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Research Article

SOLUTION FOR REDUCTION OF TRAFFIC CONGESTION: A CASE STUDY OF THALTEJ ROTARY INTERSECTION

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ABSTRACT
In urban areas, traffic congestion is a major problem. Heavy traffic flow on National highways with high speed, when mixed up with local traffic at crossings, traffic congestion is likely to occur. This causes many negative effects like pollution, delay, accidents and improper traffic management at crossings. At the intersection of National highway-147 and Ahmedabad-Thaltej road, the above problems frequently occur. To reduce the ill effects, some solution is needed to be provided. For this, classified volume count survey and analysis is carried out and the capacity of existing roundabout is checked. Various alternatives like redesigned roundabout, traffic signal, flyover, underpass, cloverleaf and uplifted roundabout are proposed and checked for their suitability.

Keywords: *Roundabout, Phase, Weaving, Lane Capacity, FOB*

INTRODUCTION
Indian cities are facing the crisis of urban transportation. Despite of investments in road infrastructure and plans for transport development, users face the problem of congestion, accidents and pollution.
Accident is a major problem, especially at the intersection of national highway and other roads, as the vehicles on the national highway move at very high speed. Also due to traffic jam, lot of time is wasted. Pedestrians face troubles in crossing the road. Due to congestion, pollution increases and it causes harmful effects on human health living adjacent to the area. National highway traffic delay and improper management as well as poor control over the flow of traffic increases rapidly.
At rotary intersection of National highway-147 and Ahmedabad-Thaltej road, above problems frequently occurs due to heavy traffic flow.

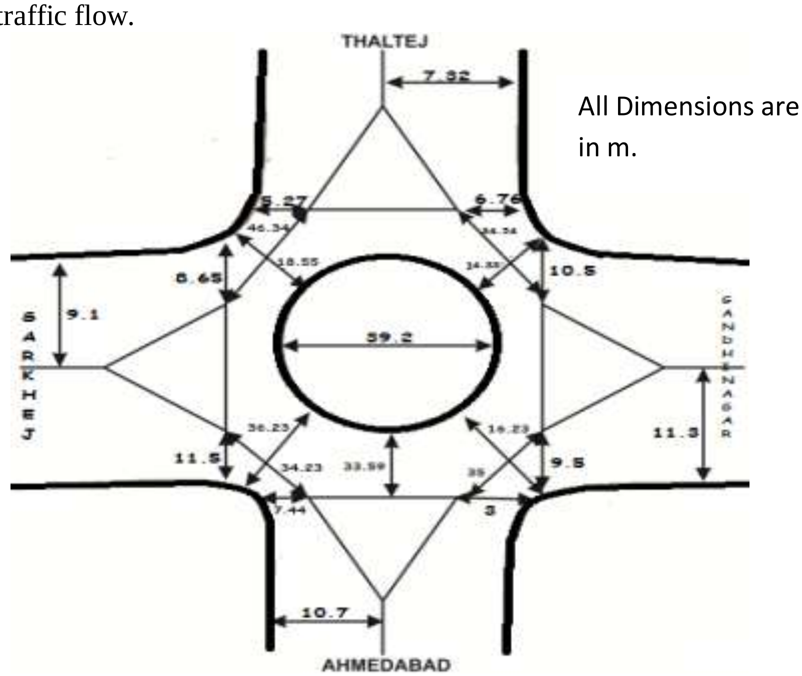

Figure 1: Existing condition of Roundabout

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Traffic Data Analysis

Classified volume count: After studying the traffic congestion at the site, classified volume count survey is carried out. Data obtained after carrying survey in morning peak hours from 9 to 11 am and evening peak hours from6 to 8 pm are as shown intable below:

Table 1:Classified volume count of vehicles

From	To	Vehicles (PCU/hr)	
		Morning	Evening
	Thaltej	176	144
Gandhinagar	Sarkhej	2282	1862
	Ahmedabad	1054	860
	Sarkhej	289	419
Thaltej	Ahmedabad	577	836
	Gandhinagar	97	140
	Ahmedabad	819	1162
Sarkhej	Gandhinagar	1288	1824
	Thaltej	235	333
	Gandhinagar	933	1133
Ahmedabad	Thaltej	171	207
	Sarkhej	594	723

Volume count axle load survey: The volume axle survey was carried out. Since number of heavy vehicles is less due to diversion of these vehicles at present; the volume count axle load could be calculated by considering the EF of the vehicles as 1 and so, axle load would be same as that of traffic count.

Accident Frequencies: Even though this junction remains busy throughout the day, traffic cannot move at high speed through this junction because of existing rotary; and as a result, the chances of accidents are minimized. However, during noon and night time, traffic is lesser on Ahmedabad-Thaltej road and so, heavy vehicles of national highway increase their speed, increasing the possibility of accident, if some mismanagement occurs. Also, during rainy season, some accidents take place due to slip of vehicles. As per local sources, there are 5 to 6 minor accidents per week occur at the site, when there is nil movement of national highway traffic on road.

Capacity

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

$$Qw=\frac{280w\,[1+\frac{e}{w}][1-\frac{p}{3}]}{1+\frac{w}{l}}$$

Where,

e = average entry and exit width, = (e1+e2)/2
w =weaving width,
l = length of weaving,
p = proportion of weaving traffic to the non-weaving traffic.

This equation is valid only under certain conditions, butall these conditions are not satisfied like,

1. Minimum and maximum weaving width at the junction is 14.53m and 35.23m instead of the limit of 6 to 18 meters,
2. Ratio of average weaving width to weaving length is in between 0.4 to 1.029 instead of the limit of 0.12 to 0.4,
3. Ratio of average width of the carriage way at entry and exit to the weaving width is in the range of 0.69 to 1.35 instead of the limit of 0.4 to 1.

So, other alternatives must be considered and checked.

Considering and Designing Various Options:

Redesigning Roundabout

As per IRC,
Design speed at rotary is 30km/hour
Entry speed of rotary is 20 km/hour.

Entry and exit radius: As per IRC, entry radius must be equal to the design entry speed. Thus, entry radius is 20 m.

Also as per IRC, exit radius is 1.5 to 2 times the entry radius. Taking multiplying factor as 1.75, exit radius of rotary is 35 m.

Radius of Rotary:

Radius of rotary as per IRC
=1.3 * design entry speed=26 m.

Exit Widths: As per IRC, the ratio of entrance to exit width must be in between 0.4 to 1. Hence, 0.85 is adopted as ratio, for each side.

Weaving width and length:

Weaving width is given as,

$w_{weaving} = [(e1 + e2) / 2] + 3.5m$

Where,

e1 = carriageway width at the entry
e2 = the carriageway width at exit.

Also, as per IRC, the minimum ratio of weaving length to weaving width must be 4.

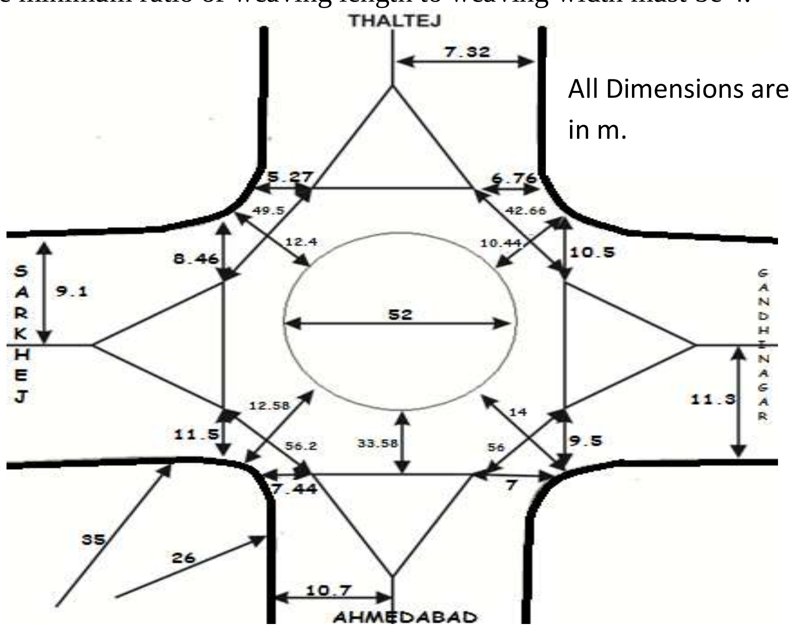

Figure 2: Inventory of redesigned roundabout

In this redesigned case, all the necessary conditions of the rotary are satisfied.

Thus, capacity of rotary,

$$Qw = \frac{280w[1+\frac{e}{w}][1-\frac{p}{3}]}{1+\frac{w}{l}}$$

= 4329.85 PCU/hr

Since the total traffic at the junction is much more than the limit of 3000 PCU/hr specified by IRC, this condition is not sufficient for controlling traffic operations.

Hence, other options are needed to be studied.

Traffic Signal

Case 1- 1st Four Phase Signal Design: In this four phase signal, phases are divided as follows
Phase1: Flow from Gandhinagar
Phase2: Flow from Sarkhej
Phase3: Flowfrom Ahmedabad
Phase4: Flow from Thaltej
As per Webster's equation, optimum cycle time
Co= [(1.5 * L) + 5] / (1-Y)
Where,
Co=optimum cycle time
L=total lost time
Y= lane capacity of junction = q/s
Total lost time
L = 2 * N + R
Where,
N = number of phase
R = all red time= 3 sec for each leg
Lane capacity of junction
Y = q / s
Where,
q= PCU/hr from each side
S= saturation flow
Total flow in each phase (q) is:
Flow in Phase 1 – 2838 PCU/hour
Flow in Phase 2 – 3316 PCU/hour
Flow in Phase 3 – 2004 PCU/hour
Flow in Phase 4 – 1197 PCU/hour
Saturation flow is considered as per different formula:

1. Webster formula

S=525 * w
Where, w = width of road

2. Saturation flow as per Indian scenario

S = 626 * w + 268

3. Alternative formula

S = (647 * w) + (709 * tw) + (270 * b) + (702 * au) – (1568 *c) – (1552 * bi)
Where,
w = width of road in meters
tw = % two wheelers passing through road
b= % of buses
au = % of auto
c = % of cars
bi = % of bicycles
The percentage of various vehicles that pass through various sides are given in the table below

Table 2: Percentage of various vehicles passing through the junction

From	Car(c)	Auto(au)	T/W(tw)	Cycle(bi)	Bus(b)
Sarkhej	0.35	0.11	0.49	0.01	0.03
Gandhinagar	0.43	0.12	0.38	0.02	0.06
Ahmedabad	0.33	0.13	0.52	0.02	0.005
Thaltej	0.17	0.14	0.56	0.11	0.007

Calculation from above equation shows that Co<0, thus this option is not possible.
Case 2 - Changing of phase and redesigning signal: The phasing of signal is changed and a four phase signal is redesigned as
Phase1: Gandhinagar-Sarkhej straight-ahead flow
Phase2:Exclusive phase for right turnersfrom Sarkhej and Gandhinagar
Phase3: Ahmedabad-Thaltej straight-ahead flow
Phase4:Exclusive phase for right turners from Ahmedabad and Thaltej
Optimum cycle time
Co = (1.5L + 5) / (1-Y)
Total flow in each phase (q)
Flow in Phase 1 – 2282 PCU/hour
Flow in Phase 2 – 1162 PCU/hour
Flow in Phase 3 – 836 PCU/hour
Flow in Phase 4 – 1133 PCU/hour
Saturation flow is calculated from formula
S = 626 * W + 268
From calculation, Y = 2.12; and so, Co<0. Thus, this option is not valid.
Case 3 - Increasing one lane of the road and designingthe signal: In this case, width of road is increased by 3.5m.Phasing and saturation flow equation is similar to second alternative.
From calculation, Y = 1.29; and so, Co<0. Thus, this is not possible.
Modification of Webster's equation: Since Webster's equation is not applicable as y>1, for all the above cases, modified equation is applied considering over congested condition.
Optimum cycle time
Co = 1.5 * L * $e^{1.8*y}$
For case,
I) Co=853.3 sec
II) Co = 1362.66 sec
III) Co = 305.88 sec
It is observed that the cycle time is more even after increasing the lane, and hence other available options are needed to be checked.

Flyover

Flyover could be provided in limited space and also the problem of water logging can be eliminated. But the initial cost of a flyover bridge (FOB) is quite high and sometimes uneconomical and not used until required. Also signal needs to be provided for traffic movementin addition ofFOB.
In present case, FOB needs to be provided along NH147 as there is heavy movement of traffic along this road as well as there is probability of NH 147 to be used as expressway in future.
The design of signal under FOB was carried out for following three options:
Three phase signal:
Phase1: Flow from Ahmedabad,
Phase2: Flow from Thaltej,
Phase3: Flow from Gandhinagar and Sarkhej simultaneously.
Optimum cycle time
Co= [(1.5 * L) + 5] / (1 – Y)
Total flow in each phase (q) is:
Flow in Phase 1 – 1132 PCU/hour
Flow in Phase 2 – 1254 PCU/hour
Flow in Phase 3 – 1450 PCU/hour
Saturation flow is given by
S = 626 * w + 268
Co= 1527.77 sec = 32 minutes, which is a quite long signal time.

Change of phase:
Phase1: Ahmedabad-Thaltejstraight-ahead flow,
Phase2: Exclusive phase for right turners from Ahmedabad and Thaltej,
Phase3:Exclusive phase for right turners from Gandhinagar and Sarkhej.
Optimum cycle time
$Co= [(1.5 * L) + 5] / (1 – Y)$
Total flow (PCU/hour) in each phase (q) is:
Flow in Phase 1 – 836 PCU/hour
Flow in Phase 2 – 1133 PCU/hour
Flow in Phase 3 – 1162 PCU/hour
Saturation flow is given by
$S = 626 * w + 268$
Here, $Y = 1.17 > 1$, and so, $Co<0$. This is not possible and other options are needed to be checked.
*Modified Webster's equation:*Saturation flow equation used is
$S = 626 * W + 268$ and
$Co = 1.5 * L * e^{1.8 * y}$
For case
A) Co = 131.77 sec
B) Co = 184.84 sec
Optimum cycle time obtained is 2.5 minutes and 3 minutes respectively.
But, the cost of six lane flyover at present is around 25 to 30 crores and hence other economical solution should be considered if available.

Underpass

Under bridge could allow passage of national highway traffic below the local traffic of Ahmedabad - Thaltej road and it does not require much land acquisition. But, the problem of instability of backfill remains as usual and due to presence of black cotton soil layer at site, seepage of either ground or rain water would create a problem. During rainy season, water logging would be a major issue, and as per IRC, water must never be retained on national highway. Also underpass creates problem when the relative movement of weaving traffic is quite high as it allows only perpendicular movement for traffic.

Interchange

Other option considered is an interchange. Interchanges are the best solution for controlled and efficient movement of traffic in all directions. It may be of clover leaf type, clover stack interchange, stack interchange,etc. They arederived from flyover, in which provision is made for movement of cross traffic. It can handle large amount of traffic very efficiently and thus increases capacity of intersection.
But, it require large amount of space and also the initial cost of construction is quite high. The space required for interchange is not available at site, and so, it cannot be provided.

Uplifted Roundabout

Figure 3: Uplifted Roundabout
Source: http://gulfnews.com/news/gulf/uae/traffic-transport/dh617m-first-interchange-complete-in-dubai-1.998545

As shown in figure, the under pass could be provided on NH 147 side and elevated roundabout could be provided on Ahmedabad-Thaltej side.
*Check for capacity:*Entry width at each approach = 7m (two lane)
As per IRC, the ratio of entrance to exit width must be between 0.4 and 1. Hence adopting ratio of 0.85 (assumed) for each side,exit width= 6/0.85 = 7.64 m
Weaving width at each approach
= [(e1+e2)/2] + 3.5
= [(7+7) / 2] + 3.5
=10.5 m
As per IRC the minimum ratio of weaving length to weaving width must be 4.
Weaving length of each side = 10.5 * 4 = 42 m
As per IRC, entry radius must be equal to the design entry speed.
Assuming entry radius = 20 m.
Also as per IRC, exit radius is 1.5 to 2 times the entry radius. Taking multiplying factor as 1.75 (assumed)
Exit radius of rotary = 1.75 * 20 = 35 m.
Radius of rotary (as per IRC) on each side is
=1.3*design entry speed=26 m
All the conditions required for capacity equation is fulfilled and so, capacity of roundabout

$$Qw = \frac{280\,w\,[1+\frac{e}{w}][1-\frac{p}{3}]}{1+\frac{w}{l}} = 3048 \text{ PCU/hr.}$$

At present, the traffic at junction is 2628 PCU/hr and hence for present condition and also considering the future expansion, uplifted roundabout is sufficient.
Total height of structure required is 8.5 meters, in which S.G highway side is excavated upto 4.25 m below existing ground level and the portion along Ahmedabad-Thaltej could be elevated by 4.25 m above the existing ground level. Gradient is 1:100 for underpass as well as for elevated corridor. Proper drainage is necessary as water-choking may disrupt traffic operation along NH 147 side. Preferably, earth work is only need to be provided for the elevated portion, and this reduces its cost considerably as only two piers are there to support the uplifted portion.
Internal diameter of rotary required is 52 m. Three lane and two lane road is to be provided on NH 147 side and Ahmedabad-Thaltejside respectively, as this design is sufficient for present condition as well as for future expansion.
Providing such a flyover/roundabout reduces the traffic congestion at the junction and also, it is very economical.

Justification by Sidra Software

The validity of all the above alternatives is justified by intersection design software SIDRA INTERSECTION.Average controlled delay per vehicle or average pedestrian delay;level of service, total vehicle travel time, totalfuel consumption, totalcarbon dioxide emission and total vehicle operating and time cost or pedestrian time cost of above designed roundabout, signal, fly over signal and uplifted roundabout is studied. SIDRA Standard Delay Model is used.

Roundabout

Table 3: Validity of existing roundabout using SIDRA Standard Delay Model

	South	East	North	West	Intersection
Delay (seconds)	5179.7	12433.8	7757.0	14138.1	10913.7
LOS	F	F	F	F	F
Travel Time (veh-h/h)	3631.2	14929.3	4680.8	17801.6	41042.9
Cost ($/h)	102513.5	428325.1	131343.3	498869.1	1161051.0
Fuel (litre/h)	5337.0	24975.1	6648.5	25088.0	62048.6
CO2 (Kg/h)	13348.1	62511.6	16629.5	62759.3	155932.2

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Effective intersection capacity of roundabout is 2117 vehicles/hour. Total travel distance is 7426.5 vehicles-km/hour and travel speed is 0.2 km/hour. Total emission of Hydrocarbons, Carbon Monoxide and NOx are 345.211, 3402.82 and 115.347 kg/hourrespectively.

Signal

Table 4: Validity of signal design case1 using SIDRA Standard Delay Model

	South	East	North	West	Intersection
Delay (seconds)	8579.2	13279.0	5697.0	14503.1	11746.2
LOS	F	F	F	F	F
Degree of Saturation	5.30	6.40	3.14	6.42	6.42
Travel Time (veh-h/h)	5253.5	16051.9	2194.8	12604.8	36104.9
Cost ($/h)	151889.1	466399.8	63485.8	362298.9	1044074.0
Fuel (litre/h)	9537.7	29274.9	3870.7	21808.5	64491.7

Effective intersection capacity of roundabout is 1715 vehicles/hour. Total travel distance is 5745.6 vehicles-km/hour and travel speed is 0.2 km/hour. Total emission of Hydrocarbons, Carbon Monoxide and NOx are 299.139, 2607.47 and 96.347 kg/hour respectively.

Flyover Signal

Table 5: Validity of flyover signal using SIDRA Standard Delay Model

	South	East	North	West	Intersection
Delay (seconds)	1926.9	2351.4	3740.7	1256.7	2318.1
LOS	F	F	F	F	F
Degree of Saturation	2.50	1.70	2.52	2.54	2.54
Fuel (litre/h)	1978.6	2621.4	3244.1	1086.4	8930.5
CO2 (kg/h)	4948.4	6561.2	8114.3	2717.7	22446.1

Uplifted Roundabout

Table 6: Validity of uplifted roundabout using SIDRA Standard Delay Model

	South	East	North	West	Intersection
Delay (seconds)	28.7	13088.3	5675.1	2734.7	5067.4
LOS	C	F	F	F	F
Degree of Saturation	0.97	4.99	3.03	1.97	4.99
Travel Time (veh-h/h)	67.8	7282.3	3435.3	1579.9	12365.3
Cost($/h)	2077.4	211987.8	96756.2	45423.1	356244.4
Fuel (litre/h)	171.3	13332.7	4985.0	2556.6	21045.6
CO2 (kg/h)	428.5	33371.3	12468.6	6395.4	53196.4

CONCLUSION

Above discussion shows that, because of heavy traffic flow on SG highway (NH147), existing roundabout is not sufficient and some solution is required to reduce congestion at junction. This is possible by providing either signal, flyover, under pass or uplifted roundabout.

But as discussed above, there are problems due to water logging in rainy season, instability of back fill, excessive seepage problem through retained soil; the option of under bridge is eliminated. Also traffic signal cannot be provided as it has very long Cycle time.Construction of flyover is very costly and there is a need to provide signal underneath, which causes delay and so should not be provided.

Thus, modified roundabout could be the best option as the heavy traffic of National highway could be diverted under the rotary and the remaining traffic, through the elevated rotary.Hence, chances of accidents, traffic jam could be considerably reduced, which would cause reduction of pollution. Also by

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considering future expansion of national highway, to make NH147 as an expressway; and also by validation of all options and by SIDRA intersection design software, it proves to be a best solution.

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