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# To Evaluate the Capacity of Roundabouts by Using Analytical Method

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**ABSTRACT**

*This thesis addresses the most important elements of capacity evaluation and operational performance of roundabout traffic intersections in Visakhapatnam on capacity analysis movements of the vehicles were observed at 5 roundabouts. Gap acceptance and follow up time were estimated for cars for one hour analysis. The relation between a roundabout performance measure and capacity is expressed in terms of degree of saturation (volume – Capacity ratio). The capacity analysis is done based on gap acceptance method that is adopted by Tanner based on the HCM 2010. The traffic movement data with vehicles characteristics were collected from 5 roundabouts in Visakhapatnam. These 5 roundabouts are directly related to their approach leg numbers.*

*Approach entry capacity has been analysed for all 5 roundabouts at their legs. Effective capacity verses entry flow relationship have been developed in order to find out the causes of their over saturation (v/c ratio greater than 0.85) And the result indicates; number of entry lanes, number of circulatory lanes and high traffic flow are the major causes of their over saturation.*

*Tanner models use the gap-acceptance theory (or critical headway) to simulate the behaviour of entering vehicles and vehicles circulating within the roundabout. Finding a safe gap (or headway) with circulating traffic stream to enter the roundabout is the control variable that determines the ability of approach vehicles to enter the roundabout. Current research work on roundabout models mostly concentrates on determining the capacity of an approach based on the entering and circulating flows. Approach capacity is calculated as a mathematical function.*

***Key words**: Roundabout, capacity, Gap Acceptance, Follow up time, Delay, Queue length, LOS, Degree of saturation.*



## I. INTRODUCTION

*1.1 General*

A roundabout is an alternative form for traffic control at intersections. Roundabouts are generally circular in shape, characterized by yield on entry and circulation around a central island. Roundabouts are appropriate for many intersections including locations experiencing high number of crashes, long traffic delays, and approaches with relatively balanced traffic flows. Roundabouts have the potential to resolve various traffic flow problems. Traffic volume on one approach is significantly higher that it prevents vehicles at any other approach from entering the roundabout especially at a downstream approach or the next following approach. Evaluation of junction capacity of roundabout is very important since it is directly related to delay, level of service, accident, operation cost, and environmental issues. There are three legs, four legs and five legs roundabouts in vizag.Since little attention has been paid to the design and capacity evaluation of the roundabouts, no one knows their capacities or level of services.

*1.2 Advantages of Roundabouts*

Less Serious Accidents

Head-on and angle collisions are virtually non-existent because of the circular rather than opposing flow of traffic. The angles of traffic interaction and slower speed through the interchange reduce the severity of accidents. Roundabouts in the USA and other countries have achieved a 50 to 90 percent reduction in collisions compared to intersections using 2- or 4-way stop control or traffic signals.

Construction, Operating, and Maintenance Costs

A simple signalized intersection costs about $3,000 (US) per year for electricity, Maintenance of loops, controller, signal heads, timing plans, etc. Inaddition, signal heads and controllers have to be replaced and completely rebuilt on a regular basis. Larger signalized intersections are more expensive to maintain. The only maintenance costs for a roundabout are for landscape maintenance and occasional sign replacement.

*1.3 Introduction on Roundabouts*

An intersection is the junction (that is to say, on the same level) of two or more roads either meeting or crossing. An intersection may be three way (a T junction or Y junction – the latter also known as a fork if approached from the stem of the Y), four-way (often in the form of a crossroads), or have five (a 5-points) or more arms. Busy intersections are often controlled by traffic lights and/or roundabouts.

Intersections may be classified into two broad groups:

➢ Intersection at grade: these include all roads which meet at more or less the same level. The traffic manoeuvres like merging, diverging and crossing are involved in the intersections at grade.

- Unchannelized intersections
- Channelized intersections
- Rotary intersections

➢ Grade separated intersection: the intersection roads are separated by difference in level, thus eliminating the crossing manoeuvres.

**Fig 1.1 intersection**

*1.4 Roundabout parameters:*

- Design of vehicles
- Design speed
- Sight distance
- Deflection
- Central island
- Circulating width
- Inscribed circle diameter
- Entry and exit design
- Splitter island
- Super elevation and drainage

- Pavement markings
- Signage
- Lighting

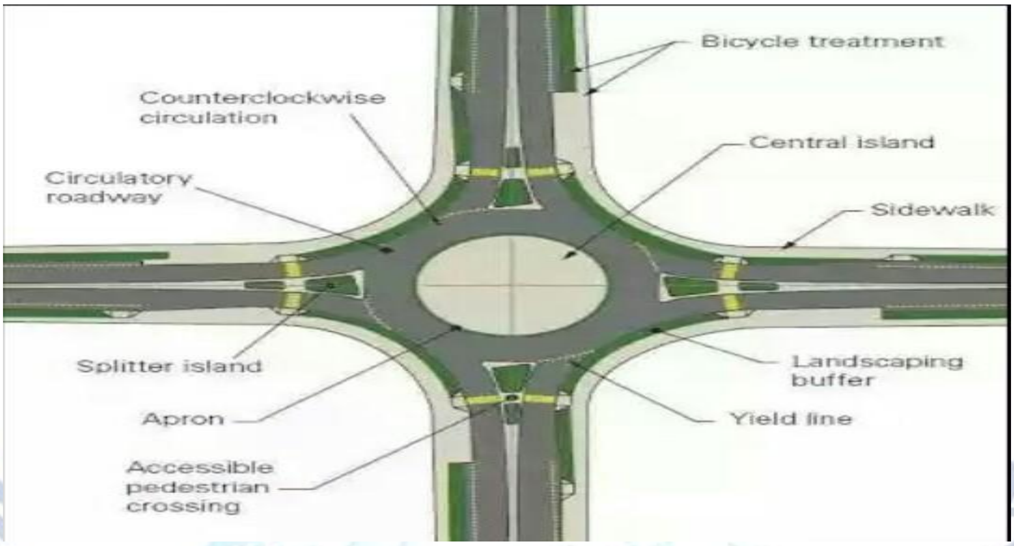



**Fig 1.2 parameters of roundabout**

*1.5 Traffic Volume Study*

Traffic volume is the number of vehicles crossing a section of road per unit time at any selected period. Traffic volume is used as a quantity measure of flow; the commonly used units are vehicles per day and vehicle per hour. A complete traffic volume study may include the classified volume study by recording the volume of various types and classes of traffic, the distribution by direction and turning movements and the distribution on different lanes per unit time. There are variations in traffic flow from time to time. Hourly traffic volume varies considerably during day, the peak hourly volume may be much higher than average hourly volume. It varies also from seasons

- Traffic volume is generally accepted as a true measure of the relative importance of roads and in deciding the priority for improvement and expansion.
- Traffic volume study is used in planning, traffic operation and control of existing facilities and also for planning and designing the new facilities.
- This study is used in the analysis of traffic patterns and trends.
- Classified volume study is useful in structural design of pavements, in geometric design and in computing roadway capacity.

1.6 Gap Acceptance Study

Gap acceptance is one of the most important components in microscopic traffic characteristic. The gap acceptance theory commonly used in the analysis of uncontrolled intersections based on the concept of defining the extent drivers will be able to utilize a gap of particular size or duration entering into or going across a traffic stream must evaluate the space between a potentially conflicting vehicle and decide whether . This interaction takes place when a driver changes lanes merging into a traffic stream or crosses a traffic stream. Inherent in the traffic interaction associated with these basic maneuvers is concept of gap acceptance.

Gap acceptance can be determined by parameters:

- Critical gap
- Follow-up time
- Number of entry lanes
- Number of circulatory lanes

*1.7 Capacity*

Roundabout capacity is defined as the sum of all entering approach capacities. Capacity of each entry is defined as the maximum number of vehicles that can enter the roundabout within 1 hour; this is defined for a given volume of circulating vehicles. This is similar in concept to the analysis method of the Highway Capacity Manual HCM for un-signalized intersection capacity, whereby the capacity of each minor traffic stream is defined separately, depending in the critical gap and the conflicting traffic-stream volume.

*1.8 Volume To Capacity Ratio (V/C)*

Volume-to-capacity (V/C) ratios are the primary measure of effectiveness for evaluation against the operational performance. V/C ratios for roundabouts should be calculated based on the entry demand and capacity for the most critical approach (i.e. approach with the highest v/c ratio) for single-lane roundabouts and the most critical lane (i.e. individual lane with the highest v/c ratio) for multilane roundabouts.

## 2. METHODOLOGY FOR THE STUDY

The study is carried out to estimate the capacity of roundabout. The present study involves collection of the data through field studies. Traffic volume count survey according to movement wise and roundabout inventory survey is conducted. The entire Process is depicted in below sequence of steps.

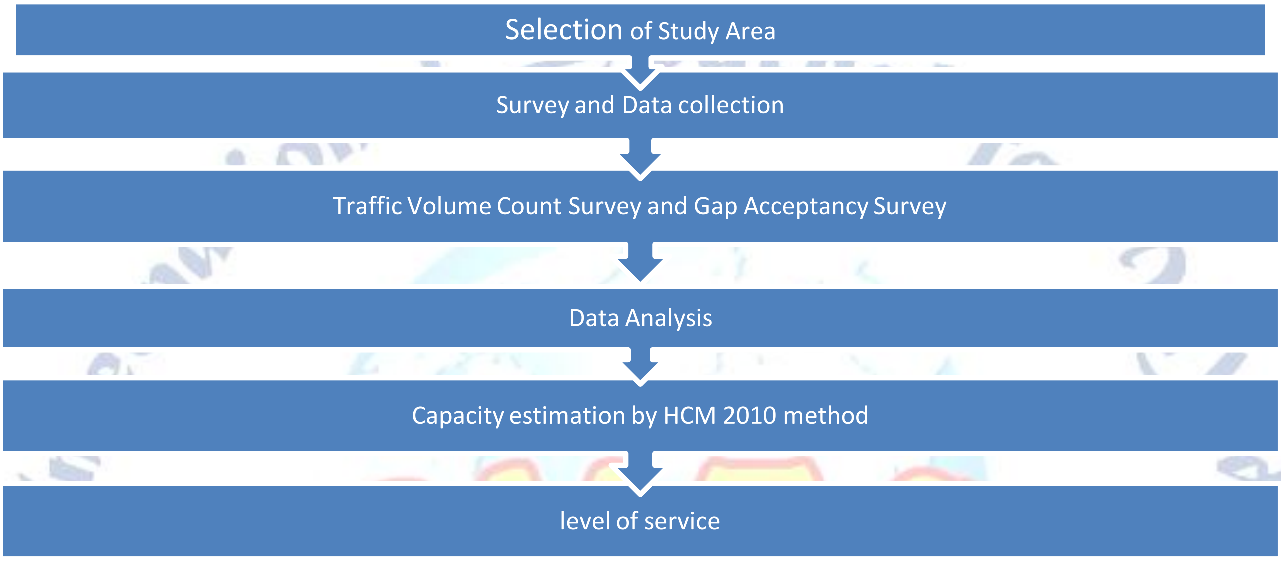



**Fig 2.1 showing methodology**

*2.2 Overview Of The Methodology*

- Selection of Study Area

From the context of urbanization and statistics of population growth in India the city Visakhapatnam in Andhra Pradesh can be best suited.Visakhapatnam district, located in Coastal Andhra region.The population of the district according to the Census 2011 was 17, 28,128 of which 57.95% were urban. visakhapatnam city is its administrative headquarters of Visakhapatnam district.

- Location for study

To fulfill the specified objectives of the study five roundabouts have been chosen.

1. Dabagardens junction
2. Diamond park
3. Convent junction
4. Waltier junction

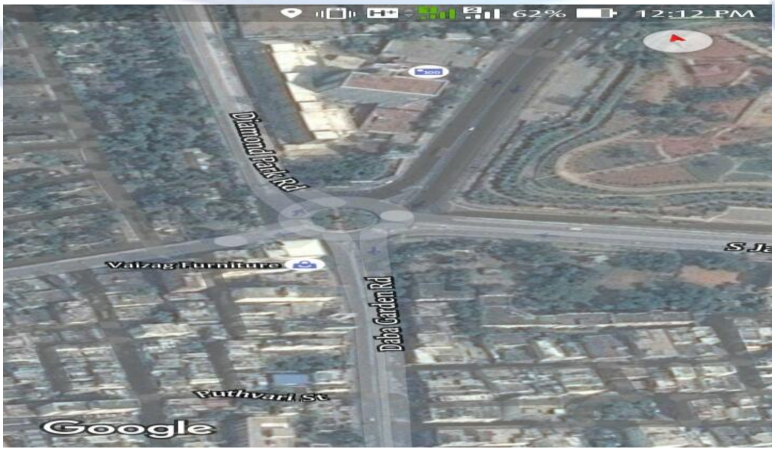



**Fig 2.2 Junction-I LIC**

**Fig 2.3 Dabagardens(field fig)**

**Fig 2.4 Diamondpark(field fig)**


**Fig 2.5 Junction 3 Convent junction**

**Fig 2.6 Junction 4 Waltair**

These four Junctions are selected because these are the Junctions with roundabouts of irregular parameters without a proper design which are affecting the junction's Capacities and Performances. Hence, these 43 Junctions are considered for the study among all the junctions and roundabouts in the visakhapatnam Town.

Survey And Data Collection

Surveys will be carried out to get the reliable data at the chosen intersection consisting of heterogeneous traffic. Different modes of traffic such as Buses, Trucks, cars, auto rickshaws, cycles and low commercial vehicles etc.apply on these roads. The following surveys will be conducted.

- Gap Acceptance Survey
- Traffic Volume Count Survey
- Field studies

*2.3 Gap Acceptance Survey*

Gap Acceptance data is a collection of the Gap accepted by the drivers at the roundabout. The acceptance details of the roundabout are collected by the team of enumerators. The Gap acceptance details constitute the following surveys.

- Critical Gap
- Follow-up Time

*2.4 Traffic Volume Count Survey:*

Traffic volume survey according to direction wise will be carried out on the selected roundabout locations. The traffic volume survey will be conducted for duration of 4 hours on all locations, for the peak hour data.

*2.5 Capacity Estimation:*

Generally the capacity of the roundabout has been estimated by using the empirical approach and gap acceptance approach. In the present study the capacity will be estimated by empirical method namely:

And also under the gap acceptance approach the HCM 2010 method will be used.

## 3. TRAFFIC SURVEYS AND ANALYSIS

*3.1 General*

The study of traffic behaviour is useful for traffic engineer to design intersections, for developing traffic control warrants, timing traffic signals, to design vehicle storage lanes etc. A principal objective of capacity analysis is the estimation of the maximum number cf persons or vehicles that can be accommodated by a given facility in reasonable safety within a specified time period. However, because facilities generally operate poorly at or near capacity, they are rarely planned to operate in this range. Accordingly, capacity analysis also provides a means of estimating the maximum amount of traffic that can be accommodated by a facility while maintaining prescribed operational qualities. Capacity analysis at intersections depends upon a clear description and understanding of the interaction of drivers. Capacity is either analyzed by the empirical regression method, which is mainly applied in the context of British research results, or by the so called gap-acceptance procedures (GAP). In this study the capacity is calculated by using the gap acceptance method as HCM 2000 formula.

*3.2 Data Collection*

Gap acceptance/rejection, follow-up time and free-flow speed are collect from the video for the roundabouts. Any unusual driver behaviour such as gap-forcing behaviour, violation of the right-of-way, and unnecessarily tentative drivers was noted. All the data is collect manually. The traffic data collected should indicate the existing peak hour traffic conditions. Data are collected with the aid of a video camera to record the entry and exit of vehicles atthree roundabouts in Nellore. The video enabled information on volume, delay and speed and gap acceptance to be determined. The use of a video camera is noteworthy because it permits the use of the minimum number of persons and the tapes can be reviewed several times to obtain the most accurate information. The video is used to determine the rejected gaps or lags of drivers approaching the roundabout and eventually the accepted gaps or lags that the drivers used to merge into the roundabout plus the follow-up times in instances where there is a queue

*3.3 Field Study:*

Geometric Parameters Of Roundabouts:

**Table 3.1 field study at Junction-1 LIC JUNCTION**

| legs | diameter of central island(m) | Circulatory width(m) | Flare+Entry width(m) | Flare+exit Exit(m) | Entrywidth(m) | | Exit width(m) | |
|---|---|---|---|---|---|---|---|---|
| | 30 | | | | | | | |
| A | | 15.24 | 4.85 | 13.58 | 3.57 | 6.85 | 10.54 | 11.22 |
| B | | 11.83 | 14.86 | 16.12 | 9.75 | - | 11.95 | - |
| C | | 15.15 | 6.74 | 8.33 | 5.77 | - | 5.72 | - |
| D | | 20.4 | 12.1 | 7.6 | 6.79 | - | 7.6 | - |
| E | | | 16.97 | 11.69 | 10.20 | 5.7 | 10.49 | - |

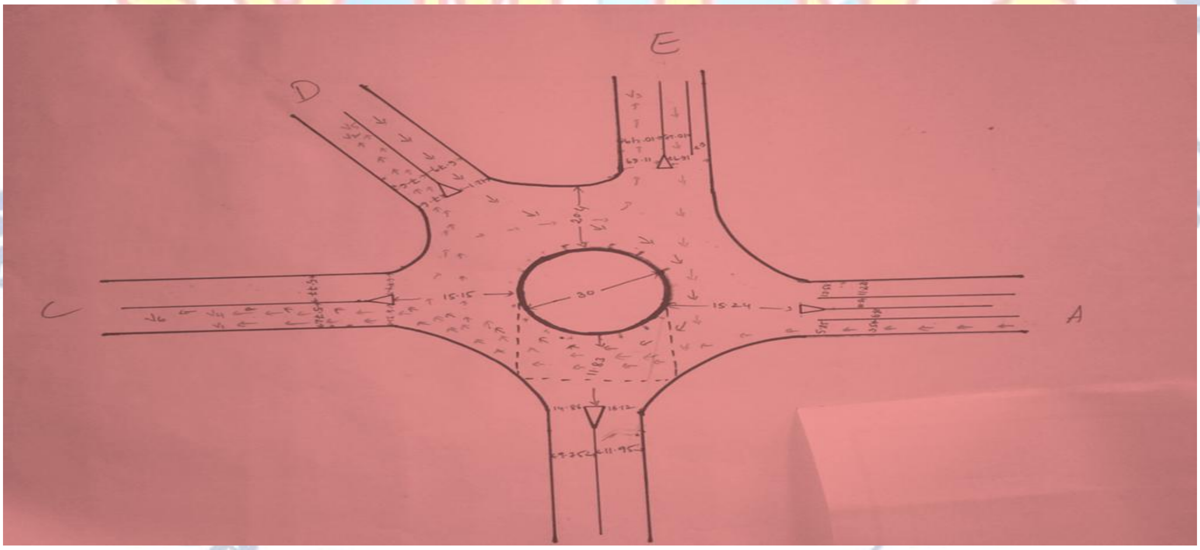



**Fig 3.1 Field Study at LIC JUNCTION**

**Table 3.2 field study atJunction-2 DIAMOND PARK**

| Legs | Diameter of central island(m) | Circulatory width(m) | Flare width at entry(m) | Flare width at exit(m) | Entry width(m) | Exit width(m) |
|---|---|---|---|---|---|---|
| | 47.8 | | | | | |
| E | | 10.94 | 8.99 | 7.9 | 8.23 | 7.54 |
| S | | 10.19 | 10.2 | 8.69 | 8.47 | 8.65 |
| N | | 9.47 | 8.74 | 8.64 | 8.17 | 8.12 |
| W | | 10.36 | 7.34 | 7.15 | 7.53 | 7.31 |

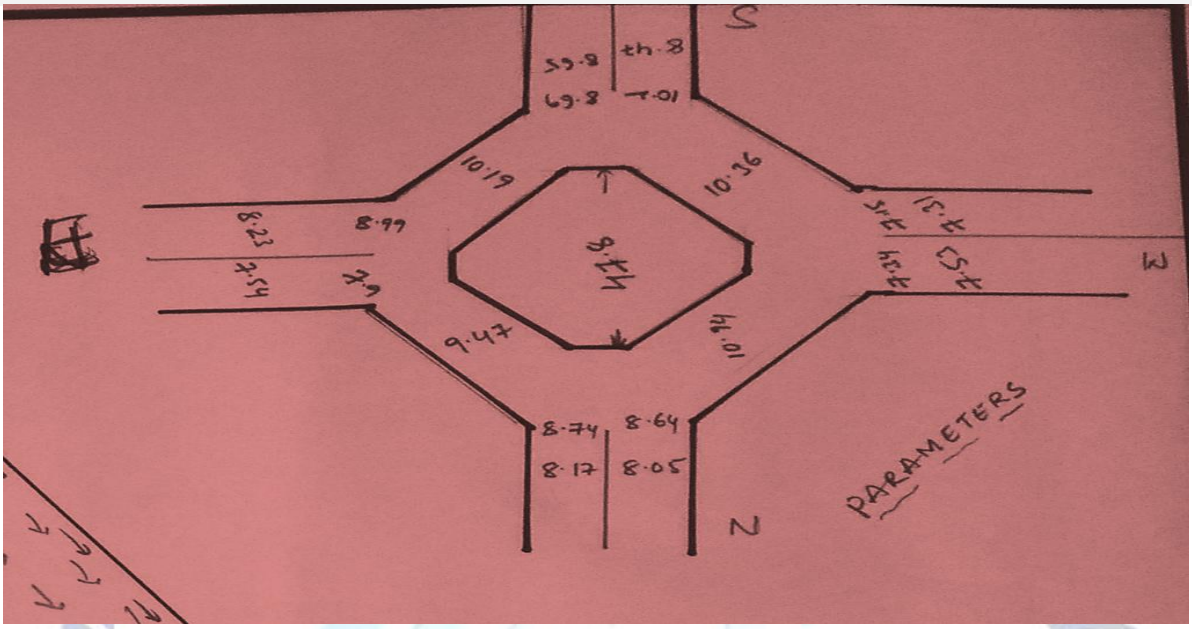



**Fig 3.2 Field Study at DIAMOND PARK**

**Table 3.3 field study atJunction-3 CONVENT JUNCTION**

| Legs | Diameter of central island(m) | Circulatory width(m) | Flare width at entry(m) | Flare width at exit(m) | Entry width (m) | Exit width (m) |
|---|---|---|---|---|---|---|
| | 37.95 | | | | | |
| A | | 19.77 | 15.57 | 19.71 | 14.21 | 16.69 |
| B | | 25.6 | 18.1 | 17.30 | 9.88 | 17.19 |
| C | | 16.4 | 16.4 | 27.35 | 16.68 | 26.90 |
| D | | 21.43 | 10.26 | 9.42 | 5.34 | 5.0 |
| E | | | 15.79 | 15.46 | 9.64 | 9.64 |

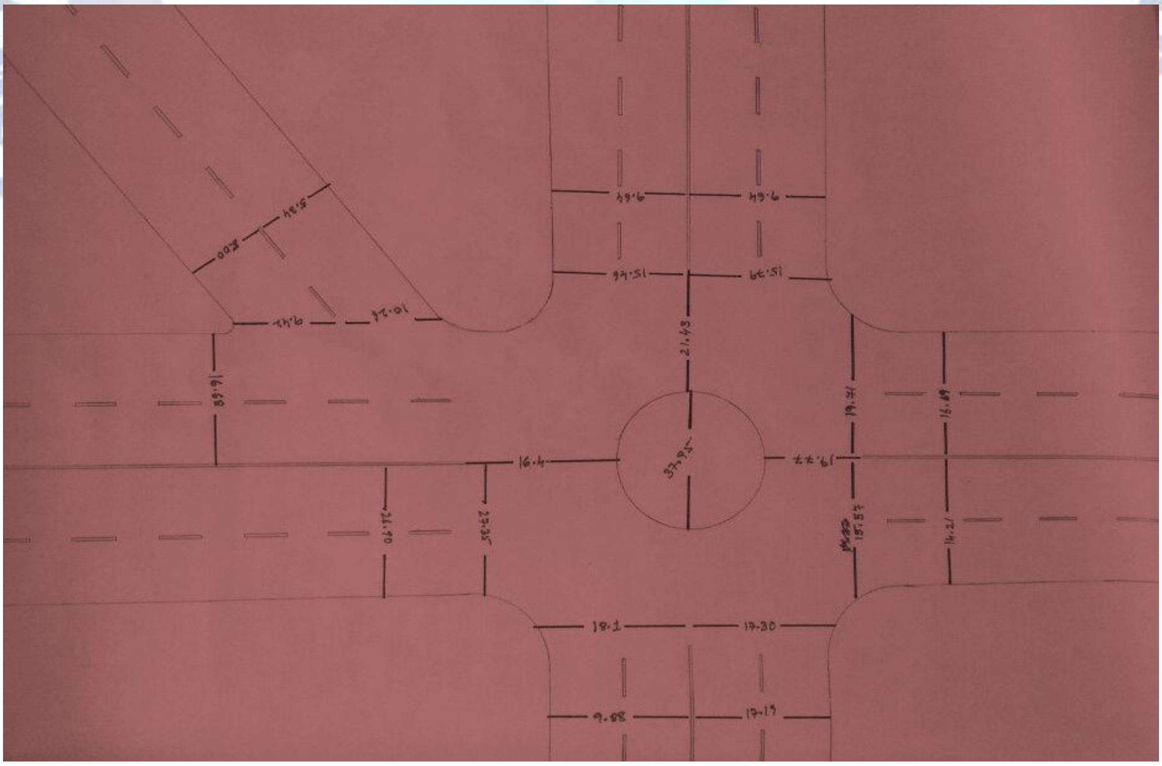



**Fig 3.3 field study at CONVENT JUNCTION**

**Table 3.4 field studyJunction-4 WALTAIR**

| Legs | Diameter of central island(m) | Circulatory width(m) | Flare width at entry(m) | Flare width at exit(m) | Entry width (m) | Exit width( m) |
|---|---|---|---|---|---|---|
| | 8.06 | | | | | |
| N | | 8.78 | 7.05 | 12.04 | 8.1 | 7.52 |
| S | | 9.76 | 7.64 | 10.22 | 7.34 | 7.62 |
| E | | 9.1 | 7.66 | 6.3 | 5.51 | 6.3 |
| W | | 9.44 | 7.7 | 8.78 | 5.7 | 9.14 |

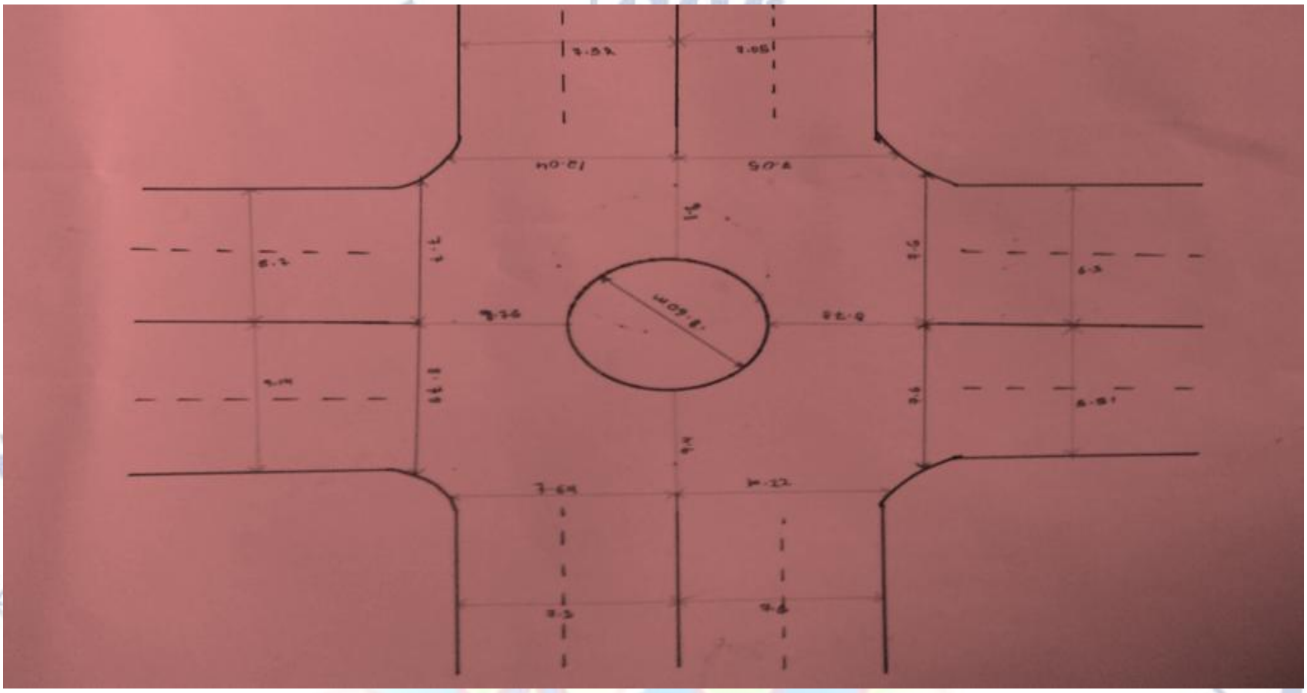


**Fig 3.4 Field Study at WALTAIR**

PASSENGER CAR UNIT:

The various vehicle types having different sizes and characteristics were converted into equivalent passenger car units. The Passenger Car Units (PCU) factors recommended by Indian Road Congress were used as shown in **Table 3.5**

**Table 3.5PCU Factors for Different Vehicle Categories**

| Vehicle Type | Passenger Car Equivalent(PCE) |
|---|---|
| Motor Cycle | 0.5 |
| Bicycle | 0.5 for roundabout |
| Private car, | 1 |
| Bus , tractor, truck | 3 |

**Table 3.6 Summarized vehicle volume of Junction 1 on each leg at peak hour.**

Time 1hour

| Junction | Leg | H.V | Car/Auto | 2W | Total Veh | Total Veh in PCUs |
|---|---|---|---|---|---|---|
| A | AB | 6 | 52 | 114 | 172 | 127 |
| | AC | 20 | 70 | 112 | 302 | 236 |
| | AD | 8 | 92 | 230 | 330 | 231 |
| | AE | 22 | 68 | 78 | 168 | 173 |
| | AA | 0 | 10 | 26 | 36 | 23 |

| | | | | | | |
|---|---|---|---|---|---|---|
| B | BC | 7 | 24 | 62 | 93 | 76 |
| | BD | 6 | 106 | 324 | 436 | 286 |
| | BE | 32 | 174 | 252 | 458 | 396 |
| | BA | 5 | 70 | 140 | 215 | 155 |
| | BB | 4 | 11 | 27 | 42 | 36.5 |
| C | CD | 6 | 18 | 50 | 74 | 61 |
| | CE | 8 | 72 | 148 | 228 | 170 |
| | CA | 6 | 88 | 214 | 308 | 213 |
| | CB | 14 | 164 | 120 | 298 | 266 |
| | CC | 2 | 9 | 27 | 38 | 28.5 |
| D | DE | 7 | 10 | 28 | 45 | 45 |
| | DA | 32 | 86 | 226 | 344 | 295 |
| | DB | 6 | 132 | 366 | 504 | 333 |
| | DC | 14 | 36 | 86 | 136 | 121 |
| | DD | 3 | 7 | 19 | 29 | 25.5 |
| E | EA | 13 | 52 | 70 | 135 | 126 |
| | EB | 42 | 234 | 278 | 554 | 499 |
| | EC | 48 | 78 | 142 | 268 | 293 |
| | ED | 6 | 10 | 12 | 28 | 34 |
| | EE | 3 | 9 | 11 | 23 | 23.5 |
| TOTAL | | 408 | 1695 | 3262 | 5264 | 4273 |

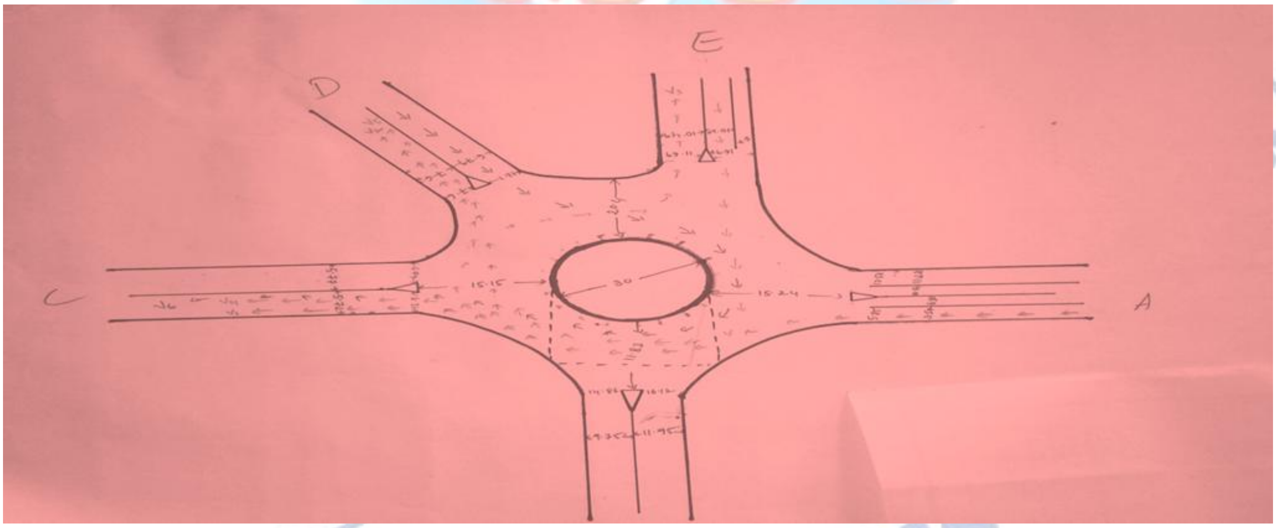



**Fig 3.5 volume analysis at junction-1**

**Table 3.7 Summarized vehicle volume of Junction 2 on each leg at peak hour.**

| **JUNCTION diamond park** | | | | | | |
|---|---|---|---|---|---|---|
| **LEG** | **FLOW** | **H.V** | **Car/Auto** | **2w** | **Total veh** | **Total veh in PCUs** |
| NORTH | NE | 13 | 80 | 164 | 257 | 201 |
| | NS | 6 | 110 | 236 | 352 | 246 |
| | NW | 12 | 56 | 192 | 260 | 188 |
| | NN | 5 | 23 | 29 | 57 | 52.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| EAST | ES | 9 | 84 | 124 | 217 | 173 |
| | EW | 7 | 108 | 148 | 263 | 203 |
| | EN | 16 | 66 | 64 | 146 | 146 |
| | EE | 3 | 13 | 26 | 42 | 35 |
| SOUTH | SW | 20 | 72 | 98 | 190 | 181 |
| | SN | 36 | 70 | 274 | 380 | 315 |
| | SE | 8 | 40 | 178 | 226 | 153 |
| | SS | 2 | 16 | 21 | 39 | 32.5 |
| WEST | WN | 13 | 82 | 92 | 187 | 167 |
| | WE | 6 | 148 | 124 | 278 | 228 |
| | WS | 5 | 106 | 192 | 303 | 217 |
| | WW | 3 | 12 | 16 | 31 | 29 |
| TOTAL | | 171 | 1086 | 1978 | 3228 | 2567 |

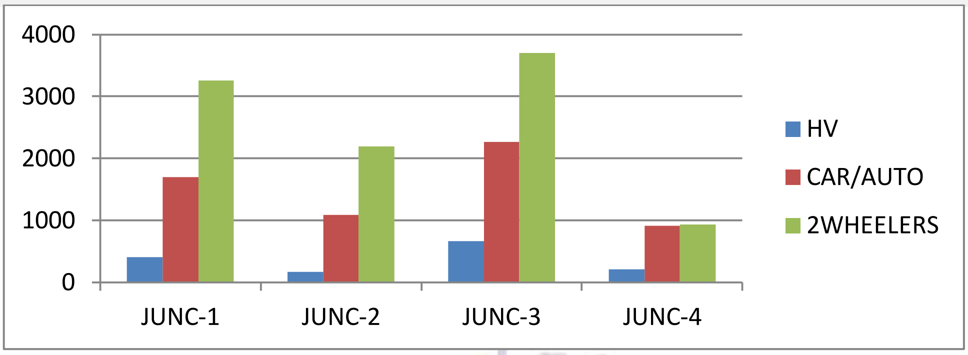
**We can also Summarized vehicle volume of Junction 3 and Junciotn 4 like above tables**

**Table 3.8 Summarized vehicles volume for legs on intersections at peak hour**

| junction | leg | H.V | Car/auto | 2w | Total Veh | Total Veh in PcUs |
|---|---|---|---|---|---|---|
| Junction 1 | A | 56 | 292 | 660 | 1008 | 790 |
| | B | 54 | 385 | 805 | 1264 | 1009.5 |
| | C | 36 | 351 | 559 | 946 | 738.5 |
| | D | 62 | 271 | 725 | 1116 | 967.5 |
| | E | 112 | 383 | 513 | 1031 | 1044.5 |
| Junction 2 | N | 36 | 269 | 621 | 926 | 687.5 |
| | S | 35 | 271 | 362 | 675 | 578 |
| | E | 66 | 198 | 571 | 835 | 681.5 |
| | W | 27 | 348 | 641 | 1016 | 641 |
| Junction 3 | A | 164 | 219 | 247 | 938 | 1137.5 |
| | B | 87 | 262 | 343 | 1776 | 1433.5 |
| | C | 152 | 199 | 328 | 2113 | 1786 |
| | D | 152 | 250 | 397 | 1404 | 1309.5 |
| | E | 69 | 149 | 183 | 401 | 447.5 |
| Junction 4 | N | 56 | 350 | 424 | 830 | 730 |
| | S | 40 | 97 | 57 | 194 | 245.5 |
| | E | 46 | 298 | 274 | 618 | 573 |
| | W | 65 | 166 | 178 | 409 | 450 |

**Table 3.9 Summarized vehicles Volumes on Intersections at peak hour.**

| Junction | H.V | Car/Auto | 2W | Total Veh | Total Veh in PCUs |
|---|---|---|---|---|---|
| Junction 1 | 320 | 1682 | 3262 | 5365 | 4273 |
| Junction 2 | 164 | 1086 | 2195 | 3452 | 2567 |
| Junction 3 | 618 | 1079 | 1498 | 6632 | 3686 |
| Junction 4 | 207 | 911 | 933 | 2051 | 1998.5 |




**3.7 PEAK HOUR VOLUMES AT INTERSECTIONS:**

### 3.4 GAP ACCEPTANCE:

Gap-acceptance parameters, critical gap and follow up headway were measured during the traffic flow count. So better results are obtained and it is good to do it simultaneously with the traffic count.. Critical and follow up headway collected from roundabouts which is attached in the APPENDIX-A and also show in table

**Table 3.10 Average Critical Gap and Follow-up Time from the collected data**

| AVERAGE CRITICAL GAP AND FOLLOW-UP TIME | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **LEG NAME** | **NORTH / A** | | **EAST/B** | | **SOUTH/C** | | **WEST/D** | | **E** | |
| **JUNCTION** | **Critical Gap** | **Follow up Time** | **Critical Gap** | **Follow up Time** | **Critical Gap** | **Follow up Time** | **Critical Gap** | **Follow up Time** | **Critical Gap** | **FollowUp Time** |
| | (sec) | (sec) | (sec) | (sec) | (sec) | (sec) | (sec) | (sec) | (sec) | (sec) |
| JUNCTION-1 | 4.35 | 1.7 | 2.24 | 3.2 | 4.63 | 2.4 | 3.62 | 3.3 | 3.86 | 3.4 |
| JUNCTION-2 | 3.6 | 2.5 | 5.6 | 2.7 | 6.64 | 3 | 7.36 | 2.6 | - | - |
| JUNCTION-3 | 4.2 | 1.4 | 2.2 | 2.97 | 3 | 2.54 | 4.2 | 2.71 | 2.8 | 3.4 |
| JUNCTION-4 | 6.26 | 2.1 | 6.5 | 2.4 | 4.93 | 2.6 | 3.64 | 2.4 | - | - |

*3.5 Variation of Traffic*

Hourly variation of traffic observed at all the survey locations hence, from the peak hour traffic data the important inferences drawn are presented below :

- At Junction – 1, the peak hour traffic is 5342Veh/hr, which is 4273 PCUs/hr.
- At Junction – 2, the peak hour traffic is 3452Veh/hr, which is 2573 PCUs/hr.
- At Junction – 3, the peak hour traffic is 6632Veh/hr, which is 3686 PCUs/hr.
- At Junction – 4, the peak hour traffic is 2051Veh/hr, which is 1998.5 PCUs/h

*3.6 Summary*

- In this chapter, the Data collection, Traffic volume count survey data sheets, and their analysis is presented.

## 4. CALCULATION OF CAPACITIES &RESULTS

4.1 *General*

From the data collected from the traffic surveys conducted at the Junctions, the capacities are calculated using the HCM 2010 method. The details are presented below.

4.2 *Calculation of Circulating Flows*

In practice, it is necessary to convert the intersection turning movements into entry and circulating flows. Entry flow is simply sum of the through, left and right turn movements on an approach. Circulating flow is the sum of the vehicles from different movements passing in front of the adjacent upstream splitter island. At existing roundabouts, these flows can simply be measured in the field. Left turns are included in approach volumes and require capacity, but are not included in the circulating volumes downstream because they exit before they exit before the next entrance.

For example, for leg-1 the conflicting flow would be equal to v1+v2+v3.This methodology can be extended to roundabouts with more or less than four legs.

CALCULATION OF CIRCULATING FLOW AT JUNCTIONS

**Table 4.1 circulating flow at junction-1**

| Legs at junction | Circulating capacity | circulating capacity value |
|---|---|---|
| **A** | E(B+C+D+E)+C(B+C)+D(B+C+D)+BB | 1660 |
| **B** | A(C+D+E+A)+E(C+D+E)+D(C+D)+CC | 1188.5 |
| **C** | B(D+E+A+B)+ A(D+E+A E(D+E)+DD | 1383.5 |
| **D** | C(A+B+C+E)+B(A+B+E)+A(A+E)+EE | 1484.5 |
| **E** | D(A+B+C+D)+C(A+B+C)+B(A+B)+AA | 1496.5 |

**Table 4.2 circulating flow at junction-2**

| Legs at junction diamond park | Circulating capacity | Circulating Capacity value |
|---|---|---|
| **N** | W(E+S+W)+S(E+S)+EE | 694.5 |
| **E** | N(S+W+N)+W(S+W)+SS | 765 |
| **S** | E(W+N+E)+N(W+N)+WW | 653.5 |
| **W** | S(N+E+S)+E(N+E)+NN | 734 |

We can also tabulated Circulating flow at Junction-3 and Junction-4 like as above tables

4.3 CAPACITY CALICULATION IN HCM 2010 MODEL

This capacity model was revised in the HCM 2010 :

$$Q_e = \frac{3600}{t_f} * e^{-(\frac{t_c - 0.5t_c}{3600})Q_c}$$

**JUNCTION - 1**

| **HCM 2010** | **Lane-1** | **Lane-2** | **Lane-3** | **Lane-4** | **Lane-5** |
|---|---|---|---|---|---|
| CRITICAL HEADWAY (tc) | 4.35 | 2.24 | 4.63 | 3.62 | 3.86 |
| FOLLOW UP TIME (tf) | 1.7 | 3.2 | 2.4 | 3.3 | 3 |
| Qc | 1660 | 1188.5 | 1383.5 | 1484.5 | 1496.5 |
| CAPACITY | 777 | 778 | 616 | 517 | 537 |
| TOTAL CAPACITY | 3225 | | | | |

**JUNCTION – 2**

| **HCM 2010** | **NORTH** | **EAST** | **SOUTH** | **WEST** |
|---|---|---|---|---|
| CRITICAL HEADWAY (tc) | 3.6 | 5.6 | 6.64 | 7.36 |
| FOLLOW UP TIME (tf) | 2.5 | 2.7 | 3 | 2.6 |
| Qc | 695.5 | 765 | 653.5 | 734 |
| CAPACITY | 1017 | 735 | 656 | 653 |
| TOTAL CAPACITY | 3061 | | | |

We can also tabulated above parameters at Junction-3 and Junction-4 like as above tables

4.4 *Performance Measures*

Control Delay

Delay data collected for roundabouts in the U.S. suggest that delays can be predicted in a manner similar to that used for stop-controlled intersections. Given equation shows the model that should be used to estimate control delay for each lane of an approach of a roundabout.

$$D = \frac{3600}{c} + 900\,T\left[\frac{v}{c} - 1 + \sqrt{\left(\frac{v}{c} - 1\right)^2 + \frac{\left(\frac{3600}{c}\right)\frac{v}{c}}{450T}}\right]$$

Where: D = Control Delay, sec/veh;

v = Flow in subject lane, veh/h;

c = Capacity of subject lane, veh/h;

T = Time period, h( T=1 for 1 hr analysis, T=0.25 for 15 min analysis).

Average control delay for any particular lane is a function of the capacity of the lane and its degree of saturation. The analytical model used to estimate control delay assumes that the demand is less than capacity for the period of analysis. If the degree of saturation is greater than about 0.9, average control delay is significantly affected by the length of the analysis period. In most cases, the recommended analysis period is 15 min.

Level Of Service

Level of service (LOS) for a roundabout is determined by the computed or measured control delay and is defined for each lane. LOS is not defined for the intersection as a whole. LOS criteria are given

**Level of Service Criteria for Roundabouts**

| **LOS** | **Control Delay (s/veh)** | **Comments** |
|---|---|---|
| A | D ≤10 | Usually no queue or conflicting traffic |
| B | 10<D ≤20 | Occasionally more than one in the queue |
| C | 20< D ≤35 | Not uncommon to have a standing queue ofat least one vehicle |
| D | 35< D ≤50 | Delay is long enough to be an irritation to |
| E | 50< D ≤70 | Delay approaches most drivers tolerance level |
| F | D>70 | Approximate at capacity |

Volume To Capacity Ratio (V/C)

Volume-to-capacity (V/C) ratios are the primary measure of effectiveness for evaluation against the operational performance. V/C ratios for roundabouts should be calculated based on the entry demand and capacity for the most critical approach (i.e. approach with the highest v/c ratio) for single-lane roundabouts and the most critical lane (i.e. individual lane with the highest v/c ratio) for multilane roundabouts.

**Level of service criteria for roundabouts according to HCM MANUAL**

| **Level of service** | **v/c ratio** |
|---|---|
| A | <0.60 |
| B | <0.70 |
| C | <0.80 |
| D | <0.90 |
| E | <0.95 |
| F | >0.95 |

**Table 4.3 Estimation of Capacity On Approach Legs**

| | **HCM 2010** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Junction** | **Leg** | **circulating flow** | **Volume** Entry flow | **Control Delay** | **Capacity** | **V/C Ratio** | LOS |
| Junction – 1 | A | 1660 | 790 | **114.7078** | 777 | **1.0** | **F** |
| | B | 1188.5 | 1009.5 | **562.3187** | 778 | **1.29** | **F** |
| | C | 1384 | 738.5 | **396.6814** | 616 | **1.19** | **F** |
| | D | 1485 | 967.5 | **1590.905** | 517 | **1.8** | **F** |
| | E | 1496 | 1044.5 | **1721.067** | 537 | **1.94** | **F** |
| Junction - 2 | A | 695 | 687.5 | 11.16953 | 1018 | 0.6758 | B |
| | B | 765 | 578 | 22.10177 | 736 | 0.7859 | C |
| | C | 653.5 | 681.5 | **147.2489** | 657 | **1.037871** | **F** |
| | D | 734 | 641 | **89.8225** | 653 | **0.9803** | **F** |
| Junction - 3 | A | 984 | 1136 | 12.18627 | 1448.8 | 0.7840 | C |
| | B | 1114 | 1433.5 | **1207.807** | 862.4 | **1.662** | **F** |
| | C | 1235.5 | 1786 | **2007.885** | 847 | **2.108** | **F** |
| | D | 1241 | 1303 | **1858.494** | 645 | **2.023** | **F** |
| | E | 1280 | 447 | 18.07929 | 643 | 0.69449 | B |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Junction - 4 | A | 430 | 730 | 7.97266 | 1179 | 0.6188 | B |
| | B | 911 | 245.5 | 8.696067 | 659 | 0.3725 | A |
| | C | 478 | 573 | 8.43225 | 999 | 0.5738 | A |
| | D | 590 | 450 | 5.424245 | 1113 | 0.4042 | A |

*4.6 Legs with Critical Condition (V/C>0.85)*

| Roundabout | No. of Legs (V/C) > 0.85 |
|---|---|
| Junction 1 (LIC BUILDING) | 5(A,B,C,D,E) |
| Junction 2(DIAMOND PARK) | 2(C,D) |
| Junction 3 (CONVENT) | 3(B,C,D) |
| Junction 4 (WALTAIR) | NILL |

A total of 10 legs are in critical condition.

Before we investigate the reason for their inadequacy it is better to see the assumption on the theory in respect of direct relationships of capacity at legs and opposing circulatory flow. Capacity at legs is influenced by the average entry lane width and number of entry lane. Since it was first developed considering opposing circulatory flows vs capacity at legs relationship, as it was mentioned using curve fitting techniques.

| JUNCTION | ENTRY LANE | CONTROL DELAY | V/C RATIO |
|---|---|---|---|
| JUNCTION-1 | A | 191.7 | 1.07 |
| | B | 643 | 1.3 |
| | C | 480 | 1.2 |
| | D | 174 | 1.9 |
| | E | 1841 | 2 |
| JUNCTION-2 | C | 173 | 1.05 |
| | D | 107 | 1 |
| JUNCTION-3 | B | 1489 | 1.8 |
| | C | 2600 | 2.4 |
| | D | 3641 | 3 |
| JUNCTION-4 | NO OVER SATURATION | | |

5.6 *Operating Performance Of Rounabouts*

**Table 4.4 Summary of the Condition of the Roundabouts by Observation.**

| Roundabout | Problem |
|---|---|
| Junction 1 | Entry flow is more. Circulation lane numbers are not adequate.width of entry lanes not proper. If signal operating is takes place then it is observed to be traffic jam at jail road junction. |
| | The over saturation in this lane is due to improper parking facilities near shopping malls. |
| | Entry lanes are not adequate. This lane had down slope. Heavy vehicles are facing problem while taking turning movement. |
| Junction 2 | Circulatory lanes are not adequate, Heavy traffic flow occurs at peak hours. Heavy vehicle turning movement is little harder at Shankarmatam road. |
| Junction 3 | This roundabout is mainly for heavy industrial vehicles. Circulatory lanes are high. Markings are absent at this junction. |
| Junction 4 | Very less diameter of roundabout.Turning movements are facing problem at waltair depot.No clear distance between splitter island and roundabout.Buses will park at depot in afternoon times. At that time delay is more through mvp road. |

## 5. CONCLUSION

5.1 *Conclusion*

Based on the study carried out the following conclusions have been made:

The oversaturation at roundabouts completely depends on Gap acceptance parameters. With increase in follow up time delay also getting increased and it decreases capacity. Gap acceptance approach that is driver behavior, type of vehicle, circulating and entering splits and conflicting circulating flow are included in Analytical Method.

- Visakhapatnam roundabouts capacity analysis results indicate the most of the legs of roundabouts are in serious problems or over saturation. Based on observed actual field conditions it is common to see that at peak hours, the traffic police need to regulate the traffic at these roundabouts since traffic control devices cannot function or regulate the traffic. As the study uncovered the real issues are identified with deficiency of number of entry lanes, number of circulatory lanes, high traffic flow and unbalanced traffic on the approaches of roundabout.
- Besides, most of the roundabouts in visakhapatnam were built without proper planning or according to the design standards of the IRC codes. Most of the roundabouts have irregular parameters.
- All the input parameters of empirical method for capacity analysis do not exist at visakhapatnam Roundabouts. Thus, only one Germany's empirical method and analytical method was carryout the capacity analysis with parameter based on HCM 2010.
- Maximum flow occurs at the Junction 1 (dabagardens) and Junction 3 (convent junction), Minimum flow occurs at Junction 4 (waltair junction).
- Maximum volume occurs at Junction 1 (dabagardens) and minimum volume occurs at Junction 4 (waltair).
- High traffic entry flows at Junction 1 roundabout (dabagardens) was found to be more than 3500. This traffic is very high to be accommodated by the roundabout. In addition there is also high traffic flow at leg E of Junction 1 that show high percentage of traffic volume share, which is not recommended for roundabouts.
- The circulatory lane of Junction 1, junction 3 are not adequate.

*5.2 Scope of Future Work*

- After study or peak hour data collection for the roundabouts that have high and unbalanced traffic flow, their replacement with other junction type is suggested. The roundabouts which are located at DABAGRDENS JUNCTION are not providing the expected service levels.Due to heavy traffic flow at peak hours. There is also time delay during peak hours.
- Since the collected data for the analysis was limited especially regarding peak hour traffic the chart developed by this current research just understands on the subject of my exploration. In this respect, further study is prescribed with more data accumulation so as to refine the chart and for use of roundabout traffic services improvement. The refined chart can help the visakhapatnam Authority when taking measures to improve roundabout intersections. They can additionally utilize it as a part of determining the traffic capacity identifying with area utilization. Therefore, if more traffic is generated because of new land use the charts can be used to easily forecast traffic in respect of each roundabout.

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**Code Books**

[1] Highway Capacity Manual 2010 Glossary.
[2] IS code manual of specification and standards
[3] IRC 106-1990 GUIDELINES