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Analysis and Design of Trikon Baug 3 – Leg Intersection at Rajkot City

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Abstract: The extreme growth rate of automobiles have caused considerable traffic overcrowding on roads and intersections and it worsens at peak time traffic. An intersection which is not well designed, particularly traffic flow in Indian traffic scenario which drivers do not keep distance as a gap and mixed up with each other at crossings, traffic congestion is likely to occur. This causes many negative effects like pollution, delay and improper traffic management at crossings.
From the point of view of traffic safety, intersections act potentially dangerous places. It's believed that over half of the serious road accidents and fatal in built-up areas occur at junctions, therefore, it is essential to design or re-design the intersections in a further reasonable way.
Minimizing conflict points and smoothing the traffic stream or flow are objectives of this study which are achieved by means of space and time-sharing.
This study focuses on different design options based on the traffic survey outcomes in bright of Indian Road Congress IRC code, Highway Capacity Manual HCM
Keywords: Intersection, Conflict Points, Time Share, Space Share

I. INTRODUCTION

An intersection is where two or more roads join or cross at-grade. The intersection comprises the areas required for all means of travel: pedestrian, bicyclist, motor vehicle, and transit. Thus, the intersection includes not only the pavement area, but typically the adjacent sidewalks and pedestrian ramps. At the intersection there are through, turning and crossing traffic and these traffic movements may be handled in different ways depending on the type of intersection its design and control of traffic. Generally, intersection problems are unavoidable except in case of expressways or freeway systems where such problems are avoided by providing grade separated intersection and controlled access. Signal control is a frequently used remedy of capacity shortage in urban areas. A sufficiently accurate method of predicting the capacity of signalized intersections is important for correct road way design and for effective traffic management. Signal control is generally considered to be the highest type of control possible at an at-grade intersection. If the signal control plan is not designed properly, the signal control may become counterproductive. The ill effects of improper signal plan can be congestion, undue delays, fuel wastage, air pollution, reduced intersection capacity and tremendous inconvenience for the road user. To avoid such a situation, it becomes mandatory on the part of the traffic engineer to study the traffic situation thoroughly, to understand it properly and to evolve the optimum cycle time and proper phasing to suit the requirements of the traffic with due consideration to the location geometrics.
Intersections are a key feature of road design in four respects:

A. Focus of Activity
The land near intersections often contains a concentration of travel destinations.

B. Conflicting Movements
Pedestrian crossings and motor vehicle and bicycle turning and crossing movements concentrated at intersections.

C. Traffic Control
At intersections, movement of users is assigned, through traffic control devices such as yield signs, stop signs, and traffic signals. Traffic control often results in delay to users travelling along the intersecting roadways.

D. Capacity
In many cases, traffic control at intersections limits the capacity of the intersecting roadways, defined as number of users that can be accommodated within a given time period.

E. Intersection Users

All roadway users are affected by intersection design such as:

F. Pedestrians.

Key elements affecting intersection performance for pedestrians are:

1) The amount of right-of-way provided for the pedestrian including both sidewalk and crosswalk width;
2) The crossing distance and resulting duration of exposure to motor vehicle and bicycle traffic;
3) The volume of conflicting traffic; and (d) the speed and visibility of approaching traffic.

G. Bicyclists.

Key elements affecting intersection performance for bicycles are: (a) the degree to which pavement is shared or used exclusively by bicycles; (b) the relationship between turning and through movements for motor vehicles and bicycles; (c) traffic control for bicycles; and (d) the differential in speed between motor vehicle and bicycle traffic.

H. Motor Vehicles.

Key elements affecting intersection performance for motor vehicles are: (a) the type of traffic control, (b) the vehicular capacity of the intersection, determined primarily from the number of lanes and traffic control; (c) the ability to make turning movements; (d) the visibility of approaching and crossing pedestrians and bicycles; and (e) the speed and visibility of approaching and crossing motor vehicles.

I. Transit.

Transit operations usually involve the operation of motor vehicles (buses), and therefore share the same key characteristics as vehicles as outlined above. In addition, transit operations may sometimes involve a transit stop in an intersection area, thereby influencing pedestrian, bicycle, and motor vehicle flow and safety. Additionally, in some cases, the unique characteristics of light-rail transit must be taken into account. In addition to the users of the street and intersections, owners and users of adjacent land often have a direct interest in intersection design. This interest can be particularly sensitive where the intersection is surrounded by retail, commercial, historic or institutional land uses. The primary concerns include: maintenance of vehicular access to private property; turn restrictions; consumption of private property for right-of-way; and provision of safe, convenient pedestrian access.

II. OBJECTIVES OF STUDY

A. The Objectives of This Study Are

1) To minimize the number and severity of potential conflicts.
2) To suggest recommendations for better performance of intersection.

III.DATA COLLECTION

For better understanding of the current situations at the site and for getting the required true data, following surveys are being done: Geometry survey to have all the required dimensions of the intersections facility such as width of all approaches of Intersection, shoulders, pedestrian sidewalks, motorcycle lane etc. Traffic volume survey at all legs of Intersection for 12 hours from 08:00am to 08:00pm using video graphic survey technique for two consecutive days at Trikon Baug 3-leg intersection with the help of a camera installed on a three pod at a height building to cover all approach’s traffic entering to the intersection has been done.

A. Data Extraction

Then the extraction data processes have been started after completion of data collection, traffic entering in the intersection is counted in each 10 minutes’ interval of time in two categories: As far as the type of traffic is concern there are 8 different type of traffic which has been counted so far for first intersection (Trikon Baug) as per IRC-86-1983.

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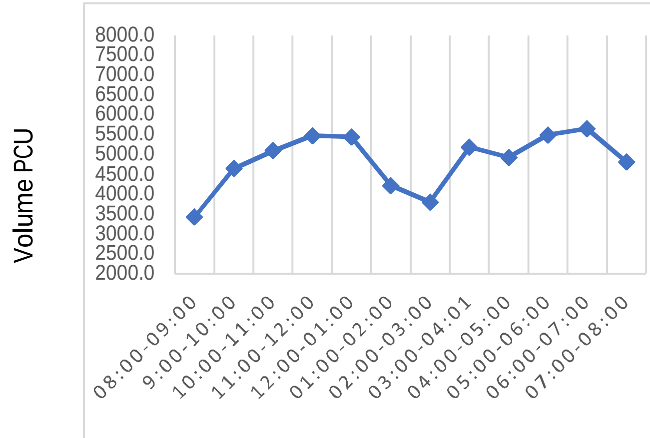


Time 08:00 am – 08: 00pm
Fig. 1. All traffic flow in 12 hours

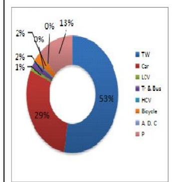
Date:		05/01/2018							
Surveyor Name:		Ahmad Reshad Aziz							
Time		Traffic Volume in all approaches							
		LCV			HCV		NMT		
		Two Wheelers	Passenger Cars/Temp os/Tractors /auto rick-shaw/Pick up Vans/ Jeep	Agricultural tracktor / Light comersial vehicle	Trucks/Buses	Tractors /Trailer/ Truck /Trialer units	Bicycle	Animal / Drawn Car	Other /Pedisterian
11:50:00	12:00:00	698	435	19	31	3	29	0	171
12:00:00	12:10:00	768	406	17	22	4	49	0	176
12:10:00 -	12:20:00	725	399	12	31	8	41	0	183
12:20:00 -	12:30:00	771	423	11	20	6	35	0	172
12:30:00 -	12:40:00	762	379	7	21	2	30	0	185
12:40:00 -	12:50:00	833	425	9	33	3	43	0	201
Total		4557	2467	75	158	26	227	0	1088
Grand Total		8598							

Fig. 2. Morning peak hour traffic (vph)

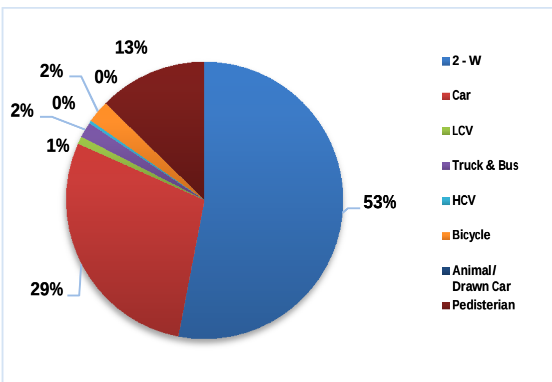


Fig. 3. Morning peak hour traffic volume proportion (%)

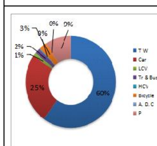
Date:		05/01/2018							
Surveyor Name:		Ahmad Reshad Aziz							
Time		Traffic Volume in all approaches							
		LCV			HCV		NMT		
		Two Wheelers	Passenger Cars/Temp os/Tractors /auto rick-shaw/Pick up Vans/ Jeep	Agricultural tracktor / Light comersial vehicle	Trucks/ Buses	Tractors /Trailer/ Truck /Trialer units	Bicycle	Animal / Drawn Car	Other/ Pedisterian
18:10:00	18:20:00	909	375	19	25	7	40	0	193
18:20:00	18:30:00	840	390	19	33	2	35	0	146
18:30:00	18:40:00	790	364	17	33	3	44	0	147
18:40:00	18:50:00	846	337	20	27	6	47	0	106
18:50:00	19:00:00	1033	337	12	27	3	49	0	135
19:00:00	19:10:00	796	305	17	23	1	25	0	73
Total		5214	2108	104	168	22	240	0	800
Grand Total		8656							

Fig. 4. Evening peak hour traffic (vph)

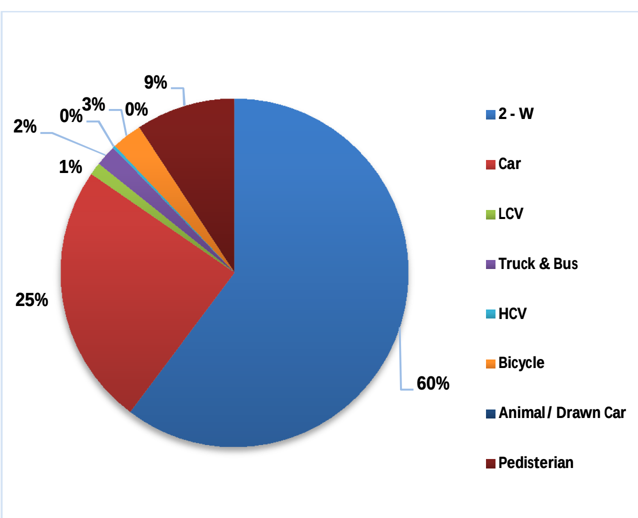


Fig. 5. Evening peak hour traffic volume proportion (%)

Vehicle (PCU/hr)			
From	To	Morning	Evening
Lakhaji	Jawahar	1466	1122
	Yagnik	851	809
Jawahar	Yagnik	501	723
	Lakhaji	1110	1500
Yagnik	Lakhaji	823	821
	Jawahar	123	546
Total		4874	5521

Fig. 6. Morning & evening peak hour traffic volume (PCU)

B. Summary of Data Extraction

Peak periods are between 08:00am to 12:00pm and from 04:00pm to 08:00pm. Traffic on approaches are unequal in numbers as well as in type.

Traffic volume proportion which are passing selected intersections consist of:
Two – Wheeler (40 to 60) %
Personal Car, Auto Rikshaw (25 to 40) %
LCV (0 to 5) %
Bus and Truck (0 to 10) %
HCV (0 – 3) %
Bicycle (0 – 1) %
Pedestrian (0 – 3) %

IV. DESIGN OF THE INTERSECTION

The traffic flow situation can be evaluated through finding the capacity and level of service, as stated at the topic of the capacity and level of service for Trikon Baug 3 – Leg intersection is calculated as below:

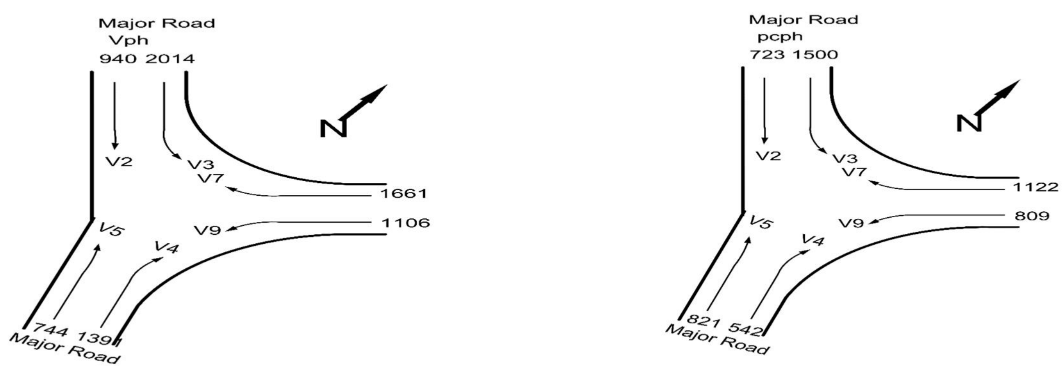


Fig. 7. Traffic volume and movements

TABLE I INTERSECTION CAPACITY AND LEVEL OF SERVICE CALCULATION

Volume Adjustment						
2	3	4	5	7	9	Movement no.
940	2014	1391	744	1661	1106	Volume (Vph)
NA	NA	542	NA	1122	809	Volume (pcph)
Step (1) LT minor street	V9					
Conflicting flow Vc	$\frac{1}{2}V_3 + V_2 = V_{c9}$					
	$\frac{1}{2} * 2014 + 940 = 1947\ vph$					
Critical Gap Tc Table (111-2)	5.1 sec					
Potential Capacity Cp fig (111-2)	$Cp_9 = 156\,(pcph)$					
Percent of Cp Utilized	$\frac{V9}{Cp9} * 100 = \frac{809}{156} * 100 > 100\ \%$					
Impedance factor P (fig 111-4)	$P_9 = 0$					
Actual Capacity Cm	$C_{m9} = C_{p9}$=156 pcph					
Step 2 RT from major road	(V4)					
Conflict flow Vc	$V_3 + V_2 = V_{c4} = 2014 + 940$					
	$V_{c4} = 2954$					
Critical Gap Tc Table (111-2)	4.8 sec					
Potential Capacity Cp fig (111-2)	$Cp_4 = 50\ (pcph)$					
Percent of Cp Utilized	$\frac{V4}{Cp4} * 100 => 100\%$					
Impedance factor P (fig 111-4)	$P_1 = 0$					
Actual Capacity Cm	$C_{m4} = C_{p4}$=50 pcph					
Step 3 TH from minor road	(V7)					
Conflict flow Vc	$\frac{1}{2}V_3 + V_2 + V_5 + V_4 = V_{c7}$					
	$\frac{1}{2}2014 + 940 + 744 + 1391$					
	$= 2691\ vph$					
Critical Gap Tc Table (111-2)	5.4 sec					
Potential Capacity Cp fig (111-2)	$Cp_7 = 50\ (pcph)$					
Percent of Cp Utilized	$\left(\frac{V7}{Cp7}\right) * 100 = > 100\%$					
Impedance factor P (fig 111-4)	$P_7 = 0$					
Actual Capacity Cm	$C_{m7} = C_{p7} * P_4$=0 pcph					

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TABLE II INTERSECTION CAPACITY AND LEVEL OF SERVICE CALCULATION

Capacity Calculation of Un-signalized				
Movement	**V (pcph)**	**Cm (pcph)**	**CR=Cm-V**	**LOS**
7	1122	0	-1122	F
9	809	156	-653	F
4	542	400	-142	F

The above table shows that this 3 – leg intersection also needs to be redesign for finding out a solution for smoothen the traffic flow, based on the approach traffic, there is need for approaches widening but, since the intersection surrounding land is occupied and its private land widening of the road is not possible therefore, the traffic flow can't be smoothening, thus we have to evaluate another option.

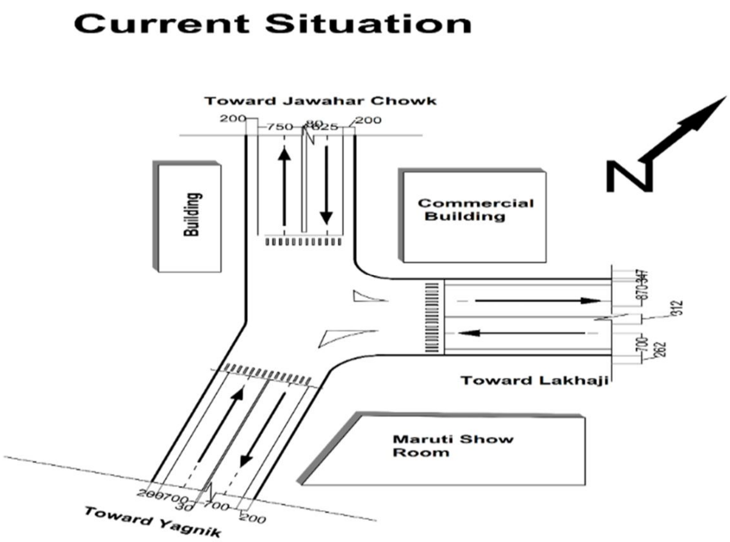

Fig. 8. Autocad drawing of Trikon Baug Intersection

V. DESIGN OF ROUNDABOUT FOR TRIKON BAUG 3 – LEG INTERSECTION:

As one of the objective of this research work is reducing conflict point so the bellow illustration shows that design of a roundabout for 3 – leg intersection will reduce the number of conflict point from 9 points to 6 points.

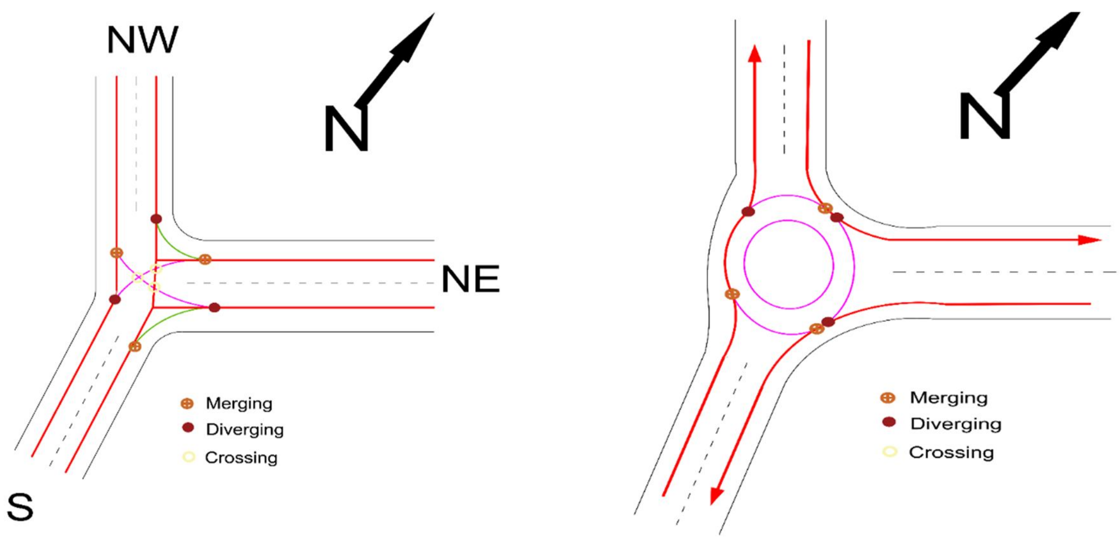

Fig. 9. Autocad drawing of Trikon Baug Intersection

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A. Roundabout design Based on the Traffic Volume at Trikon Baug 3 – Leg intersection:

Design speed accepted 30 Kmph

Entry Radius 15 to 25 m. (General practice) accepted 15m.

Exit Radius 1.5 to 2 times of entry radius

Exit Radius = 22.5 m (because of pedestrian)

Central Island Radius is theoretically equal to the entry radius =15 m

1) Width of the rotary: Based on IRC the 3-lane width of approach 10.5m should have entry width 7 m and exit width 7.5 m. As per IRC minimum weaving length 30m for speed of 30 kmph.

2) Capacity: The capacity of rotary is determined by the capacity of each weaving section Transportation Road research lab (TRL) Proposed this empirical formula to find the capacity of the weaving section

B. This formula is Applicable When

1) Weaving width of the rotary is in between (6 and 18 meters).

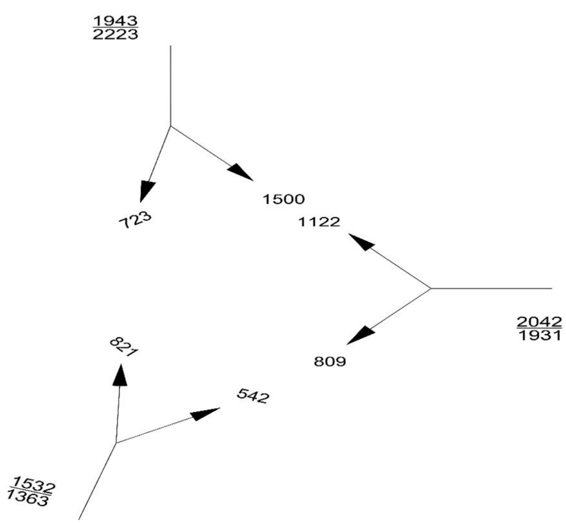
2) The ratio of average width of carriage way of entry and exit to the weaving width is in the range of 0.4 to 1

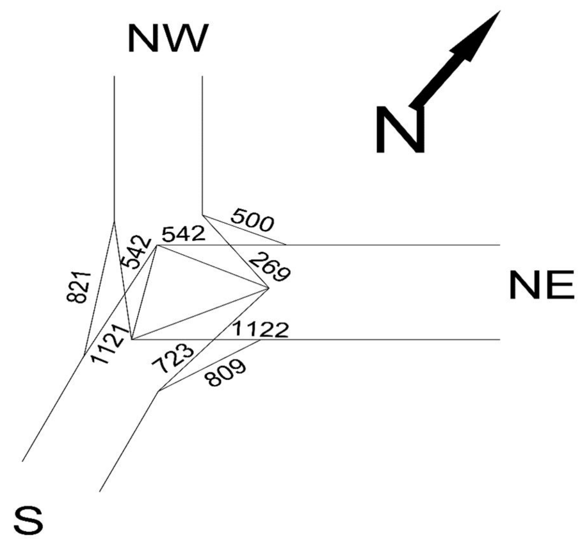
C. Average Width of the Carriage way at Entry & Exit to the Weaving Width

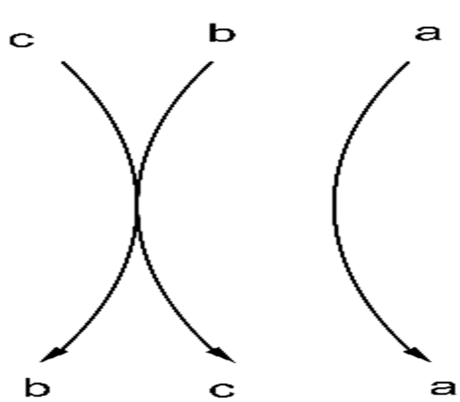
1) The ratio of weaving width to weaving length to be between 0.12 to 0.4

2) The proportion of weaving traffic to non-weaving traffic in the rotary is in the range of 0.4 and 1

3) The weaving length available at the intersection is in between 18 and 90m.







Thus, the proportion of weaving traffic to non-weaving traffic is highest in the NE- S direction. Therefore, the capacity of the rotary will be capacity of this weaving section.

From equation;

Since the capacity of the rotary intersection is too less than the traffic volume therefore we need to find another solution which time is share with the help of traffic signal.

Table I Design Of Roundabout For Trkon Baug 3-Leg Intersection

Description	IRC Rec.	HCM Rec.
Accepted Design Speed	30 Kmph	30 - 50kmph
Entry Radius (General Practice)	15 to 25 m	15 – 30 m
Exit Radius 1.5 to 2 times of entry radius	30 m	Not less than 15m, 30 – 60m is common
Centre Island R is 1.3 times the entry R	15 m	16m
Entry Width	7 m	5.5m
Exit Width	7.5 m	5.5m Pedestrian/ 7m without pedestrian
Weaving Width	10.75 m	7
Weaving Length	30 m	Inscribed Circle Dia 30m
Capacity after calculation as per roundabout dimensions will be 2851 PCU/hr which is too less than traffic volume		

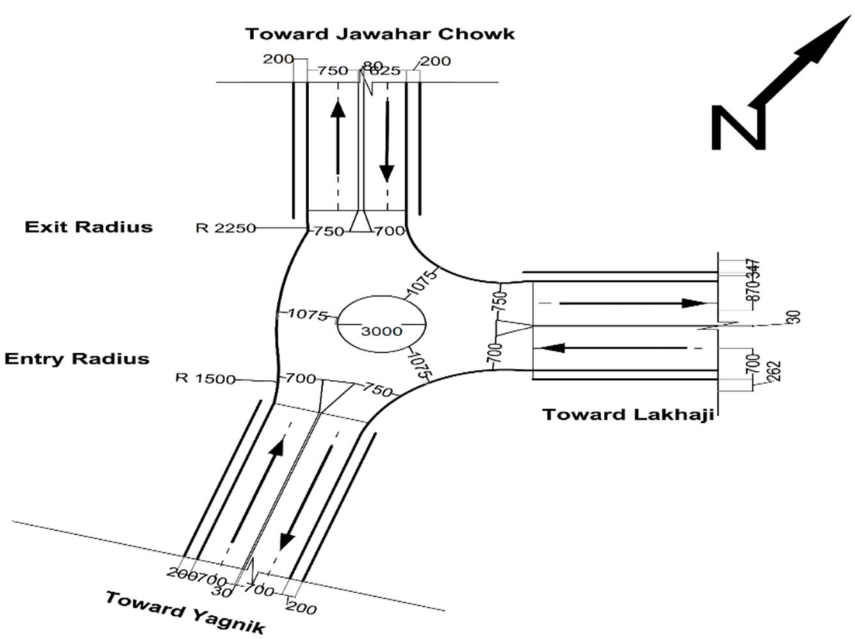


Fig. 10. Designed Roundabout for Trikon Baug Intersection

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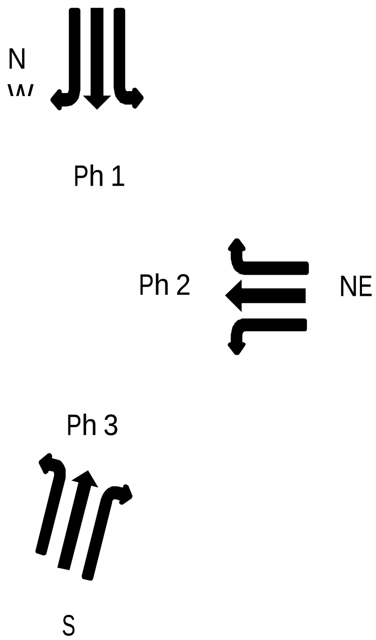
VI. DESIGN OF TRAFFIC SIGNAL FOR TRIKON BAUG 3-LEG INTERSECTION.

Three phase traffic signals are defined for the intersection for further calculation.



From	NW		NE		S	
To	NE	S	S	NW	NW	NE
Given Flow PCU/hr	1500	723	809	1122	821	542
Total Flow Phase 1	2223					
Saturation Flow	626*7.5=4695					
y1	2223/4695=0.47					
Total Flow Phase 2			1931			
Saturation Flow			626*10=6260			
y2			1931/6260=0.31			
Total Flow Phase 4					1363	
Saturation Flow					626*7=4382	
y4					1096/4382=0.31	

Y=1.09

Lost time:

=

Effective Green Time= 128 – 12 = 116 second

second

34 second

Effective green time after correction is also = 118 second

Fig. 11. Signal timing diagram

Evaluation of traffic signals for Trikon Baug 3-leg Intersection after 10 years Traffic growth rate Traffic growth rate can be estimated: Formula of Finding Future Traffic: In case of Trikon Baug 3-leg intersection the future traffic after 10 years will be:

= 16191 VPH

The traffic volume of the mentioned intersection looks to be more than capacity of a signalized intersection after 10 years.

Thus, the intersection should enhance to a great separated intersection so that it can handle traffic in an efficient way.

Evaluation of traffic signals for Trikon Baug 3-leg Intersection after 10 years

From	NW		NE		S	
To	NE	S	S	NW	NW	NE
Given Flow PCU/hr	2982	1250	1332	1822	1205	987
Total Flow Phase 1	4232					
Saturation Flow	626*7.5=4695					
y1	4232/4695=0.9					
Total Flow Phase 2			3154			
Saturation Flow			626*10=6260			
y2			3154/6260=0.5			
Total Flow Phase 4					2192	
Saturation Flow					626*7=4382	
y4					2192/4382=0.5	

Y=1.9

Lost time:

=

Thus, this option is not valid.

Since Y>1 modified Webster's formula is applicable

As it's a long time for a cycle of signals and it's not Practically possible.

So, a suitable type of grade separated solution should be evaluated for solving the problem of the intersection in the future.

VII. CONCLUSIONS

A. Level of service for both lanes of minor road approach is F and a right turn from south to NE is also F, the intersection needs some enhancement to be considered, one of those enhancement factor could be widening the approach width and redesign curvatures base on IRC recommendations, in this 3 – leg intersection also lands is not available, widening of the approaches width and redesign of curvatures are not possible.

B. The research designed a roundabout to reduce the number and severity of conflict points from 9 points to 6 points but, due to large number of traffic (traffic volume) the implementation of roundabout is not recommended for this intersection since, a rotary intersection can handle maximum traffic volume up to 3000 PCU/h but the actual traffic volume at the Trikon Baug intersection is 5521 PCU/h which is higher than that.

C. Minimizing the number and severity of conflict point and smoothen the traffic flow is also possible by time sharing, the research result shows that sharing time by applying traffic signal system, can reach us to our objectives which is mentioned before.

D. A traffic signal with the effective green time equal to 118 seconds in 3 phases has been suggested for regulating current traffic at Trikon Baug 3 – leg intersection.

E. Calculation result shows that after 10 years due to increase in number of vehicles at all the cities of the country specifically in Rajkot city signal system won't be able to manage the traffic as the ratio of volume to capacity Y>1.

VIII. ACKNOWLEDGMENT

Frist of all, I am grateful to The Almighty Allah for establishing me to complete this research paper.
I wish to express my sincere thanks to Assistant Professor Ms. Monicaba Vala my guide for providing me such a support and help, and my Co - guide Mr. Mayank Kanani.
I place on record, my sense of gratitude to one and all who, directly or indirectly, have lent their helping hand in this venture.

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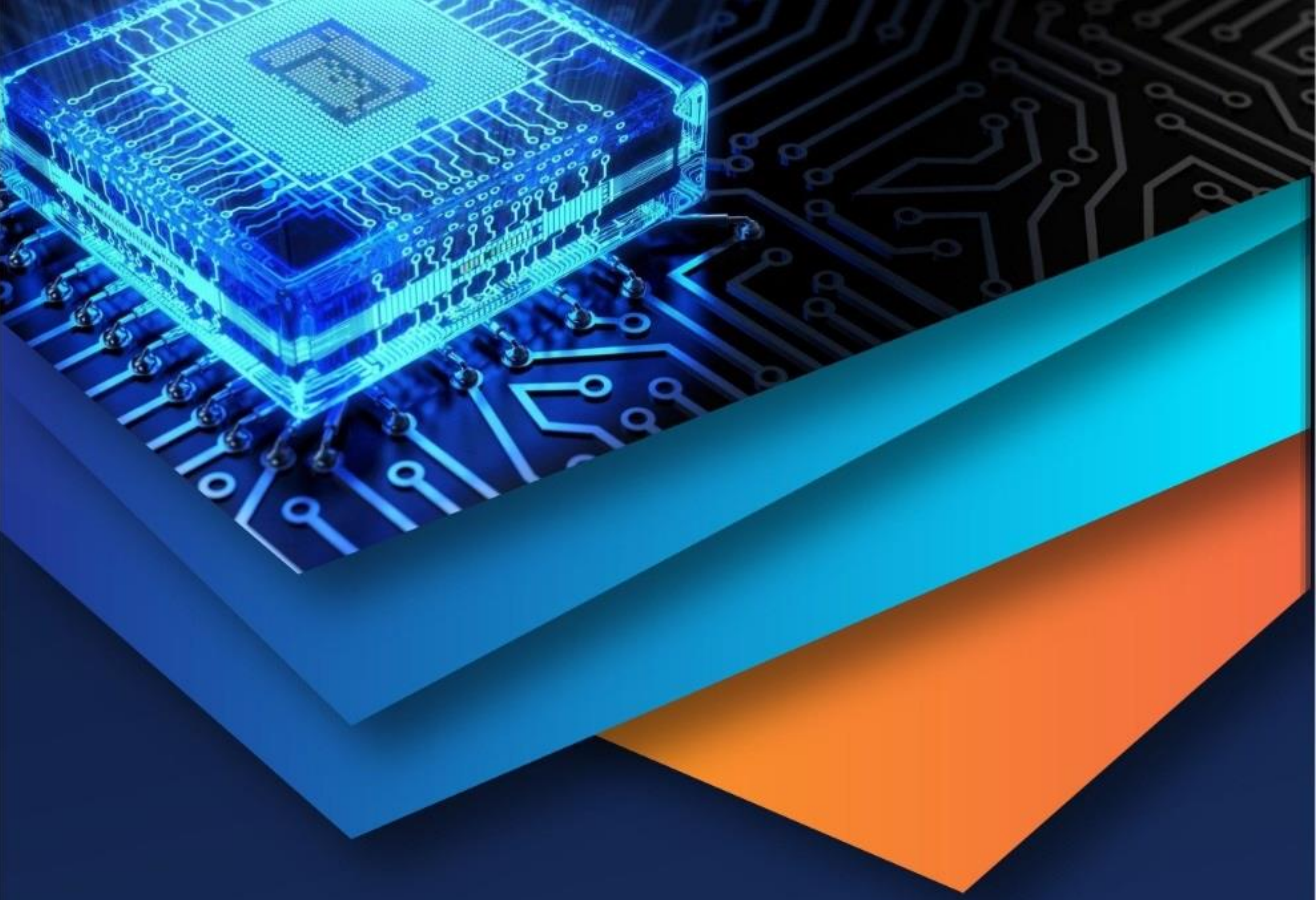

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