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# Study on Capacity of Road with Vehicle Characteristics and Road Geometrics

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## ABSTRACT
Capacity of roads plays a vital role in assuming better network characteristics and in providing good performance of roads. Capacity values play an important role for further modifications of roads. Various geometric measures like carriage way width, sidewalks, service roads, verge, medians, and road reserve and traffic patterns related to different roads. Passenger car Unit (PCU) are typically used for road capacity analysis with heterogeneous traffic conditions. Mathematical model is developed which uses IRC specifications on which regression analysis is performed for capacity values provided for urban roads, which are used for developing standard capacity functions. Relations between capacity and cross section elements are identified, which derives the capacity effecting zones. This relation helps in studying variation in capacity with respect to various widths of road elements. Impact of geometrics and road elements on capacity is considered and, which results in realistic prevailing road capacities, in Indian roads.

***Keywords:-*** Indian Road Congress (IRC), Passenger car unit (PCU), Road capacity, Road geometrics, Traffic Network Evaluation.

## I. INTRODUCTION

### 1.1 General:

Road traffic in India is termed to be highly heterogeneous which comprises of different types of vehicles like buses, trucks, auto-rickshaws, bikes, scooters, cycles etc. comprising of wide range of static and dynamic characteristics. Due to the high variations in its dimensions at its physical levels and speeds, it is tedious to make these vehicles to follow traffic lanes and the vehicles generally occupy any convenient lateral position on the road depending on the road space that is available for a given instance of time. Hence, expressing traffic volume as number of vehicles for a specified section of road or traffic lanes per unit time those are available terms to be inappropriate for vehicles related to different types with its static and dynamic characteristics comprising in traffic, which generally varies for large extent. The problem for the measurement of volume of traffic measures of vehicles belonging to different types related to its equivalent passenger cars values and expressing its volume basing on Passenger Car Unit (PCU) per hour. It is always very hectic to compute the interaction between the vehicles under heterogeneous traffic conditions. Impedance measure is derived, which is termed to be a mechanism of measuring the interaction between vehicles caused by its flow, subjected to vehicle type, for a specific PCU. This measure is defined in variant with passenger cars and the relative impedance here is quantified in terms of this PCU measures.

Capacity is considered as a function of traffic and road geometrics the above mentioned road types involve in the capacity calculations in present study. The study is conducted by considering various capacities based on the functioning of various types of roads and the vehicle characteristics are taken by considering passenger car units which involves traffic stream characteristics in the function. Capacity is termed be the flow of vehicles or passengers per unit time which is independent of demand. Since roads have certain width with varying lanes, flow is always defined in terms of width, ADT, termed as average daily traffic, defines the road capacity. Lanes, traffic type and vehicle characteristics are termed to be metrics for road capacity analysis. Analysis of road capacity varies from homogeneous to non-homogeneous with respect to strict lane distributions. Heterogeneous traffic always paves a serious challenge to the road planners.

Vehicle properties are always mechanically related to road capacity. Traffic volume with its stream composition and distribution of transverse gap and longitudinal clearance of vehicles are termed to be traffic measures for capacity analysis.

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Estimation of road capacity generally depends on other major factor corresponding to traffic volumes termed with passenger car units (PCU), which directly effects the capacity estimations. Level-of –service and consideration of factors corresponding to overall effects of the vehicles on traffic stream performance are the basic principles applied for the estimation of PCU values. The other important measures of traffic flow include mean travel time and time of occupancy. These generally derive LOS value of traffic. Speed is termed to be another important feature influencing performance analysis in terms of PCU estimation.

## II. LITERATURE REVIEW

Road capacity analysis is a major goal and there raised many methodologies for analysing these values, for a lucid change in the measures in case of any changes in measures. As per the study made by **central Road Research Institute (CRRI,1982),** there is a large variant in $R^2$ factor calculated by Multiple-Linear-Regression analysis. Simple linear regression is also deployed by taking total traffic volume as an independent parameter. It has been found that the multiple-linear-regression equations developed has major deviations. The $R^2$ values, in the case of simple regression equations, are also found to be higher than in the case of multiple linear regression equations.

As per the methodology proposed by **Hoban**, (**1987**), regression analysis is summarized with linear speed-volume relationship, which is claimed to be used in speed-volume relations. It is given that several factors of road capacity analysis measures is varied with the slopes of the speed-volume relationships appeared.

Linear and quadratic forms of speed-volume relationships on urban roads in India, given by **Sarna, A.C., Jain, P.K. and Chandra, G. (1989),** have given relation between speed and volume. An enveloping curve technique is used by plotting a curve bounding the data points for accuracy in point of turning on the speed-volume curve.

An important feature of speed-flow fundamental diagram, as designed by **Hall et al. (1993),** is analyzed using two-segment linear functions. It is derived that speed may remain constant with increasing flow for some considerable range of flows. The break point, at which speed starts to decrease, is somewhere around two-thirds or three-quarters of the maximum flows and the speed at maximum flows, in the absence of congestion . Linear model has been derived for estimation of capacity of rural roads speed-flow fundamental measures has been defined for road capacity analysis, as defined by **Bang et al. (1995)**. Speed, density and flow characteristics are studied for establishing relations between the measures. It is derived by **Kumar and Rao (1998)** that speed decreases with increase in traffic density, indicating a linear relationship between them.

## III. METHODLOGY

## ROTARY INTERSECTION:

Traffic Rotary at road intersections is special form of grade change of lanes to channelize movement of vehicles in one direction around a central traffic island. With rapid growth of traffic it is experienced that widening of roads and providing flyovers have become imperative to overcome major conflicts at intersections such as collision between through and right turn movements. In this way, major conflicts are converted into milder conflicts like merging and diverging.

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.

Rotaries are suitable when the traffic entering from three or more approaches are relatively equal. A total volume of about 3000 vehicles per hour can be considered as the upper limiting case and a volume of 500 vehicles per hour is the lower limit. Rotaries are suitable when there are more approaches and no separate lanes are available for right-turn traffic thus making intersection geometry complex.

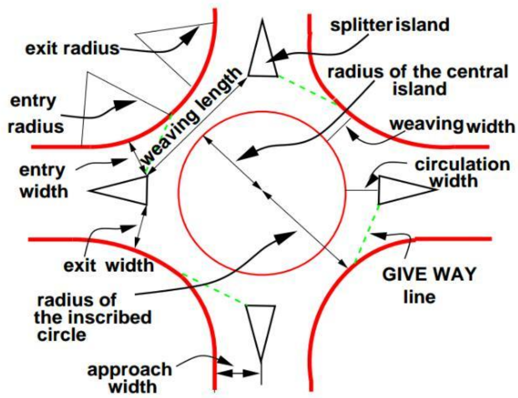



**Fig1.2: Rotary Intersection**

**Traffic operations in a rotary**

The traffic operations at a rotary are three; diverging, merging and weaving. All the other conflicts are converted into these three less severe conflicts.

- Diverging:

It is a traffic operation when the vehicles moving in one direction is separated into different streams according to their destinations.

- Merging:

Merging is the opposite of diverging. Merging is referred to as the process of joining the traffic coming from different approaches and going to a common destination in to a single stream.

- Weaving:

Weaving is the combined movement of both merging and diverging movements in the same direction.

**Design elements**

The design elements include design speed, radius at entry, exit and the central island, weaving length and width ,entry and exit widths. In addition the capacity of the rotary can also be determined by using some empirical formula.

- **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.

- **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 meters 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. A general practice is to keep the exit radius as 1.5 to 2 times 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 which is about 1.3 times that of the entry curve is adequate for all practical purposes.

- **Width of 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 of10.5 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,

$$W = \frac{(e_1+e_2)}{2} + 3.5\text{ m}$$

Where, $e_1$ = width at entrance of section
$e_2$ = width of non-weaving section

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.

- **Shape of Central Island**

The shape of Central Island provided for rotary intersection should not contain any corners. It should be formed by curves to allow the comfortable rotations around it. The shape is particularly dependent upon number of roads meeting at that particular junction. The shapes generally provided are circular, elliptical, turbine and tangential. Circular shape island is shown below as,

**Fig1.4: Circular Island**

- **Radius of Rotary Roadway**

The radius of roadway or pavement around the central island is dependent of shape of Central Island. If it is circular shape, radii are similar at all points and if it is elliptical or tangent radii is different at different points. The radius of rotary roadway should be designed by just considering the friction force and super elevation should be neglected.

Normal radius of roadway in curves

$$R = \frac{V^2}{127(f)}$$ But super elevation (e) is neglected i.e., e = 0

Hence, radius of rotary

$$R = \frac{V^2}{127(e+f)}$$

Where f = coefficient of friction = 0.43 to 0.47

- **Weaving Angle and Weaving Distance of Rotary Intersections**

Weaving angle is the angle formed by paths of vehicle entering the rotary and other vehicle leaving the rotary at adjacent road. The exits of two vehicles may be different but they travel in same way for some short distance in the rotary section which is nothing but merging of vehicles and when the required exit is come two of the vehicles diverged into different directions. The length of which the two vehicles travel in same way is called as weave length. The weaving angle should be small but minimum of 15° is maintained. The weave length should be at least four times the width of weaving section.

- **Width of Carriageway at Entry and Exit**

The width of carriage way at entrance rand exits is dependent of volume of traffic in that particular region or area. But, the minimum width of 5.0 meters should be maintained for rotary intersections.

- **Curves at Entrance and Exit**

Entrance and exit curve is nothing but a curve traced by the rear inner wheel of vehicle. Generally, at entrance the vehicle will slow down to design speed of rotary intersection so, at the entrance curve radius can be provided as same as radius of central island. Coming to exit curves, the vehicle accelerates at exits hence the radius of curve at exit should be greater than the radius of curve at entrance

- **Capacity of Rotary Intersections**

The capacity of rotary is derived from the below formula and it is mainly dependent upon capacity of individual weaving section.

$$Q_p = \frac{280\,W\,(1+\frac{e}{W})(1-\frac{p}{3})}{(1+\frac{W}{L})}$$

Where W = width of weaving section

e = average width of entry and width of non-weaving section for the range of (e/W)

L = weaving length for the range of W/L

Where, p = proportion of weaving traffic = (b+c)/(a+b+c+d) = (0.4 < p < 1.0)

a = left turning traffic moving along left extreme lane

b = weaving traffic turning toward right while entering the rotary

c = weaving traffic turning toward left while leaving the rotary

d = right turning traffic moving along right extreme lane

- **Channelizing Islands**

Channelizing islands are provided at entrance or exit of road way to prevent the vehicle from undesirable weaving.


**Fig1.5: Channelizing Island**

- **Camber and Super Elevation**

If the vehicle is changing its direction to its opposite side it will travel around the central island and changes the direction. While changing, the vehicle may over turn or slip, to overcome this, minimum cross slope is provided which is nothing but camber. This camber acts as super elevation in case of rotary roadways.

- **Sight Distance**

The sight distance provided at rotary intersections should be as higher as possible and in no case the value must be less than the stopping sight distance.

- **Lighting of Rotary Intersections**

The edge of Central Island should be installed with lights which are mandatory. Additional lights may also be provided at the kerbs if the diameter of Central Island is more than 60 m. sometimes, entrance and exit curves can also be provided with lights.

- **Traffic Signs at Rotary Intersections**

Traffic signs should be installed on approaching roads to indicate the presence of rotary intersection ahead to the roadway users. Kerbs at rotary intersections should be coated with black and white strips to improve visibility. Traffic signals should be placed 1 meter above road level to indicate the direction of exit.

- **Pedestrian Ways at Rotary Intersections**

At rotary intersections, the vehicles will move consistently and will not stop. So, the footpath is provided guard rails which will block the entrance of pedestrian into roadway. If crossing of road is important and pedestrian traffic is higher, then construction of subways, over bridges is good solution.

**Traffic Volume Data**

The traffic volume data is collected in the above study locations to determine capacity. The traffic volume data is collected in terms of cars, three wheelers, two wheelers and heavy vehicles. The peak hour volume data is taken for the calculation of PCU values of respective vehicles and to determine capacity of the mid blocks.

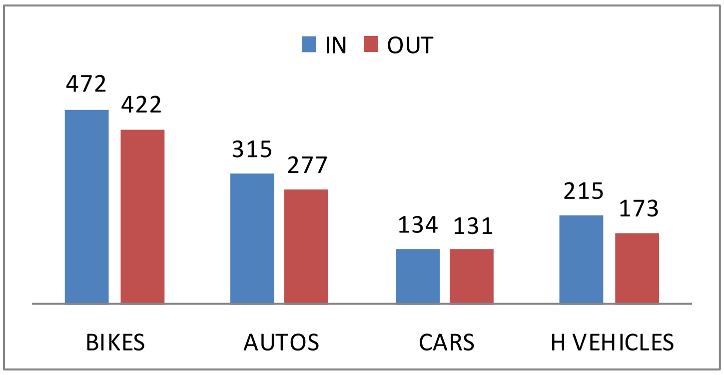
The traffic volumes are observed in various mid blocks to identify capacity of the block based on peak hour volumes and gradient of the road. The collected traffic volumes at various junctions are analyzed for peak hour traffic flow. The midblock traffic volume is categorized into three wheelers, two wheelers, cars, heavy vehicles and slow moving vehicles.

## IV. OBSERVATIONS

**Traffic Volume For Twenty Days In Road-1**

| TIME | AVG HOURLY VOLUME IN ROAD 1 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BIKES | | AUTOS | | CARS | | HEAVY LOAD VEHICLES | |
| | IN | OUT | IN | OUT | IN | OUT | IN | OUT |
| **8.00-9.00 A.M** | 1159 | 1045 | 642 | 567 | 326 | 154 | 346 | 412 |
| **9.00-10.00 A.M** | 486 | 477 | 231 | 251 | 67 | 45 | 311 | 108 |
| **10.00-11.00A.M** | 373 | 214 | 250 | 208 | 170 | 172 | 269 | 171 |
| **11.00-12.00 A.M** | 398 | 299 | 188 | 218 | 112 | 147 | 360 | 140 |
| **12.00-1.00 P.M** | 313 | 184 | 178 | 101 | 113 | 104 | 131 | 102 |
| **2.00-3.00 P.M** | 201 | 258 | 151 | 124 | 105 | 129 | 193 | 1258 |
| **3.00-4.00 P.M** | 213 | 363 | 217 | 241 | 8 | 160 | 117 | 147 |
| **4.00-5. 00P.M** | 611 | 610 | 577 | 477 | 118 | 195 | 106 | 161 |
| **5.00-6.00P.M** | 489 | 340 | 400 | 329 | 93 | 70 | 95 | 187 |
| **TOTAL** | 4243 | 3790 | 2834 | 2489 | 1202 | 1176 | 1931 | 1556 |

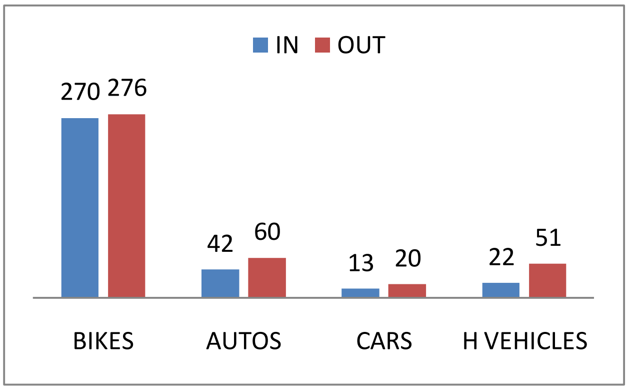
**Fig5.3: BAR CHART FOR ROAD – 1**



**Traffic Volume For Twenty Days In Road-2**

| TIME | AVG HOURLY VOLUME IN ROAD 2 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BIKES | | AUTOS | | CARS | | HEAVY LOAD VEHICLES | |
| | IN | OUT | IN | OUT | IN | OUT | IN | OUT |
| 8.00-9.00 A.M | 564 | 341 | 56 | 91 | 22 | 35 | 35 | 81 |
| 9.00-10.00 A.M | 212 | 194 | 28 | 44 | 10 | 8 | 10 | 17 |
| 10.00-11.00A.M | 260 | 324 | 46 | 34 | 15 | 21 | 17 | 47 |
| 11.00-12.00 A.M | 235 | 303 | 66 | 93 | 13 | 7 | 24 | 64 |
| 12.00-1.00 P.M | 212 | 216 | 25 | 49 | 7 | 15 | 16 | 70 |
| 2.00-3.00 P.M | 188 | 184 | 31 | 39 | 11 | 24 | 14 | 49 |
| 3.00-4.00 P.M | 165 | 174 | 25 | 25 | 14 | 17 | 27 | 41 |
| 4.00-5.00P.M | 296 | 422 | 39 | 61 | 14 | 11 | 22 | 50 |
| 5.00-6.00 P.M | 298 | 325 | 55 | 56 | 3 | 21 | 31 | 30 |
| TOTAL | 2430 | 2483 | 371 | 592 | 109 | 179 | 196 | 459 |

**Fig5.4: BAR CHART FOR ROAD - 2**

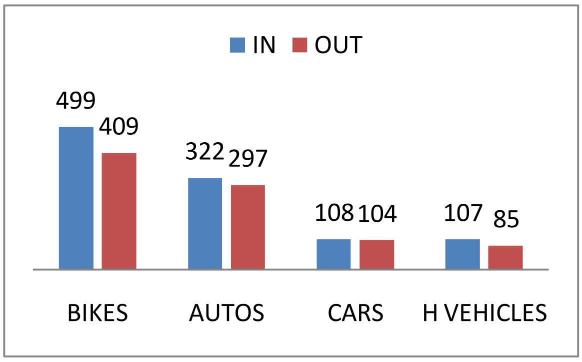



**Traffic Volume For Twenty Days In Road-3**

| TIME | AVG HOURLY VOLUME IN ROAD 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BIKES | | AUTOS | | CARS | | H. L VEHICLES | |
| | IN | OUT | IN | OUT | IN | OUT | IN | OUT |
| 8.00-9.00 A.M | 828 | 579 | 744 | 554 | 148 | 140 | 163 | 133 |
| 9.00-10.00 A.M | 435 | 374 | 339 | 407 | 98 | 69 | 83 | 60 |
| 10.00-11.00A.M | 553 | 513 | 248 | 256 | 74 | 87 | 122 | 68 |
| 11.00-12.00A.M | 479 | 369 | 286 | 245 | 135 | 122 | 100 | 114 |
| 12.00-1.00 P.M | 551 | 485 | 309 | 225 | 128 | 98 | 104 | 82 |
| 2.00-3.00 P.M | 458 | 333 | 167 | 185 | 86 | 122 | 86 | 70 |
| 3.00-4.00 P.M | 308 | 256 | 166 | 174 | 108 | 103 | 103 | 52 |
| 4.00-5.00P.M | 568 | 508 | 411 | 398 | 08 | 116 | 116 | 102 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **5.00-6.00 P.M** | 308 | 265 | 229 | 227 | 87 | 78 | 82 | 81 |
| **TOTAL** | 4488 | 3682 | 2899 | 2671 | 972 | 935 | 959 | 762 |

**Fig5.5: BAR CHART FOR ROAD – 3**




**Traffic Volume For Twenty Days In Road-4**

| TIME | AVG HOURLY VOLUME IN ROAD 4 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BIKES | | AUTOS | | CARS | | HEAVY LOAD VEHICLES | |
| | IN | OUT | IN | OUT | IN | OUT | IN | OUT |
| **8.00-9.00 A.M** | 979 | 836 | 407 | 366 | 154 | 133 | 187 | 96 |
| **9.00-10.00 A.M** | 477 | 363 | 218 | 193 | 104 | 96 | 97 | 114 |
| **10.00-11.00A.M** | 214 | 197 | 251 | 189 | 45 | 61 | 68 | 128 |
| **11.00-12.00 A.M** | 299 | 268 | 101 | 96 | 172 | 103 | 102 | 48 |
| **12.00-1.00 P.M** | 184 | 167 | 114 | 83 | 147 | 116 | 28 | 37 |
| **2.00-3.00 P.M** | 258 | 146 | 224 | 161 | 160 | 97 | 45 | 61 |
| **3.00-4.00 P.M** | 363 | 244 | 183 | 124 | 115 | 64 | 58 | 56 |
| **4.00-5.00P.M** | 510 | 485 | 412 | 239 | 142 | 79 | 44 | 44 |
| **5.00-6.00 P.M** | 340 | 472 | 286 | 214 | 121 | 113 | 16 | 25 |
| **TOTAL** | 3624 | 3178 | 2196 | 1665 | 1160 | 862 | 645 | 609 |

**Fig5.6: BAR CHART FOR ROAD - 4**

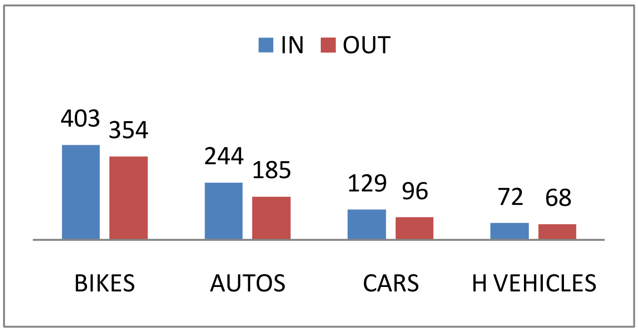


**Table 5.7: Peak Hour Volume Data in Gudur Town**

| PEAK HRS | LOCATION | BIKES | AUTOS | CARS | H.L-VEHICLES | TOTAL |
|---|---|---|---|---|---|---|
| 8.0-9.0 A.M | Ambedhkar nagar to Vijayanagar Colony | 4293 | 2834 | 1202 | 1931 | 9810 |
| | Vijayanagar colony to Dhurjati nagar | 3790 | 2489 | 1176 | 1556 | 9011 |
| | Dhurjati nagar to Sanath nagar | 2430 | 371 | 109 | 196 | 3106 |
| | Sanath nagar to Ambedhkar nagar | 2483 | 592 | 179 | 459 | 3713 |
| 5.0-6.0 P.M | Ambedhkar nagar to Sanath nagar | 4488 | 2899 | 972 | 959 | 9318 |
| | Sanath nagar to Dhurjati nagar | 3682 | 2671 | 935 | 762 | 8050 |
| | Dhurjati nagar to Vijayanagarcolony | 3624 | 2196 | 1160 | 645 | 7625 |
| | Vijayanagar colony to Ambedkar nagar | 3178 | 1665 | 862 | 609 | 6314 |

## V. CONCLUSION

Factors that are considered in the development of present model include side walk, cycle track, verge, service road, reserve, carriage way, provision for additional lane, median, unpaved shoulder and parking lane. It has been shown that the capacity function varies due to passage of pedestrians as there are interrelated to each other. Capacity function is also affected by cycle traffic cross flows and their intrusion into service lanes.

The capacity values are different from the base capacity values and are nearly equal to the theoretical models which are calculated considering other factors.

This research has been expected to be extended to vehicular and driver characteristics with precise data and more geometric elements into consideration. Certain empirical measures are further derived and maintained with more data accumulation so as to refine the model and for use of capacity estimation improvement.

**Scope of Future Work**

The present study determines a relation between capacity and road dimensions and geometrics as per Indian Road Congress specifications. It could be used only if the roads are designed as per Indian standard code provisions. The work can be extended to vehicular and driver characteristics with precise data and more geometric elements into consideration. The capacity for any kind of road can be determined by developing empirical relations with traffic volumes, road geometrics, and various elements like parking, frontage access, and pedestrian cross flows etc. Since the collected data for the analysis was limited especially regarding peak hour traffic the equation 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 model and for use of capacity estimation improvement. The refined model can help the Nellore Road Authority when taking measures to estimate road capacities by considering existing road conditions and road elements. They can additionally utilize it as a part of determining the traffic capacity identifying with area utilization.

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