic engineering are based on subjectivity, imprecision, and ambiguity. Fuzzy approach is adequate in dealing with ambiguity, subjectivity, in determination, and uncertainty present in traffic signal engineering [6].

Sahar Araghi, et.al. 2015 studied about computational intelligence system for controlling traffic signal light timing arrangement to gain quality for best traffic light management. This study supported the area of controlling traffic signal light timing, in exacting studies that describing the function on Qlearning, neural network, and mathematical logic system are presented. As per existing literature, the intelligent ways show the next performance compared to traditional controlling way situations [7].

Hamed Homaei, et.al. 2015 study regarding new traffic signal controller with the help of fuzzy logic, fuzzy argument has become a substantial intelligent management approach for traffic operation. This study contribution is to present a new fuzzy signal management system for control of a full single intersection involving emergency vehicle preemption. The proposed control system consists fuzzy part selector and fuzzy green phase extender. The primary one specifies following next Green phase and function of green extender controller makes the choice whether not to increase or terminate the current green stage [8].

K.K. Pandey, et.al. 2015 they study concerning traffic light control signal at Four-way Intersection road as a result of traffic signals are the most appropriate methodology of controlling traffic in busy junction or lane. Traffic management is major trouble of traffic department in busy lane or road within of town in intersection of lane. They try to explain means to sense the traffic and how to handle a huge traffic in four way lane with fuzzy logic [9].

Roxanne Hawi et.al. [2015] study about techniques for smart traffic control as a result of steady increase within the variety of vehicles on the road has enlarged traffic blocking in most urban cities of the world. The steady increase in variety of vehicles has prompted students to analyze other alternative solutions to traffic blocking. These systems employ actual time information and check out to imitate human way of thinking so prove promising in vehicular traffic light control and management. This study is a review on the motivations behind the emergence of good traffic control system and the different types of these systems in use nowadays for road traffic management [10].

A.D. Jovanovic et.al. 2014 study concerning green vehicle routing in urban zone supported neuro-fuzzy approach as a result of Local city authorities are making a significant effort to expand the amount of low-green house gas vehicles reception. So as to optimize the green capacity, a system has been developed to support deciding in urban green vehicle routing. The target of this examination is to propose a green vehicle conveyance display in an extremely open transportation arrange [11].

III. TRAFFIC SIGNAL

The utilization of movement signals for control of clashing stream of vehicular and person on foot activity is broad in the vast majority of the towns and urban communities. The first traffic signal is reported to have been used in London as in1868 and was of the semaphore-arm type with red and green lamps for night use. Amid the long time from that point forward movement signals have been produced to a high level of modernity. It is proposed to manage sorts, outline, area, sign and upkeep of the signs. It is a necessary measure to maintain the quality and safety of traffic circulation. Further development of present sign al control has great potential to reduce travel times, vehicle and accident costs, and vehicle emissions [3].

There are two sorts of traffic signal control, permanent time control and versatile flag control. The permanent time control depends on the chronicled activity information, accepting movement condition are unaltered in the eras. A neighborhood controller utilizes the pre-characterized timing timetable to control crossing point signals. Most extreme green time apportioned amid crest periods and decreased green time amid off pinnacle periods. This modus although may work absolutely essential during normal traffic condition, a sudden change in traffic condition results in the failure of this modus. The adaptive signal control arise as a refinement over fixed time control this application uses the actual time data that are gathered from sensors situated at an intersection. The method of signal control relied on the actual traffic condition. Latter developments on traffic signal control used artificial intelligence technology, such as fuzzy logic [14]

IV. CONVENTIONAL METHOD OF TRAFFIC SIGNAL DESIGN

A number of definitions and notations need to be understood in signal design. They are discussed below:

_ Cycle: A signal cycle is one whole rotation through all of the indications provided.

_ Cycle length: Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications. It indicates the time interval between the starting of green for one approach till the next time the green starts. It is denoted by C.

$$C = N \times L \times X_c / X_c - \sum(V/s)i \qquad \ldots\ldots\ldots(1)$$

Where N is the number of phase, L is the lost time per phase, (V/s)i is the ratio of volume to saturation flow for phase i, X_c is the quality factor called critical V/C ratio where V is the volume and C is the capacity.

_ Interval: Thus it indicates the change from one stage to another. There are two sorts of interims - change interim and freedom interim. Change interim is likewise called the yellow time demonstrates the interim between the green and red flag signs for an approach. Freedom interim is additionally called all red is incorporated after each yellow interim demonstrating a period amid which every flag confront indicate red and is utilized for clearing of the vehicles in the crossing point.

_ Green interim: It is the green sign for a specific development or set of developments and is signified by Gi. This is the real interval the green light of a traffic signal is twisted on.

$$G_i = g_i -- y_i + t_{Li} \qquad ....(2)$$

Where G_i is the actual green time, g_i is the effective green time available, y_i is the amber time, and t_{Li} is the lost time for phase i.

_ Red interval: It is the red warning for an exacting association or set of activities and is indicated by R_i. This is the actual duration the red light of a traffic signal is turned on.

$$R_i = r_i + y_i \qquad ....(3)$$

_ Phase: A phase is the green interval in addition the alteration and clearance intervals that go behind it. Accordingly, amid green interim, non clashing developments are appointed into each stage. It enables an arrangement of developments to stream and securely stop the stream before the period of another arrangement of developments begin.

_ Lost time: It demonstrates the time amid which the convergence isn't adequately used for any development. For instance, when the flag for an approach turns from red to green, the driver of the vehicle which is in the front of the line, will set aside some opportunity to see the flag (normally called as response time) and some time will be lost here before he moves.

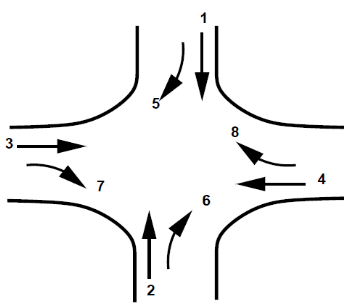

Fig.1 Four Legged Intersection

Four phase signals

There are no less than three conceivable staging choices. For instance, figure demonstrates the most basic and unimportant stage design. Where, spill out of each approach is put into a solitary stage keeping away from all contentions. This sort of stage design is in a perfect world suited in urban regions where the turning developments are practically identical with through developments and when through activity and turning movement need to share same path. This stage design could be exceptionally wasteful when turning developments are generally low. Figure demonstrates a conceivable stage design alternative where contradicting through movement are put into same stage. The non-clashing right transform streams 7 and 8 are assembled into a third stage. Also streams 5 and 6 are assembled into fourth stage. This sort of staging is extremely effective when the crossing point geometry grants to have no less than one path for every development, and the through movement volume is altogether high. Figure appears yet another stage design. In any case, this is infrequently utilized as a part of training. There are five stage signals, six stage signals and so on. They are regularly given if the crossing point control is versatile, that is, the flag stages and timing adjust to the continuous activity conditions.

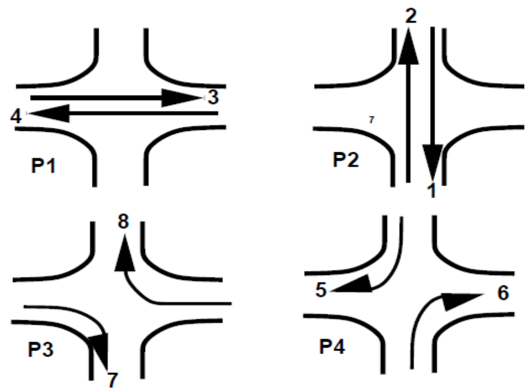

Fig.2 A possible way of providing a four phase signal

Intersection at Gole ka Mandir, Gwalior is taken as a case study. At Gole ka Mandir, roads are in a four directions. Traffic flow is coming from railway station and going to the three direction, left direction towards Morena, Right direction towards Morar, Straight going towards Bhind. Therefore, to manoeuvre the traffic, traffic signal system is required. The traffic signal is designed as per conventional method given above.

Traffic data at four durations are taken i.e. from 9:00 AM to 12:00 PM; 12:00 PM to 15:00 PM; 15:00 PM to 18:00 PM and 18:00 PM to 21:00 PM in the intersection.

Determination of traffic signal timing from 15:00 to 18:00 hr. traffic flow data i.e. no. Of vehicle in all four directions are collectors and given in the table.

Table 1: Direction wise traffic data at 15:00 to 18:00

Direction	No. of vehicles
North-South, North-West, North-East.	528, 409, 383
South-North, South-West, South-East.	464, 314, 302
West-North, West-East, West-South.	403, 691, 346
East-West, East-North, East-South.	621, 317, 442

These are traffic flow data depicted in the diagram below.

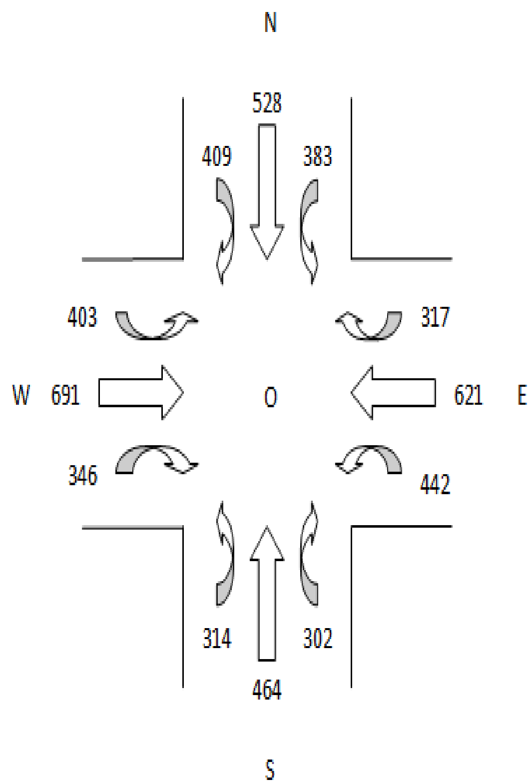

Fig.3: Traffic flow diagram for Gole ka Mandir intersection at 15:00 to18:00 hr.

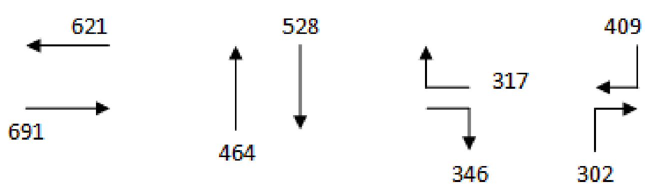

Fig.4: Phase plan of Gole ka Mandir intersection at 15:00 to 18:00 hr.

Cycle length, green time and red time of duration from 15 to 18 hr are calculated using equations 1, 2 & 3 for the flow data as cited in table 1. Consequently, the time diagram is prepared and cited below in Fig.5.

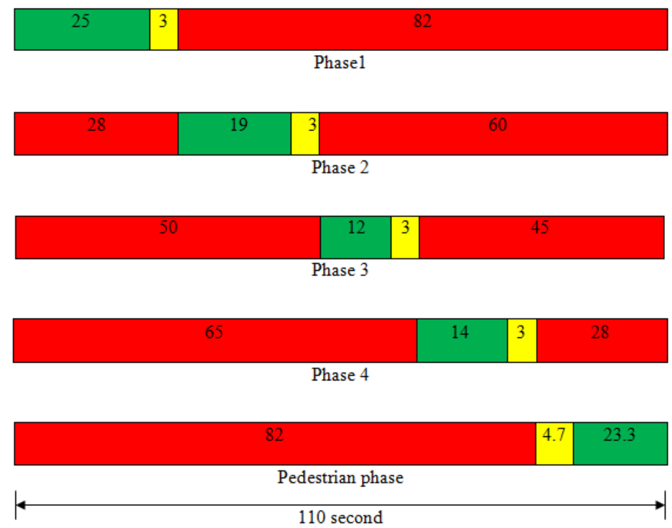

Fig. 5: Time diagram of Gole ka Mandir intersection at 15:00 to 18:00 hr.

The cycle length, green time, red time and traffic capacity as determined above are cited below in table 2..

Table 2:-Cycle length, green time, red time (stoppage time) and traffic capacity for four phases at 15:00 to 18:00

	Phase 1	Phase 2	Phase 3	Phase 4
Capacity	511.36	411.05	278.35	318.18
Cycle Length	110	104	97	99
Green Time	25	19	12	14
Red Time	82	60	45	28

Similarly for other duration i.e.9:00 to 12:00 determined.

Table 3:-Cycle length, green time, red time (stoppage time) and traffic capacity for phases at 9:00 to 12:00

	Phase1	Phase 2	Phase 3	Phase 4
Capacity	535.9	511.6	435.57	354.1
Cycle Length	93	92	89	86
Green Time	18	17	14	11
Red Time	72	52	35	21

Similarly for other durations i.e. 12:00 to 15:00 determine.

Table 4:-Cycle length, green time, red time (stoppage time) and traffic capacity for four phases at 12:00 to 15:00

	Phase 1	Phase 2	Phase 3	Phase 4
Capacity	636.30	587.62	370.18	400.00
Cycle Length	99	97	89	90
Green Time	21	19	11	12
Red Time	75	53	39	24

Similarly for other duration i.e. 18:00 to 21:00 determined.

Table 5:-Cycle length, green time, red time (stoppage time) and traffic capacity for four phases at 18:00 to 21:00

	Phase 1	Phase 2	Phase 3	Phase 4
Capacity	582.94	461.50	435.57	354.17
Cycle Length	95	90	89	86
Green Time	20	15	14	11
Red Time	72	54	37	23

V. FUZZY LOGIC

The Fuzzy Logic tool was introduced in 1965, also by Lotfi Zadeh, and is a mathematical tool for dealing with uncertainty. It presents to a soft computing partnership the significant thought of computing with words. It offers a technique to deal with imprecision and information granularity. The fuzzy theory provides a mechanism for representing linguistic constructs such as “many,” “low,” “medium,” “often,” “few.” In general, the fuzzy logic provides an inference structure that enables appropriate human reasoning capabilities. On the contrary, the traditional binary set theory describes crisp events, events that either do or do not occur. It uses probability theory to explain if an event will occur, measuring the chance with which a given event is expected to occur. The theory of fuzzy logic is based upon the notion of relative graded membership and so are the meanings of mentation and cognitive procedures. The usefulness of fuzzy sets lies in their capability to model doubtful or indefinite data. Applications of fuzzy logic occur in three primary categories: consumer products, industrial/commercial systems and decision support systems [12].

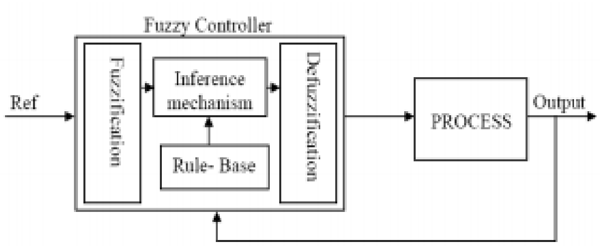

Fig 6:Fuzzy Logic Process

Our intelligent traffic controller was developed using the MATLAB fuzzy logic toolbox. The development stage comprises of five steps: (i) fuzzification of the input variable, (ii) application of fuzzy operator (AND or OR) in the antecedent, (iii) implication from the antecedent to the consequent, (iv) aggregation of the consequents across the rules and (v) defuzzification of the output variables.

There are five essential GUI tools for building, altering, and analyzing fuzzy inference systems in the Fuzzy Logic Toolbox are Fuzzy Inference System or FIS Editor, the Membership Function Editor, the Rule Editor, the Rule Viewer, and the surface viewer.

Outputs Rules

The fuzzy inference engine exchanges the input fuzzy set into an output fuzzy set through an inference process which consists of rule block creation, rule composition, rule firing, implication and aggregation. There are three crisp i/p(s) in every rule to account for 3 dissimilar i/p fuzzy sets and the composition uses these 3 membership values. The amount of rules is established in line with the difficulty of the associated fuzzy system. The fuzzy rule is composed of two parts, namely an IF part and a THEN part.

Using the MATLAB Tool Box system, 28 rules were established for organising and controlling traffic at cross junction. Figures 7, 8, & 9 depict the rule base of the fuzzy system as implemented in MATLAB and in tabular form respectively. Similarly other duration generated 28 rules.

In our case, the expected final output is a linguistic value which correspond to a particular degree of access to cycle time granted to a particular phase, for example an output linguistic value of high on a phase indicate that phase should be green light while other phases are put on hold (i.e. is red). We run system with cycle length,, stoppage time and traffic capacity for four phases at 9 to 12, 12 to 15, 15 to 18, 18 to 21hr. these values obtained from the table 2, 3, 4 and 5.

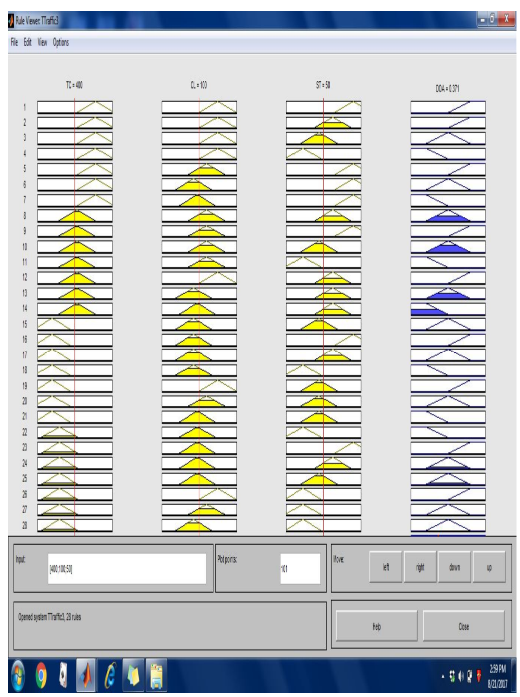

Fig.7: Rule Viewer in MATLAB

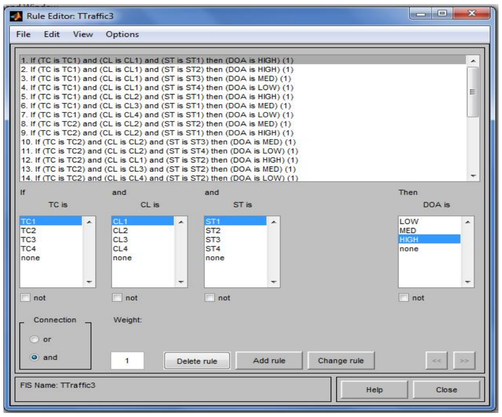

Fig.8: Rule Editor

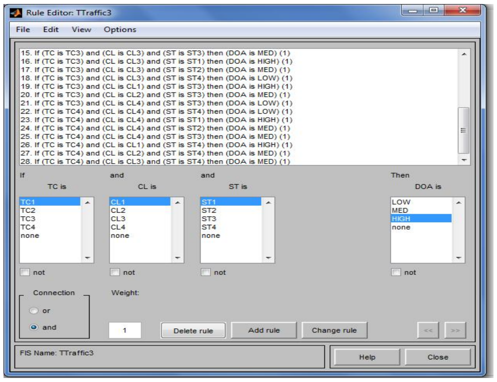

Fig.9: Rule Editor (Cont.)

FIS output surface: Figure 10 shows the surface view of the system that represents the input and output relationship in terms of data distribution. The Surface Viewer can generate a three dimensional output surface where two of the inputs vary.

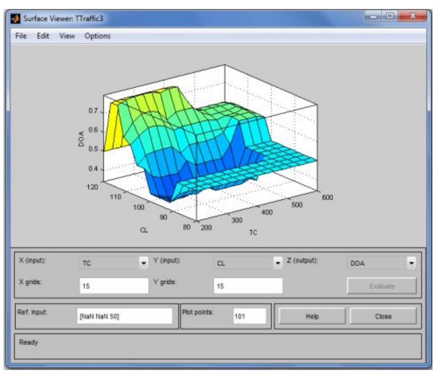

Fig.10: Surface Viewer of the Intelligent Traffic Controller

Inputs

In the below figures 11, 12 and 13, it show the TC, CL and ST membership function representation in MATLAB fuzzy logic tool box. Similarly other duration calculated membership function in MALAB tool box.

Traffic Capacity

Measure of channel time utilization (traffic load / amount of traffic), which is the average channel occupancy measured in Erlangs. Dimensionless and Denoted by A.

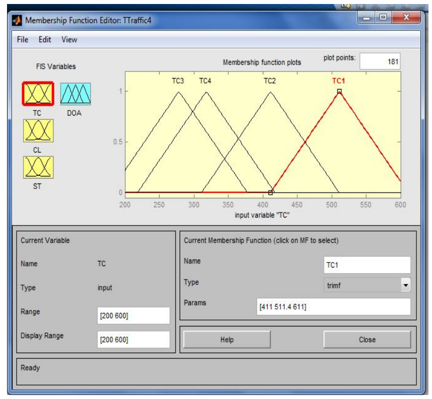

Fig.11: TC Membership Function Representation

Cycle Length

A signal cycle is one complete rotation through all of the indications or phases that are provided. Cycle length is the time that it takes a signal to complete one full cycle of indications or phases.

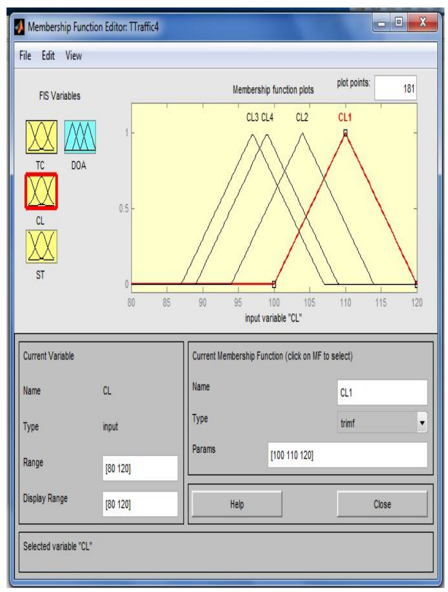

Fig.12: CL Membership Function Representation

Stoppage Time

The stoppage time will be the sum of the red time and followed with yellow time.

Fig. 13: ST Membership Function Representation

Table 6; Degree of Access of duration

Time	Degree of Access			
	Phase1	Phase2	Phase3	Phase4
9:00 to 12:00	0.610	0.578	0.485 max.	0.389 max.
12:00 to 15:00	0.747	0.590 max.	0.334	0.345
15:00 to 18:00	0.817 max.	0.479	0.344	0.322
18:00 to 21:00	0.687	0.481	0.445	0.339

The maximum value of Degree of Access for phase1, phase2, phase3 and phase4 of various periods has been taken, which will be the most favorable signal timings at the intersection of Gole ka Mandir.

VI. RESULT AND DISCUSSION

(a) Phase1; the signal time diagram for phase is given below. As well as the description of timings are given. East to west direction flow are 621 vehicles and west to east direction flow are 691 vehicles. Cycle time 110 seconds, stoppage time 82 seconds and traffic capacity is 511.36.

(b) Phase2; the signal time diagram for phase is given below. As well as the description of timing are given. South to north direction flow are 795 vehicles and north to south direction flow are 697 vehicles. Cycle time 97 seconds, stoppage time 53 seconds and traffic capacity is 587.62.

(c) Phase3; the signal time diagram for phase is given below. As well as the description of timing are given. East to north direction flow are 557 vehicles and west to south direction flow are 504 vehicles. Cycle time 89 seconds, stoppage time 35 seconds and traffic capacity 435.57.

(d) Phase4; the signal time diagram for phase is given below. As well as the description of timing are given. North to west direction flow are 331 vehicles and south to east direction flow are 437 vehicles. Cycle time 86 seconds, stoppage time 21 seconds and traffic capacity 354.1.

The pictorial diagram of phase1, phase2, phase3 and phase4 are shown below.

Fig.14; pictorial diagram of phases 1, 2, 3 and 4

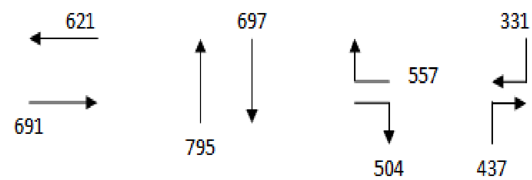

Fig. 15; phase diagram

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