A Traffic Congestion Problem and Solution at Simadanaka Junction, Surat, Gujarat

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***Abstract*: There are certain areas of traffic attraction due to the rapid urbanization, growing population, and increasing commercial and economic activities. More population generate a large number of vehicles, leading to conflict with vehicles and congestion. It in turn adversely affects the ultimate goal of efficient mobility of the citizens. So it is likely to offer high accessibility with the provision of transportation infrastructures; it is also threatened by mobility challenges resulting in low productivity and loss of man-hours, thus adversely affecting the overall wellbeing of residents. We observes the challenges of traffic congestion and management problems within Surat (Varachha-Kamrej), on a major arterial known as, 'SIMADANAKA JUNCTION' having a four road intersection. We obtained data through identification of area, interact with road users, shopkeepers, tea stall man, traffic police, pedestrian etc., and observing major traffic activity. For addressing the traffic congestion, classified volume count survey and PCU survey count of 4 days i.e. Friday, Saturday, Sunday, and Monday through videography method under permission of Deputy commissioner, traffic of surat city DR. SUDHIRKUMAR DESAI (IPS). Findings exposed an irregular land use pattern, resulting in traffic, vehicular conflicts and unnecessary traffic congestion, longer travel time and loss of human hours during a day-time. The project deliberates the need for a solution of traffic congestion problem of SIMADANAKA JUNCTION (VARACHHA-KAMREJ) by the execution of the planning and regulatory rules for effective traffic management.**

***Keywords*: Rotary, Automated signal, Intersection, PCU, IRC.**

1. Introduction

Traffic engineering is that branch of engineering which deals with planning and geometric design of roads and highways, and with traffic operation thereon, as their use is related to the safe, convenient and economics transportation of persons and goods.

The term traffic management is sometimes used to express means and methods adopted to utilize the road systems of a town to the maximum extent.

Traffic volume study: Traffic Volume study is variable; it is of great importance to the traffic engineer. It is essentially the quantity of movement per unit of time at a specified location. The quantity of movement may be either of single traffic unit-pedestrians, cars, buses or goods vehicles, etc. Time period will be depended on the purpose of study.

Traffic Volume: The number of vehicles crossing a section of road per unit time at any selected period is called traffic volume. The unit of traffic volume is vehicles per hour or vehicles per day.

A. Types of traffic volume counts

1. Peak Hour Volume (PHV) or Peak Hour Flow (PHF)
2. Average Annual Daily Traffic (AADT)
3. Average Daily Traffic (ADT)
4. Classified volumes
5. Short counts less than an hour
6. Cordon count volumes
7. Pedestrian volumes
8. Turning movement counts

Hourly traffic volumes, and average daily volumes are those commonly used in planning, design and operation of highway facilities. Traffic demands in vehicle per hour per lane are of great significance in dealing with practical traffic problems.

We conduct Peak Hour Volume (PHV) or Peak Hour Flow (PHF) for a volume counts.

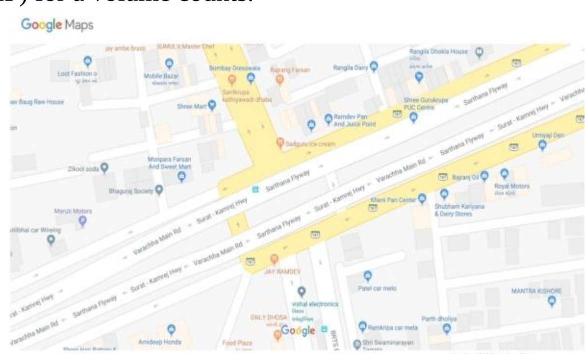

Fig. 1. Google image of Simadanaka junction

2. Literature review

Ishant Sharma et. al. [2] (2015) proposed an automatic traffic signal at Madhya Marg, Chandigarh in which pre timed signals were designed by making use of Webster's method and I.R.C method of signal design. Webster's method gives the optimum cycle length whereas the I.R.C method gives minimum green time on basis of time taken by pedestrians to cross the approach lane. The count was taken by slow playback of video on laptop. In this paper, He has compared pre timed signal with automated signal in which automated signals were proven to be more efficient as these signals save the wasted time and increase the capacity.

Rubiyah yusuf et. al. [3] (1996) presented a combination of electromagnetic sensors and fuzzy logic technology in which electromagnetic sensors where responsible for counting the number of cars and fuzzy logic technology was responsible for allotment green time to the traffic to clear off the intersection efficiently. This method was proven to be very effective in handling the traffic

Sachin Jat et. al. [4] (2015) designed a traffic signal at intersection of Vidisha, Madhya Pradesh. The traffic volume were collected manually without using any device or sensors with respective vehicle categories like passenger, commercial and agriculture. The design of traffic signal according to I.R.C method by adopting maximum P.C.U on the intersection in each direction.

Saleem Akhter et. al. [3] (2015) presented a paper in which an attempt has been made whether to provide traffic signal or rotaries. Classified traffic volume data was collected for 12-minute duration. The classified volume was converted to a common unit called Passenger Car unit. The 12-minute data is then scaled to 1 hour to find the traffic volume in PCU/hr. The traffic capacity of rotary comes out to be 3017 PCU/hr which is greater than 3000 PCU/hr (maximum traffic volume a rotary can handle). Thus, traffic signal system should be introduced at the intersection with total cycle time of 140 seconds.

3. Methodology

A. Collection of data

In present study firstly, Traffic field studies are used to have the traffic volume at Simadanaka junction which are used as input for the design of rotary. Classified traffic volume (cars, two wheelers, buses, trucks) are collected for a period of 1 Hours (8:00-9:00) in order to have entire day data and to identify peak and non-peak hours. The data was collected for the interval of 5 minutes for 1 hours for 4 days. The 5 minutes data is then converted to 1 hour to find the traffic volume in PCU/hr.

Table 1
Vehicles (PCU/hr)

From	To	Vehicles(PCU/hr)	
		Morning	Evening
Varachha	Motavarachha	576	2296
	Kamrej	708	3024
	Canal Road	475	1148
Motavarachha	Kamrej	340	1080
	Canal Road	609	897
	Varachha	612	1027
Kamrej	Canal Road	412	811
	Varachha	1187	1677
	Motavarachha	227	2137
Canal Road	Varachha	416	710
	Motavarachha	572	1037
	Kamrej	529	667
Total PCU		**6663**	**16511**

As there are 9 directions at our junction, we worked in two groups of 8 persons in each group for interval of 6hrs each.

We used videography method for PCU survey. We placed one camera in centre of simada naka junction for collection of vehicle data on canal-varachha road. And another three camera for varachha to kamrej road and mota varachha to canal – kamrej road.

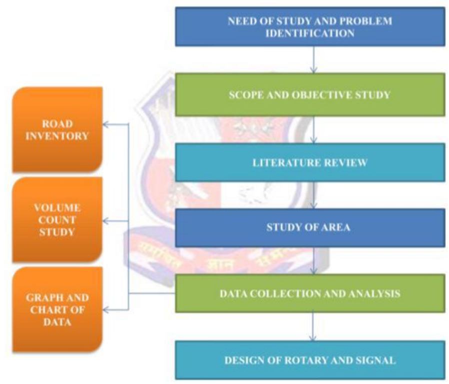

Fig. 2. Methodology Chart

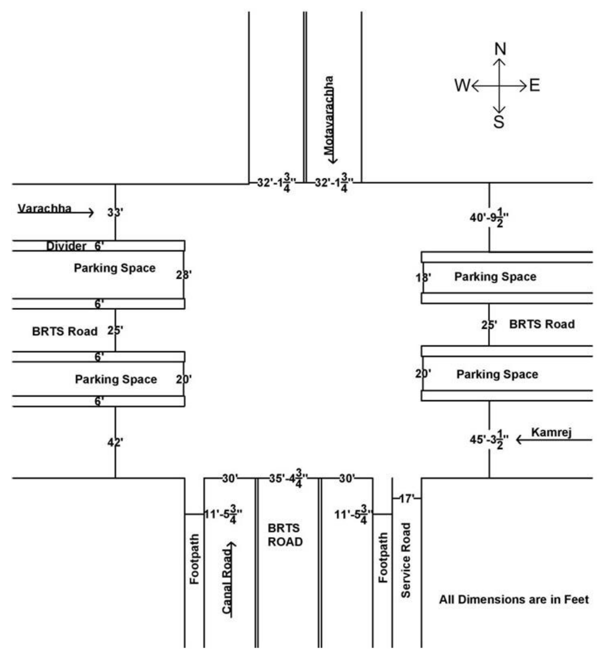

Fig. 3. Dimension of study area

B. Conversion of Traffic Count

There are several types of vehicles (also called Classes) available on roads like cars, trucks, trailers, motorbikes. Their impact/interaction on traffic-flow is also varies due to variation in their sizes, shapes and speeds. It is very difficult to deal with such variety of vehicles from the design and engineering point of view. Therefore, a standard vehicle unit has been defined known as Passenger Car Unit, PCU. There are two set of PCU values according to IRC as,

1. Urban roads. (I.R.C:106-1990, Guidelines for capacity of urban roads in plain areas.
2. Non-urban roads (I.R.C: 64-1990 Guidelines for capacity of roads in rural areas.

Based on the type of road the PCU values are worked out. In this case we are using urban roads. After conversion of collected data into PCU/hr., the 7days average PCU/hr. value is obtained by taking average values of PCU/hr. for 12 hours i.e. (07:00-08:00 average in all 7 days and similarly for all 12 hours). The peak value obtained is used for design consideration as it satisfies for all the condition.

C. Weekly Variation of Traffic

The following graph shows the weekly variation in traffic:

It can be observed from the graph, there is a rapid increase in traffic during morning hours then it starts decreasing during afternoon hours of the day and it again increases at evening hours for all 7 days. The volume of traffic is observed more on weekdays as compared to weekends.

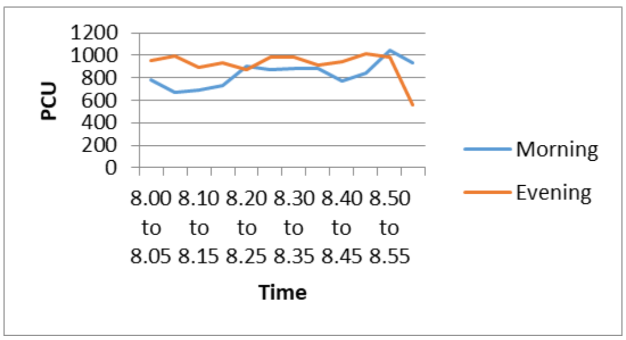

Fig. 4. Weekly traffic chart

D. Weekly Average Composition of Vehicles at Intersection

The graph below shows the different composition of vehicles passing through the junction. It can be observed 2-wheelers are more as compared to other type of vehicles followed by cars and buses.

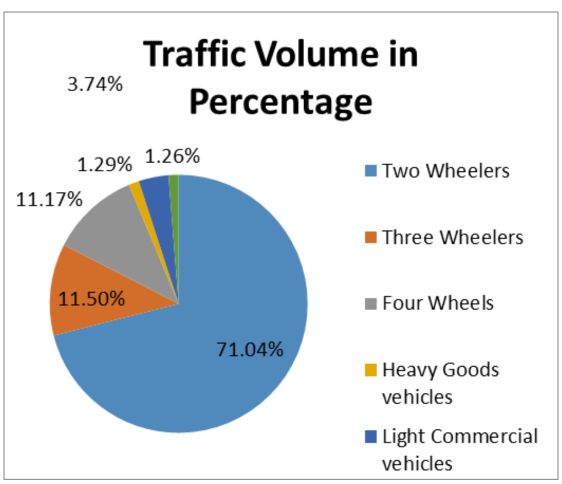

Fig. 5. Weekly average composition of vehicles

E. Presentation of data

1) Traffic flow at intersection on Sunday

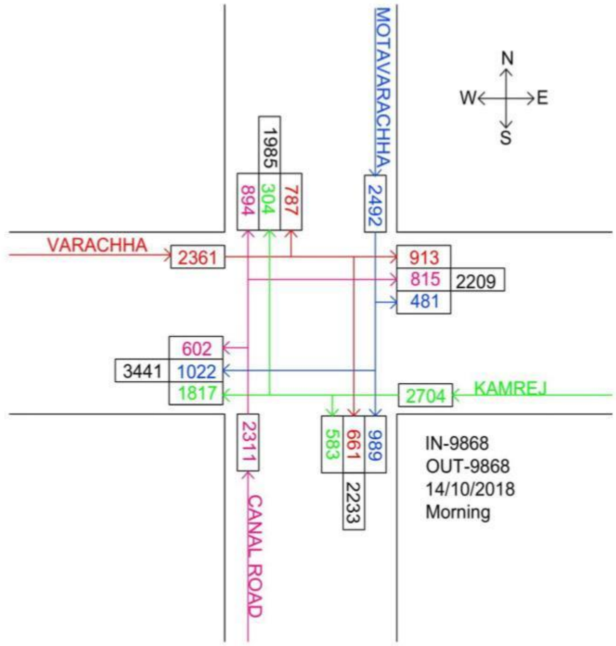

Fig. 6. Traffic flow at intersection on Sunday Morning

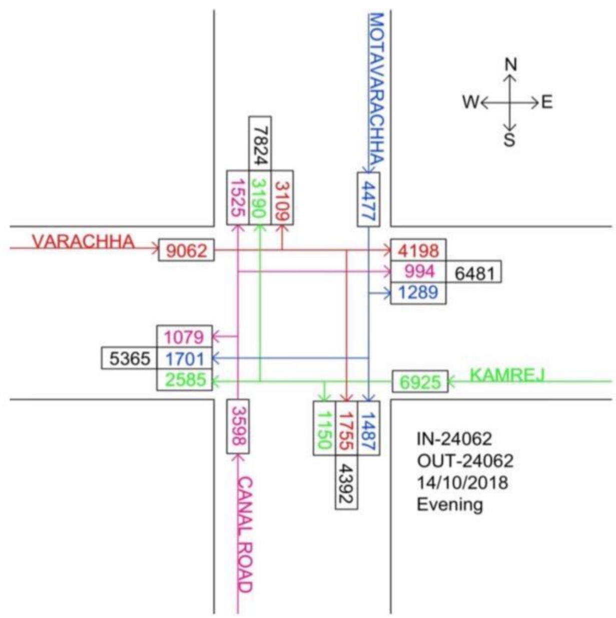

Fig. 7. Traffic flow at intersection on Sunday Evening

4. Design of rotary

A. Overview

Rotary intersections or round about are special form of at-grade intersections laid out for the movement of traffic in one direction around a central traffic island. Essentially all the major conflicts at an intersection namely the collision between through and right-turn movements are converted into milder conflicts namely merging and diverging. The vehicles entering the rotary are gently forced to move in a clockwise direction in orderly fashion. They then weave out of the rotary to the desired direction. The benefits, design principles, capacity of rotary etc. will be discussed in this chapter.

B. Traffic Operation in rotary

1. *Diverging:* It is a traffic operation when the vehicles moving in one direction is separated into different streams according to their destinations.
2. *Merging:* Merging is the opposite of diverging. Merging is referred to asthe process of joining the traffic coming from different approaches and going to a common destination into a single stream.
3. *Weaving:* Weaving is the combined movement of both merging and diverging movements in the same direction
4. These movements are shown in figure. It can be observed that movements from each direction split into three; left, straight, and right turn.

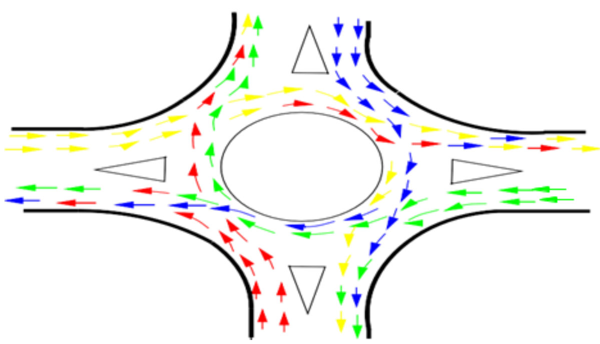

Fig. 8. Traffic operation in rotary

C. Design speed

All the vehicles are required to reduce their speed at a rotary. Therefore, the design speed of a rotary will be much lower than the roads leading to it. Although it is possible to design roundabout without much speed reduction, the geometry may lead to very large size incurring huge cost of construction. The normal practice is to keep the design speed as 30 and 40 kmph for urban and rural areas respectively.

D. Entry, exit and island radius

The radius at the entry depends on various factors like design speed, super-elevation, and coefficient of friction. The entry to the rotary is not straight, but a small curvature is introduced. This will force the driver to reduce the speed. The entry radius of about 20 and 25 metres is ideal for an urban and rural design respectively.

The exit radius should be higher than the entry radius and the radius of the rotary island so that the vehicles will discharge from the rotary at a higher rate. A general practice is to keep the exit radius as 1.5 to 2 times the entry radius.

However, if pedestrian movement is higher at the exit approach, then the exit radius could be set as same as that of the entry radius.

The radius of the central island is governed by the design speed, and the radius of the entry curve. The radius of the central island, in practice, is given a slightly higher radius so that the movement of the traffic already in the rotary will have priority**.** The radius of the central island which is about 1.3 times that of the entry curve is adequate for all practical purposes.

E. Width of the rotary

The entry width and exit width of the rotary is governed by the traffic entering and leaving the intersection and the width of the approaching road. The width of the carriageway at entry and exit will be lower than the width of the carriageway at the approaches to enable reduction of speed. IRC suggests that a two lane road of 7 m width should be kept as 7 m for urban roads and 6.5 m for rural roads. Further, a three lane road of 10.5 m is to be reduced to 7 m and 7.5 m respectively for urban and rural roads.

The width of the weaving section should be higher than the width at entry and exit. Normally this will be one lane more than the average entry and exit width. Thus weaving width is given as,

$$W_{weaving} = \frac{e_1+e_2}{2} + 3.5\text{m}$$

where e_1 is the width of the carriageway at the entry and e_2 is the carriageway width at exit.

Weaving length determines how smoothly the traffic can merge and diverge. It is decided based on many factors such as weaving width, proportion of weaving traffic to the non-weaving traffic etc. This can be best achieved by making the ratio of weaving length to the weaving width very high. A ratio of 4 is the minimum value suggested by IRC. Very large weaving length is also dangerous, as it may encourage over-speeding.

F. Capacity

The capacity of rotary is determined by the capacity of each weaving section. Transportation road research lab (TRL) proposed the following empirical formula to find the capacity of the weaving section.

$$Q_p = \frac{280W\left[1+\frac{e}{W}\right]\left[1-\frac{p}{3}\right]}{1+\frac{W}{L}}$$

Where Q_p is practical capacity of rotary, e is the average entry and exit width, i.e,$\frac{e_1+e_2}{2}$, W is the weaving width, L is the length of weaving (L = 4*W), and p is the proportion of weaving traffic to the non-weaving traffic. Figure 40:3 shows four types of movements at a weaving section, a and d are the non-weaving traffic and b and c are the weaving traffic. Therefore,

$$P = \frac{b+c}{a+b+c+d}$$

a = left turning traffic moving along left extreme lane
b = crossing / weaving traffic turning toward right while entering the rotary
c = crossing / weaving traffic turning toward left while leaving the rotary
d = right turning traffic moving along right extreme lane

G. Design process of rotary intersection

Radius of Rotary = 19 m, from the formula

$$R = \frac{v^2}{127f}$$

V = design speed of rotary = 30 kmph
f = 0.43 (friction factor)

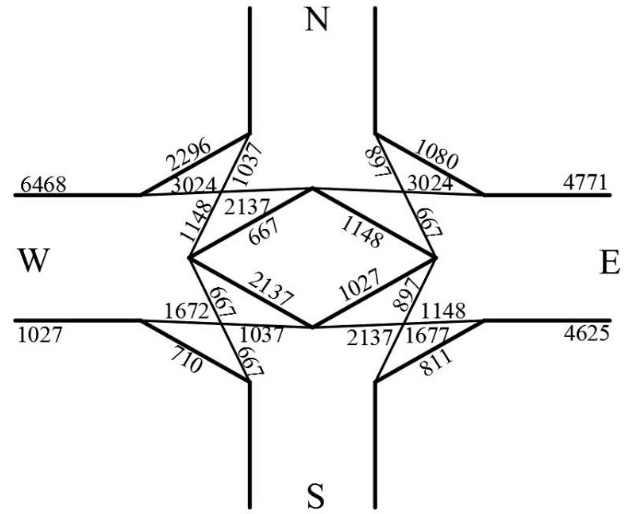

Fig. 9. Vehicles approaching rotary

Parameters of various phases

Canal to Varachha Road (S – W)

$$E = \frac{9.14 + 12.18}{2}$$

= 10.97m

$$W = \frac{9.14 + 12.18}{2} + 3.5$$

=14.47m

$$L = 4 \times 14.47 = 57.78m$$

Varachha To Mota varaccha Road (W – N)

$$E = \frac{10.06 + 10.06}{2}$$

$$= 10.06$$

W = 13.56m

L = 13.56 X 4 = 54.24

Mota Varaccha To Kamrej (N – E)

$$E = \frac{10.06 + 12.05}{2} = 11.28m$$

W = 14.78m

L = 59.12m

Kamrej To Canal (E – S)

$$E = \frac{14.02 + 9.14}{2} = 11.58m$$

W = 15.08m

L = 60.32m

$$P_{S-W} = \frac{1037 + 667 + 1027 + 1627}{710 + 4408 + 2137}$$

$$= \frac{4408}{7255}$$

= 0.607

$$P_{W-N} = \frac{3174 + 4172}{2296 + 3174 + 4172 + 667}$$

$$= \frac{7346}{10309}$$

= 0.71

$$P_{E-S} = \frac{677 + 2137 + 897 + 1144}{1027 + 5855 + 811}$$

$$= \frac{5855}{7693}$$

= 0.76

1) Capacity of various approaches

Capacity of Rotary of Canal to Varachha

$$Q_{P(SW)} = \frac{280 \times 14.47(1 + \frac{E}{W})(1 - \frac{P}{3})}{1 + \frac{W}{L}}$$

$$= \frac{280 \times 14.47 \times (1 + 0.75)(1 - 0.20)}{1 + 0.25}$$

=4537.80 PCU/hr

Capacity of Rotary of Varachha to Mota Varacchha

$$Q_{P(WN)} = \frac{280 \times 13.56(1.76)(0.76)}{1.25}$$

= 4016.71 PCU/hr

Capacity of Rotary of Mota Varaccha to kamrej

$$Q_{P(NE)} = \frac{280 \times 14.78(1.76)(0.76)}{1.25}$$

= 4428.41 PCU/hr

Capacity of Rotary of Kamrej to Canal

$$Q_{P(ES)} = \frac{280 \times 15.08(1.77)(0.75)}{1.25}$$

= 4484 PCU/hr

H. Result and conclusion from design process of rotary

The capacity of intersection is the minimum of the capacity of all the weaving section. As observed from the above results that the minimum capacity of the intersection is 4016 PCU/hour and total traffic entering the intersection is 6663 PCU/hour in morning peak hour and 16511 PCU/hr in evening peak hour. According to IRC, rotary can handle the traffic upto 3000 PCU/hr efficiently.

Above result shows that traffic approaching the intersection is very high, 6663 PCU/hour during morning peak hour and 16511 PCU/hour during evening peak hour. The capacity at intersection as calculated above is 4016 PCU/hour. As per IRC recommendation rotary can handle the traffic capacity up to 3000 PCU/hour efficiently. Design of rotary has been given as an solution for the above mentioned problem. But providing rotary will not be sufficient to manage traffic at an intersection efficiently. Some solutions are required to reduce congestion at junction. Possible solutions are shown below.

1. Providing signalized rotary
2. Providing underpass
3. Providing subway, etc.

5. Design of signalized rotary

A. Phase Design

The signal design procedure involves six major steps. They include: (1) phase design, (2) determination of amber time and clearance time, (3) determination of cycle length, (4) apportioning of green time, (5) pedestrian crossing requirements, and (6) performance evaluation of the design obtained in the previous steps. The objective of phase design is to separate the conflicting movements in an intersection into various phases, so that movements in a phase should have no conflicts. If all the movements are to be separated with no conflicts, then a large number of phases are required. In such a situation, the objective is to design phases with minimum conflicts or with less severe conflicts

There is no precise methodology for the design of phases. This is often guided by the geometry of the intersection, the flow pattern especially the turning movements, and the relative magnitudes of flow. Therefore, a trial and error procedure is often adopted. However, phase design is very important because it affects the further design steps. Further, it is easier to change the cycle time and green time when flow pattern changes, where as a drastic change in the flow pattern may cause considerable confusion to the drivers. To illustrate various phase plan options, consider a four legged intersection with through traffic and right turns. Left turn is ignored. The first issue is to decide how many phases are required. It is possible to have two, three, four or even more number of phases.

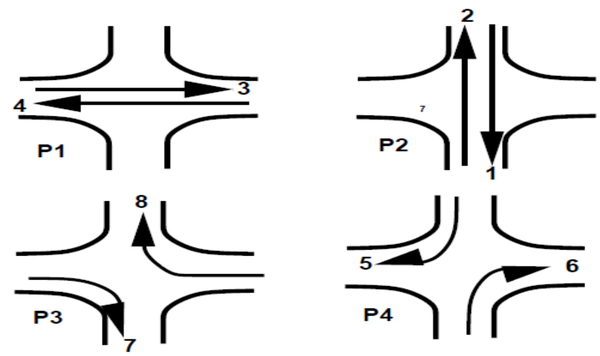

Fig. 10. Phases in Rotary

B. Signal Design by IRC method (IRC: 93 – 1985)

Major street = Varachha road
Minor street = Motavarachha road
Width of major road = 52.43m
Width of minor road = 20.12m
Pedestrian clearance time for major street,

$$= \frac{52.43}{1.2}$$

= 43.70 sec.

Pedestrian green time for crossing major street,

= 43.7+ 7

= 50.7 sec.

Pedestrian reaction time = 50.7 sec.

Therefore, minimum green time for vehicle on minor street approach = 50.7 sec.

Pedestrian clearance time for minor street,

$$= \frac{20.12}{1.2}$$

= 16.76 sec.

Pedestrian green time for crossing minor street,

= 16.76 + 7 sec.

= 23.76 sec.

Pedestrian reaction time = 23.76

Therefore, minimum green time for vehicle on major street approach = 23.76

Critical lane volume on major street,

= 6468 veh/hour/lane

Critical lane volume on minor street,

= 3004 veh/hour/lane

Green time for major street approach,

$$= \frac{6468}{3004} \times 50.7$$

= 110 sec.

Adding initial amber and clearance amber of 2 sec each forminor as well as major street

Approaches the minimum cycle length works out to be,

= (2+51+2)+(2+110+2)

=169sec.

Immediate higher multiple of 5,

= 170 sec.

Table 2
Signal Timing

Signal Timing	Initial Amber	Green	Clearance amber	Red	Cycle Length
Major street	2	110	2	56	170
Minor street	2	51	2	115	170

C. Check for design of signal cycle timings on the basis of vehicular volume

It is assumed that the first vehicle on each approach lane will take six seconds reaction time to start after stop and subsequent vehicular in the platform will follow at a constant headway of 2 secs each.

It is to be assumed that the minimum time for any vehicular phase is not kept less than 16 seconds so as to provide for built in safety.

Check for major approach:

The vehicle volume on the major street two lane is equal to 6468 veh/lane/hour

Number of vehicles per hour per lane = 6468

Number of vehicles per lane per cycle of 170 sec,

$$= \frac{6468}{170}$$

= 38

Therefore, green time required on the basis of above assumptions for major street approach,

= 1 × 6 + 36 × 2

= 78 sec.

(Since 110 sec green time is provided on the basis of pedestrian clearance period, it is safe)

Check for minor street approach:

Number of vehicles per hour per lane = 3004

Number of vehicles per lane per cycle of 170 sec,

$$= \frac{3004}{170}$$

= 17

Therefore, green time required on the basis of above assumptions for major street approach,

= 1 × 6 + 16.7 × 2

= 39 sec

(Since 110 sec green time is provided on the basis of pedestrian clearance period, it is safe).

Optimization of signal timings:

Webster's formula,

$$C_o = \frac{1.5 \times L + 5}{1 - y_1 - y_2}$$

Saturation flow = 525 w PCU/hour

Where, W is the width of the approach in meter measured form kerb to the inside of the central median or mentioned center line of the approach. Though above mentioned formula is valid for width above 5.5 m

Saturation flow for crucial approach in phase 1,

= 525 × 20.12

= 27525 PCU/hour

Saturation flow for crucial approach in phase 2,

= 525 ×20.12

= 10563 PCU/hour

$$y_1 = \frac{6468}{27525}$$

= 0.23

$$y_1 = \frac{3004}{10563}$$

= 0.28

Optimum cycle length,

$$C_o = \frac{1.5 \times 16 + 5}{1 - 0.23 - 0.28}$$

$$= \frac{29}{0.49}$$

= 59.18 sec.

Say 60 sec as the cycle time is expressed in multiple of 5

(Since total cycle length of 170 sec is more than Optimum cycle length, It is safe)

CASE 2:

Major street – kamrej road

Minor street – canal road

Calculation similar as CASE 1.

Table 3
Signal Timing (Case 2)

Signal Timing	Initial Amber	Green	Clearance amber	Red	Cycle Length
Major street	2	105	2	61	170
Minor street	2	61	2	105	170

D. Phase diagram of traffic signal

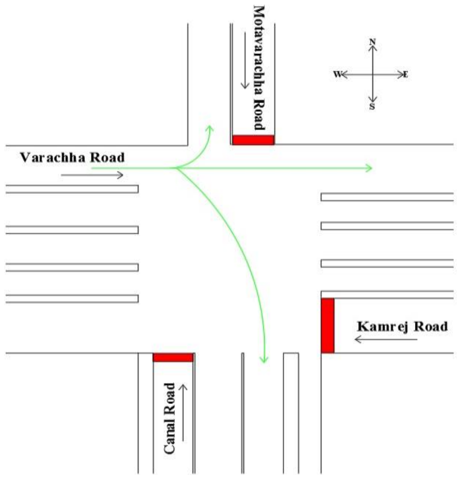

Fig. 11. Phase 1

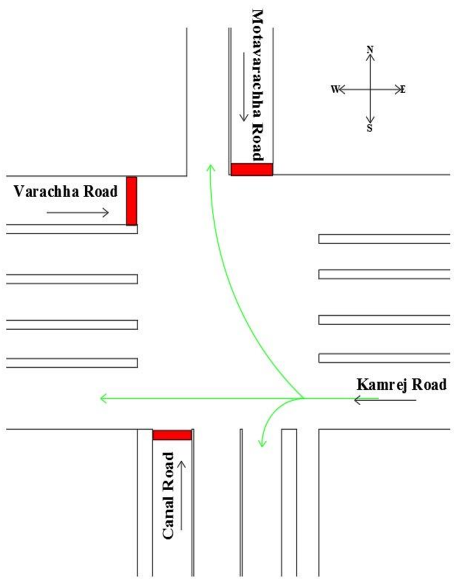

Fig. 12. Phase 2

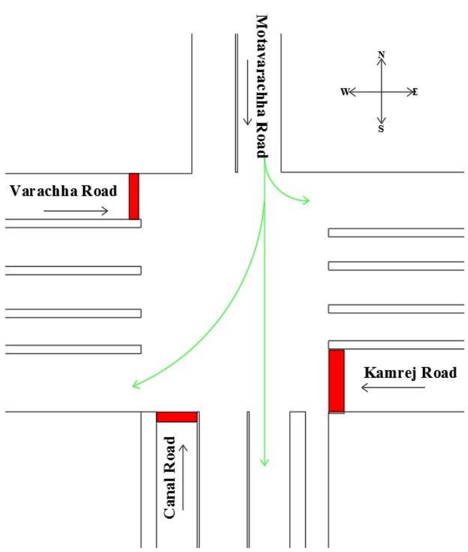

Fig. 13. Phase 3

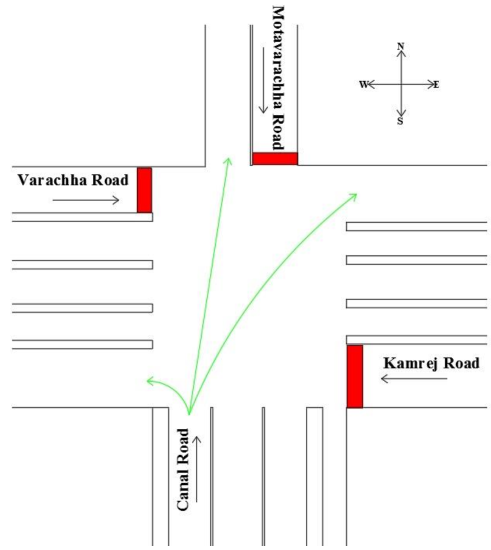

Fig. 14. Phase 4

6. Result

Based on the calculations done on the PCU values obtained from the traffic survey, the optimum Signal Cycle Length was found to be 170 seconds.

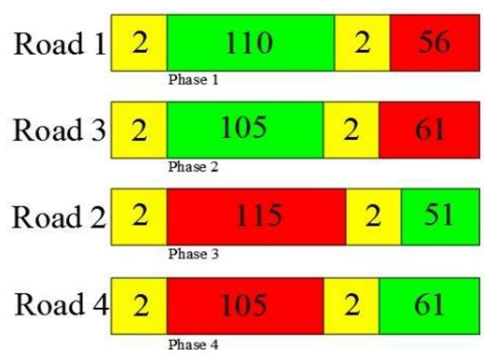

Fig. 15. Cycle length

7. Discussion

The traffic volume was collected from 08:00 - 9:00 am Morning and 08:00 - 9:00 pm Evening, It was observed that the maximum number of vehicles passed through signal were from Evening 08:00-9:00 pm, As these hours of the day during which traffic congestion on roads and crowding on public transport is at its highest. Normally, this happens twice every weekday- once in the morning and once in the evening, the times during which the most people commute.

Based on the conversion of traffic count to PCU it was observed that PCU obtained on Varachha road is 6468, Motavarachha road is 3004, Kamrej road is 4625 and Canal road is 2414.

Based on the calculations done on the PCU values obtained from the traffic survey, the optimum Signal Cycle Length was found to be 170 seconds.

8. Conclusion

The capacity of intersection is the minimum of the capacity of all the weaving section. As observed from the above results that the minimum capacity of the intersection is 4016 PCU/hour and total traffic entering the intersection is 6663 PCU/hour in morning peak hour and 16511 PCU/hr in evening peak hour. According to IRC, rotary can handle the traffic upto 3000 PCU/hr efficiently. Design of rotary has been given as a solution for the above mentioned problem. But providing rotary will not be sufficient to manage traffic at an intersection efficiently.

We designed signalized rotary with 4-phase traffic signal by IRC method,

The optimum cycle length found to be 170 seconds for Varachha to motavarachha road and 170 seconds for kamrej to canal road.

Another possible solutions are,

1. Change in geometric design of road.
2. Arranging traffic awareness programme or seminar for BRTS bus drivers and City bus drivers.
3. Make people awareness about traffic regulation by different types of posters which advertise about to follow the traffic rules and regulations.

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