International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 08
July 2019

By Using Gap Acceptance Method Modelling Performance Parameters of Roundabouts For Indian Traffic Scenario

Gannavarapu Praveen kumar[1], Mudipudi Manoj[2]
[1](M.Tech, Transportation engineering, MVR College of Engineering and Technology)
[2](Assistant Professor, MVR College of Engineering and Technology)

ABSTRACT

Road network connecting the various parts of the country defines the economy of the nation. This lead to vast development of road infrastructure. Intersections form a major unit of the road network. It is of utmost importance to design these intersections safely as they are the areas where maximum conflict points exist, which could otherwise lead to fatal. One such implication can be introducing roundabouts at intersections, which reduces the conflict points, thus providing greater safety and efficient traffic flow. The drivers' behavior is one of the prime factors which influence the performance of these roundabouts. No such procedure of analysis is available in Indian context to identify the performance of roundabouts. To develop such a model, initially, the parameter defining driver behavior, i.e. Gap acceptance parameters had been estimated for heterogeneity in traffic. For this purpose, data was collected from 10 sites from different regions of India, giving priority to variations in traffic and driver behavior. The critical headway was then determined using three methods, namely, Raff, Ning Wu and Maximum Likelihood, for determining the appropriate one for the model. These parameters were then utilized in deriving an equation for entry capacity in Indian context. The equation obtained satisfied the sites with high circulating flow. When compared with other existing gap acceptance models, the German model mostly over predicted the capacity as compared to developed model, while the HCM model underestimated the same.

Keywords: *Roundabouts, gap acceptance, capacity, heterogeneity*

INTRODUCTION

General

Roundabout is a type of unsignalised intersection was the minor traffic from different lanes merges with the major traffic circulating around the central island. The central island is usually circular in shape. Streamlining of the traffic flow at entry is obtained by channelization so as to reduce the severity and number of conflict point at the intersection. Channelization is done by thorough geometric design which enables tangential merging of traffic with the circulating flow at desirable speed.

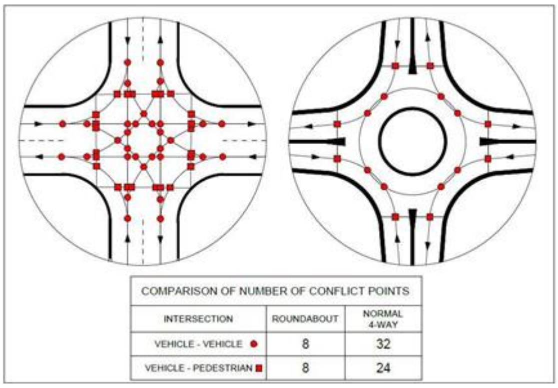


Fig 1.1 Conflict point comparison

Road is that place for a human were all his senses need to work at a perfect rhythm to get him from his origin to the destination in one piece. When it comes to intersection were two or more road meet and the vehicles in these roads compete for a common physical space, the whole scene gets a bit mushy. Intersection is that component of a road network were maximum number of accidents have been reported. A comparison of a normal four way intersection and roundabout as shown in Fig 1.1 gives the basic idea of number of conflict point involved in different intersections. Roundabout as seen drastically reduces the number of conflicts and eliminates the need to stop at the yield point.

Other than improving safety by reducing the number of conflict point and free merging of minor traffic into major traffic there are many more advantages of using roundabouts as an intersection alternative like,

- Traffic calming at intersection without the use of signals.
- Facilitate U-turn.
- Lower overall delay when working within the capacity limits thus benefiting to the environment in terms of noise reduction, less fuel consumption etc.
- Pedestrian safety, as it provides relaxation points at medians. And
- Less maintenance cost than signalised intersection.

So to avail all these advantages from a roundabout one has to design it considering the various requirements of the traffic, people and the location.

A Brief History from Time

Various studies on roundabouts has taken place in many major developed countries from the start of this century. The earliest noted use of something similar to a roundabout is around 1791 by Major L'Enfant in the Washington street road network. Unsignalised intersection took couple of centuries to evolve from the human powered traffic control to the modern roundabout as shown in Fig 1.2.

Various theories too evolved over time to explain the performances of these intersections. During the 1930's rotaries came into use, where the minor traffic merged with the major flow tangentially and at considerable speed. These were unlike the earlier traffic circles were the traffic intersected the circle perpendicularly. Weaving theory were used to explain its performance. This theory failed due to the increasing size of the rotaries and high speeding traffic at the weaving part. Thus the roundabouts were born using the yield-at entry rule and it thrived. Failure of weaving theories called for new theories to explain the performance. Using the work done by J.C Tanner British researchers developed a new theory named the Gap acceptance theory. Research then developed independently in many nations and as a result many models were developed to satisfy their native traffic needs.

Fig 1.2. Evolution of unsignalised intersection from human powered to modern roundabout

Problem Statement

As these researches developed in different countries many capacity models were formed using the traffic characteristics, geometrics and/or behavioural pattern of the drivers towards the traffic. Nations like USA, UK, Australia, France, Germany, and Switzerland etc. developed their own model from the extensive data collected from various roundabouts from their native road networks. Later, they have showed promising improvement and have upgraded their model using updated data. Many computer software were also developed for better assessment like RODEL, ARCADY and SIDRA.

When this topic is taken to India for a comparative study one can see that there is not much work done over the subject. The code which is under use for design of roundabout in India is IRC: 65-(1976). Actually this 22 page code is not for the design of "roundabouts" but that for the design of "traffic rotaries" which is long forgotten in the timeline. This code is purely outdated though being a revised version of the original, published in 1955. It uses the weaving theory and the capacity of the weaving part is determined using some geometrics and proportion of the weaving traffic as it is assumed to accommodate the least traffic. This clearly shows that the code is purely incapable of representing the driver behaviour at roundabouts.

STUDY METHODOLOGY

General

Two methods have been traditionally followed to estimate capacity of roundabouts, empirical (regression analysis) and stochastic (gap acceptance method). Nowadays micro simulations are also used to explain the phenomena. The basic way a roundabout works is by allowing the traffic from different lanes (entry flow) to enter and merge with the circulating traffic (conflicting flow) and make a clockwise maneuver around the central island then exit through the desired lane. Many models have been developed to explain this simple activity around a roundabout there by determine its various performance parameters.

Entry and Circulating Flows

Traffic flow entering from different lanes is considered as the minor flow and traffic circulating around the central island is considered as the major or the conflicting flow. These flow values can be said as the foundation for model development and the values for every lane are required exclusive of its gap acceptance parameters. The flow data can be obtained by many methods like videography, directly from site or using new ITS gadgets.

Each are every flow, may it be minor or major is heterogenic in nature. Light motor vehicles, bicycles, two- wheelers, heavy vehicles and even animal drawn vehicles are seen on the Indian roads. Each of these are counted separately and converted into PCUs. The conversions for vehicles to PCU values were taken from IRC 65-1976. The PCU values for different types of vehicles is shown in table 3.1.

Table 3.1. PCU conversion factors based on IRC 65-1976

Sl.No	Vehicle Type	Conversion Factor
1	Two- wheelers (motor cycles)	0.75
2	Car and other four-wheelers	1
3	Heavy vehicles	2.8
4	Animal drawn vehicles	5
5	Bicycles	0.5

Estimation of Gap Acceptance Parameters

Estimation of critical gap (*tc*)

There are many methods available to estimate the critical gap such as Raff (1950), Ashworth (1970), Seilogh (1973), Troutbeck (1992), Equilibrium of probabilities by Ning Wu (2006), Logit and Probit method. Of these available methods Raff method, Maximum Likelihood and Equilibrium of probabilities method were used for estimating critical gap.

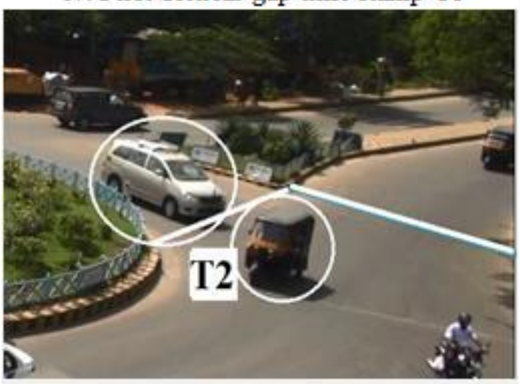
i. Conflict Lines L1 and L2 under consideration

International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 08
July 2019

ii. First follow-up time stamp Ft1

iii. Second follow-up time stamp Ft2

iv. First Critical gap time stamp T1



v. Second Critical gap time stamp T2

Images showing time stamp for data extraction

For the purpose of estimating the critical gap, gaps accepted and rejected by driver at the entry of roundabout are to be extracted from the video. To obtain these, two imaginary lines are to be considered, one at the entry of lane of roundabout (L1) and another at the line of conflict (L2) as shown in Figure 3.1 (i). To estimate a gap, two time stamps are considered. The time when front bumper of a vehicle in minor stream (entry flow) touches the imaginary line L1 is considered as the first time stamp T1, as shown in Figure 3.1 (iv). The time at which the front bumper of the vehicle in the major stream of the headway under consideration touches L2 is considered as the second time stamp T2, as shown in Figure 3.1 (v). The gap is then calculated, as the difference between theses time stamps T2 and T1 and for every gap calculated, it's checked whether the gap was accepted or rejected.

Different methods used for determination of critical gaps considered in this study are described in detail below.

- Raff method
- Equilibrium of Probabilities Method (Wu Method)
- Maximum likelihood method

STUDY AREA AND DATA COLLECTION

General

While studying about the different existing models one thing that was seen in common is the extensive data set that was used to develop each of them. Entry flow, circulating flow, headways in the entry and circulating lane etc. are some of the major parameters which were used to develop these models. These parameters give the basic description about the nature of traffic and behaviour of driver at the point of entry. When the whole process is regenerated in Indian scenario couple of other things need to be sorted out.

India is diverse in everything. When it comes to traffic, it is infamous for the heavily jammed metropolis, rash driving

International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 08
July 2019

bikers, the rickshaws which pulls into every nook and corner humanly possible and the nature of drivers, which can get a bit aggressive at times. The selection of study area should be such that all the factors which cause the heterogeneity is taken into consideration. So while doing the reconnaissance certain basic factors needs to be taken into consideration like,

- Characteristics of city.
- Location of the roundabout.
- Type of the roads the roundabout connect.
- Nearby places of socio-economic importance.

Study Area

Initial search for roundabouts started by studying the road maps of major cities. Many were located but during the initial site visit many of them turned out to have been changed to 'signalised roundabout' intersections. This scenario was seen basically inside the city area, must be mainly to manage the heavily rising traffic flow.

Chacka Junction, Trivandrum, Kerala

Kerala, the state located at the extreme southernmost tip of the motherland has the Arabian Sea at one side and the state of Tamil Nadu on the other. Though small in area, it is one among the densely populated states in India. The coastal line runs about 580km in length and houses some of the major ports of India itself. Due to the presence of many natural and man-made harbours and abundant backwaters it has grown into a hub for trade and commerce. The road network here is well distributed to cater various needs of the people but the national highways are the narrowest when compared with those in other states.

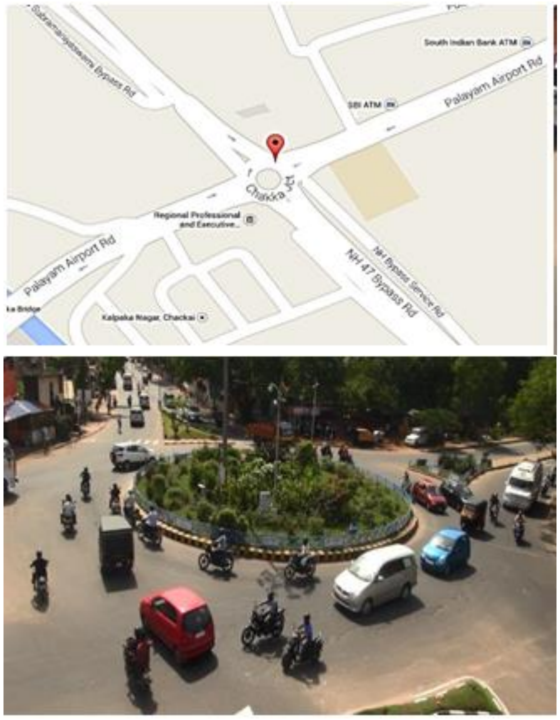


Fig 4.1. Roundabout at Chacka, Trivandrum

The city under study is Trivandrum, which is the capital of Kerala. It houses all major administrative and government offices along with many rising industries, IT parks and places of tourist interest. Chacka junction, a four lane roundabout is one of the busiest junctions in Trivandrum where the parallel bypass road of NH 47 joins with Palayam-airport road. NH 47 bypass road covers some of the major landmarks like Beemapally Mosque, Technopark, Kovalam beach etc. Palayam Airport Road is mainly used by the people going to the outskirts of the city. The traffic through these roads are always in a near saturated condition during peak hours due to the various offices and educational institute it connects. A site map of the junction showing the various roads it connects and a picture of the morning traffic it manages is shown in Fig 4.1.

Ramnagar Square, Nagpur, Maharashtra

Maharashtra as the name says is a very large state which lies at the western part of the nation. The Arabian Sea covering about 720km of coast line lies to its west and is surrounded by the states of

Karnataka, Telangana, Goa, Gujarat, Chhattisgarh and Madhya Pradesh. As the latest census says it is the world's second most populous sub-national entity. It has the largest road network in India. Though having many major rivers in the state, the cargo coming through the many existing ports uses road networks for conveying as these are not navigable.

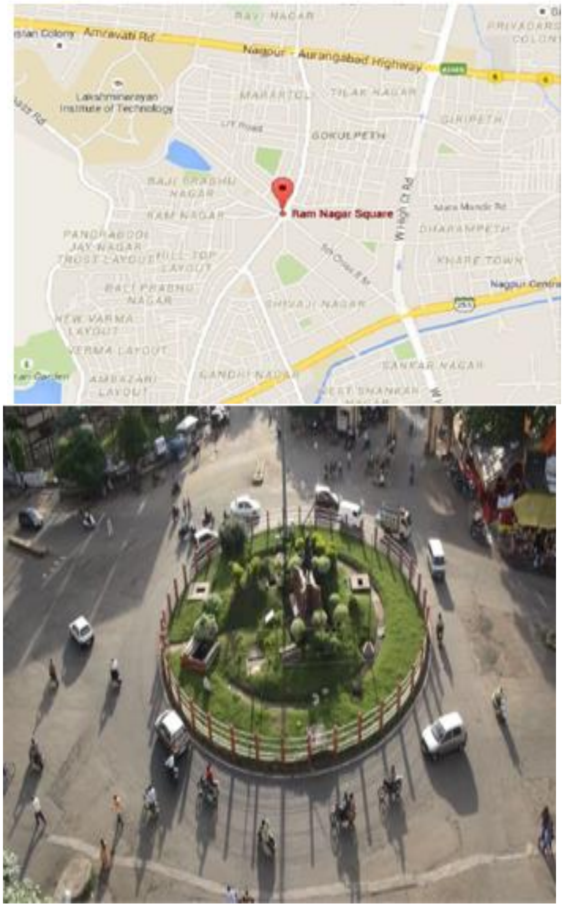


Fig 4.2. Roundabout at Ram Nagar, Nagpur

Nagpur is the third largest city of Maharashtra. It is considered as the cultural capital and is a major commercial and political centre. It has been endowed as 'The Best Indian city to live in' in terms of liveability, greenery and other indices. This city have some of the premium educational institutions making it a major education centre in central India.

The intersection under consideration is a seven lane roundabout, the Ram Nagar Square at Dharampeth. It looks like an epicentre of a web of roads which runs through many residential areas, educational institutes and various places of commercial activities between two major roads namely AH46 towards north and SH255 towards south. A detailed map and a picture of the site condition is shown in Fig 4.2. Presence of schools, colleges and residential colonies are observed in the vicinity. This can be a major factor to increase the rate of traffic during the peak hour. More number of two- wheelers and bicycles can be seen to be used by the people in this area.

Master Canteen, Bhubaneswar, Odisha

Odisha is naturally rich state located on the eastern side of the nation. It has a 485km long coastline on its eastern side along the Bay of Bengal and is surrounded by the states of West Bengal, Jharkhand, Chhattisgarh, Telangana and Andhra Pradesh. Naturally rich means it contains a fifth of India's coal and iron ore and a rich deposit of bauxite and chromite. Odisha is seen as a fertile field for investments by many indigenous and foreign companies. The rate of growth of this state in various fields is very astounding. The presence of three major ports is playing a major role in this development.

Bhubaneswar is the capital city of Odisha. It is one of the modern India's planned cities and a fast developing one. Tourism is a major industry here. Currently it is divided into two parts the old city and the new one. The old city mainly has many residential areas and couple of major temples. This area is congested and roads here are very narrow. Whereas the planned city which was designed to house the capital has all major government buildings, schools, shopping centres and dedicated residential area. Roads are designed in a grid pattern inside the city. Traffic mainly consists of two-wheelers and light motor vehicle. Rickshaws are also seen in many numbers inside the city.

Fig 4.3. Roundabout at Master Canteen, Bhubaneswar

Roundabout from which the data was collected is the Master Canteen chowk near Bhubaneswar railway station. It is the junction where Mahathma Gandhi marg and Jan Path road which runs parallel to NH 203 intersects. Very heavy traffic is seen throughout the day as its location is at the heart of the city. Almost all government and administrative offices are in the vicinity of this roundabout, which includes the secretariat. Couple of schools colleges and hospital lies along these roads which makes the peak hour traffic heavier.

Panposh Chowk, Rourkela, Odisha

Rourkela is another major city in the state of Odisha located in the northern border side. It is the Steel city and industrial capital of Odisha. It has one of the largest steel plants, The RSP (Rourkela Steel Plant). The city is well connected by roads, rail and a private airstrip. It is located on the Howrah-Mumbai rail track which gives an added advantage for the transport of goods and raw materials. This city is divided into several townships namely the Steel, Civil and Fertilizer Township.

Panposh Chowk is a three lane roundabout located at the outskirts of the city on the banks of Brahmani River. It can be said as the gateway of the city. Two of the three lanes of this roundabout is NH 23 which goes through Ranchi and Rourkela connecting Chas in Jharkhand with Nuahata in Odisha, hence contributing to heavy traffic flow. The third road goes into the city centre, hence the traffic is very high during peak hours. The traffic comprises mostly of the people going for work and the heavy vehicles transporting raw materials and goods to and fro the steel plant. Large number of heavy vehicles can be found at this roundabout.

Fig 4.4. Roundabout at Panposh Chowk, Rourkela

Salt Lake, Kolkata, West Bengal

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 08
July 2019

Fig 4.5. Roundabout at Salt Lake, Kolkata

West Bengal is one among the oldest states which have witnessed the growth and fall of many kingdoms and many activities which trimmed the face of modern India as we see it today. The geographical location of the state with Himalayas in the north and the Bay of Bengal in the south and the presence of Bhagirathi and Hooghly rivers has given it a strategic position in the logistic department of the nation.

Salt Lake City or Bidhannagar is basically a planned satellite town developed to accommodate the growing population of the city. It is a growing hub of economic and IT sectors. The intersection under study is basically a four lane roundabout near National Institute of Technical Teacher's Training & Research formed by the 1st Cross road and Fourth Avenue. The area is basically a residential area but lot of educational institutes, hospitals and commercial buildings are also present. SH 1 runs parallel to it which is also a good traffic provider to this intersection. Private vehicles of people living in these residential complexes along with the well-connected public transport systems and taxi and rickshaw services provides for the traffic of this roundabout.

Data Collection

Developing a model to determine the capacity and other parameters of a roundabout calls for an extensive and legitimate data set. This data set includes the traffic flow entering and circulating around various existing roundabouts and the geometric parameters involved with it. As the study mainly revolves around the driver gap acceptance behaviour, the geometrics is considered to have no role in it. To study the nature and to conduct the quantitative analysis of the flow conditions, video graphic recordings were taken during the suitable situation.

Reconnaissance of the above discussed sites gave an initial idea about the traffic condition of the city and the layout of the site. Time when various offices, schools and other educational institutions started and finished for a day gave an idea about the peak hour condition of traffic in the city. Presence of commercial and social activity regions were also considered. During this peak hour the roads transforms into a saturated mode and is the perfect time to take the videos. The hunt for a good position to keep the camera was the next hurdle. Mainly tall towers or high rise buildings were targeted. A good position is where we get, a view which is crystal clear, without much obstacles in the line of sight. All lanes and traffic flow in a single window in zoomed in position to ease up the extraction process. a safe cover for camera and other equipment from oncoming wind and rain.

The data was collected for two to three hours during the peak hour period. High definition cameras were used for

International Journal of Research
Available at https://journals.pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 08
July 2019

collecting the data. These cameras gave a clear output even in full zoom mode, which helped in the extraction process later. Tripod with its horizontal and vertical angular adjustments enabled easy placement of camera to obtain a clear view of the site avoiding as much obstacles in the line of sight as possible.

RESULTS AND ANALYSIS

General

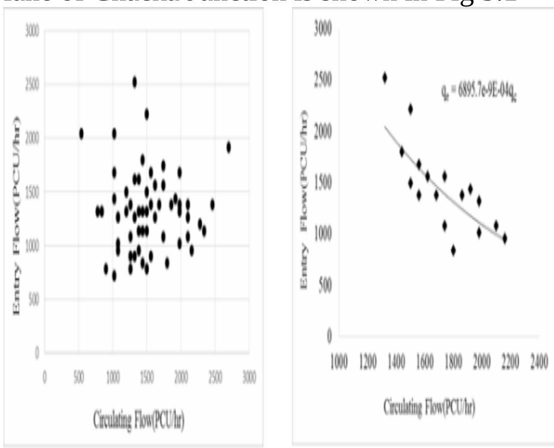
After collecting videos from the various sites as discussed in the earlier chapter, many data were extracted from it which included those which can be directly be obtained from the site and data which has to be processed for the values of different parameters which we need for developing the model. The data which are directly obtained from videos like the composition of traffic at every entry and circulating lanes of the roundabouts is tabulated in detail below. Traffic is categorised into bicycle, motorcycle, light motor vehicle, heavy vehicle and animal drawn vehicle to estimate the rate of heterogeneity we are dealing with and is recorded as PCU/hr.

Chacka Junction, Trivandrum, Kerala.

Table 5.1. Details of traffic volume at Chacka Junction, Kerala

DETAILS OF ENTRY TRAFFIC VOLUME						
Leg Direction	Heavy Vehicle	Light Motor Vehicle	Motor Cycle	Bicycle	Total Vehicles	Traffic Volume (PCU/ hr)
NE	63	928	830	32	1853	1743
NW	96	820	838	6	1762	1653
SE	91	785	808	11	1695	1651
SW	48	580	782	25	1435	1313
DETAILS OF CIRCULATING TRAFFIC VOLUME						
NE	79	554	541	9	1183	1185
NW	42	737	955	24	1758	1583
SE	58	675	676	18	1427	1353
SW	83	881	875	3	1842	1771

The scatterplot showing the relationship between the entry and the circulating flow along with regression best fit for the SW entry lane of Chacka Junction is shown in Fig 5.1



(a) (b)

(a) Scatterplot for entry to circulating flow (b) relationship between entry and circulating flow for SW approach of Chacka Junction

Critical gap using Raff method

The headways extracted from the site data sets, have been analysed to obtain critical gap using Raff method. The probabilities of rejecting and accepting a certain gap was found out for every headway. Then, cumulative probabilities were computed and graph was drawn between the cumulative probabilities of accepting and rejecting a gap. The point of intersection of two plots is taken as critical gap. The table showing sample of details of Raff method for Chacka Junction is given below.

The plot showing the graph obtained by cumulative probabilities to obtain critical gap is shown in Fig 5.2. The critical gap for the Chacka Junction, using Raff method can be estimated as 1.96 sec.

Table 5.2. Brief details of computing critical gap using Raff method

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 08
July 2019

Time Interval (sec)	Time Interval (sec)*10	Accepted /Rejected	IF C=R, NR=N+1	IF C=A, NA=N+1	Fr= E/Nrmax	Accepted Probability	Rejected Probability
0.28	0.357143	R	3	1	0.013575	0.004902	0.986425
0.32	0.3125	R	4	1	0.0181	0.004902	0.9819
0.52	0.192308	R	11	3	0.049774	0.014706	0.950226
0.56	0.178571	A	11	4	0.049774	0.019608	0.950226
0.68	0.147059	R	24	5	0.108597	0.02451	0.891403
0.72	0.138889	A	24	6	0.108597	0.029412	0.891403
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
1.04	0.096154	R	61	17	0.276018	0.083333	0.723982
1.08	0.092593	A	61	18	0.276018	0.088235	0.723982
1.48	0.067568	R	101	46	0.457014	0.22549	0.542986
1.52	0.065789	A	101	47	0.457014	0.230392	0.542986
1.76	0.056818	R	119	64	0.538462	0.313725	0.461538
1.8	0.055556	A	119	65	0.538462	0.318627	0.461538

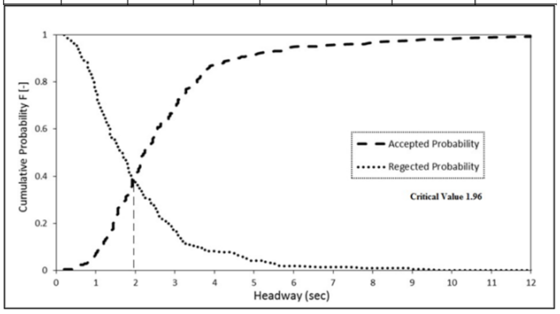


Fig 5.2. Plot of CDF's to determine Critical gap using Raff Method

Critical Gap using Equilibrium of Probabilities Method

This method overcomes certain lacunas of age old methods, like it doesn't take into consideration homogeneous nature of driver behaviour, neither has it required predefined distribution and it is not necessary for an accepted gap to be always greater than the rejected gap. This method thus have very strong base and produces robust results.

For this initially, the probability of occurrence of any headway was calculated using the data extracted. Then, the accumulated frequencies of this probabilities was estimated. The probability distribution functions based on these accumulated frequencies were then computed for accepted, rejected and the critical gap. The mean value of estimated critical gaps gives the value of critical gap using this method.

The table showing the sample of values used to compute critical gap using this method for Chacka junction is shown in

Table 5.4 and the plot obtained by this process is shown in Fig 5.3.

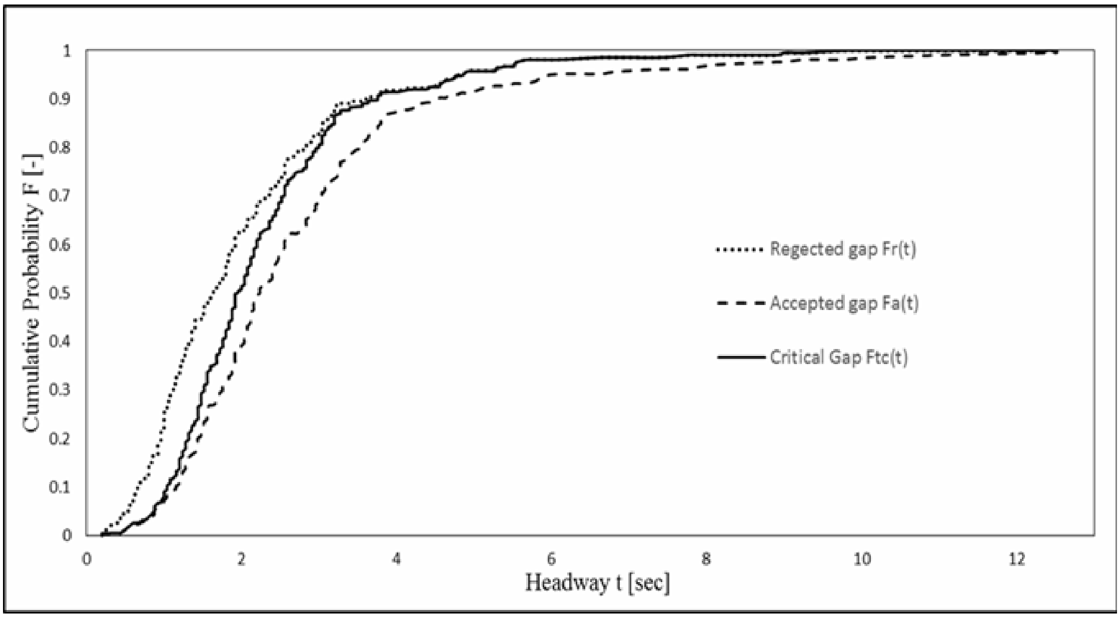


Fig 5.3: Plot of CDF's to determine Critical gap using Equilibrium of probabilities method

Critical gap using Maximum Likelihood Method

After the extraction of data, the headways are arranged in order and then the probability density and accumulative probability were calculated using the NORMDIST function in Microsoft Office Excel 2013.

Table 5.3: Iterations used for estimating be μ and σ

μ	σ	a	b
0.811	0.632	-0.55759	-0.3871
0.81	0.5	-0.69049	-0.3047
0.65	0.35	-0.42115	-0.25846
0.6543	0.3496	-0.43185	-0.256
0.645	0.325	-0.44201	-0.22587
0.655	0.3254	-0.46474	-0.22221
0.5	0.3	-0.0966	-0.2598
0.48	0.35	-0.09811	-0.00442

Table 5.4. Brief details of computing critical gap using equilibrium of probabilities method

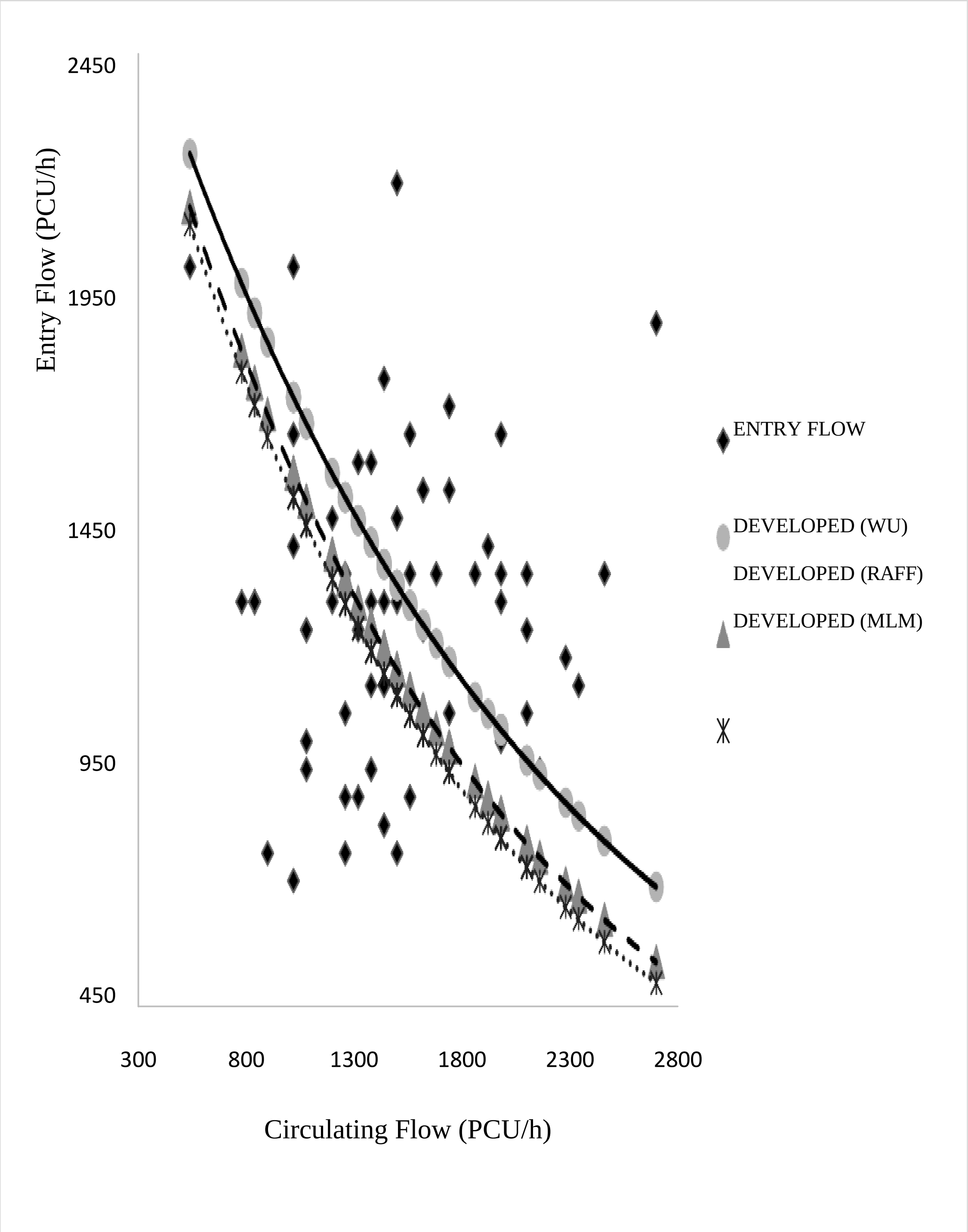
1	2	3	4	5	6	7	8	9	10	11	12
Time Interval (sec)*10	A/R	IF '2'=R, nr=n+1	IF '2'=A, na=n+1	Rejected gap, Fr(t)	Accepted gap, Fa(t)	Critical Gap, Ftc(t)	Pc=Ftc(t)-Ftc(T-1)	Td,j=(Tj+Tj-1)/2	Tc,mean=Pc*Td,j	Pc*Td,j^2	(Pc*Td,j)^2
0.208333	R	10	2	0.045249	0.009804	0.010164191	4.74593E-05	0.48	2.27804E-05	1.09346E-05	5.18949E-10
0.192308	A	10	3	0.045249	0.014706	0.015169195	0.005005004	0.5	0.002502502	0.001251251	6.26252E-06
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
0.078125	R	84	30	0.38009	0.147059	0.191740413	0.001124577	1.28	0.001439459	0.001842507	2.07204E-06
0.078125	R	85	30	0.384615	0.147059	0.192878338	0.001137925	1.28	0.001456544	0.001864377	2.12152E-06
0.069444	A	98	41	0.443439	0.20098	0.265306122	0.00478508	1.44	0.006890516	0.009922343	4.74792E-05
0.067568	A	98	42	0.443439	0.205882	0.270029674	0.004723551	1.46	0.006896385	0.010068722	4.75601E-05
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
0.060976	R	111	55	0.502262	0.269608	0.351351351	0.002059705	1.62	0.003336722	0.00540549	1.11337E-05
0.059524	A	111	56	0.502262	0.27451	0.35546875	0.004117399	1.66	0.006834882	0.011345904	4.67156E-05
0.044643	R	153	104	0.692308	0.509804	0.623616236	0.00343275	2.24	0.00768936	0.017224166	5.91263E-05
0.04386	A	153	105	0.692308	0.514706	0.625859697	0.002243461	2.26	0.005070222	0.011458703	2.57072E-05
0.007987	A	221	203	1	0.995098	1	0	11.84	0	0	0
0.007987	A	221	204	1	1	1	0	12.52	0	0	0
							1.000000117		2.271323866		0.026145517

Table 5.5: Brief description of procedure adopted for estimating critical gap using maximum likelihood method

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
i	R	A	Ln (R)	Ln (A)	μ	σ	f_a	F_a	f_r	F_r	R-U	A-U	(12)*(10)	(13)*(8)
1	9.6	12.96	2.261763	2.561868	0.811	0.632	0.013602	0.9972	0.045286	0.989148	1.450763	1.750868	0.065699	0.023816
2	1.04	5.36	0.039221	1.678964	0.811	0.632	0.245826	0.91518	0.299482	0.111011	-0.77178	0.867964	-0.23113	0.213368
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21	1.04	2.08	0.039221	0.732368	0.811	0.632	0.626371	0.450492	0.299482	0.111011	-0.77178	-0.07863	-0.23113	-0.04925
22	2.04	4.72	0.71295	1.551809	0.811	0.632	0.317569	0.879435	0.623687	0.438354	-0.09805	0.740809	-0.06115	0.235258
25	0.36	3.48	-1.02165	1.247032	0.811	0.632	0.497544	0.754879	0.009425	0.001867	-1.83265	0.436032	-0.01727	0.216945
26	1.72	3.6	0.542324	1.280934	0.811	0.632	0.478778	0.771431	0.576698	0.335375	-0.26868	0.469934	-0.15494	0.224994
27	1.04	3.64	0.039221	1.291984	0.811	0.632	0.472522	0.776686	0.299482	0.111011	-0.77178	0.480984	-0.23113	0.227275
28	0.52	4.68	-0.65393	1.543298	0.811	0.632	0.322593	0.876711	0.043004	0.010227	-1.46493	0.732298	-0.063	0.236234
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
148	0	1.72	0	0.542324	0.811	0.632	0.576698	0.335375	0.277091	0.099706	-0.811	-0.26868	-0.22472	-0.15494
390	0	6.24	0	1.83098	0.811	0.632	0.171633	0.946725	0.277091	0.099706	-0.811	1.01998	-0.22472	0.175062
406	0	11.96	0	2.481568	0.811	0.632	0.019186	0.995895	0.277091	0.099706	-0.811	1.670568	-0.22472	0.032051
				330.2876			186.772	205.1235	113.545	46.10339			-87.2077	2.342451

Comparison of Models

Comparing the developed model with different existing ones will give a general idea of how the output varies. Existing models like HCM 2010 and German were used to do this comparison. HCM model uses only critical gap and follow-up time whereas German model considers the minimum circulating headway too. The output obtained is plotted along with the scatterplot of entry and circulating flow obtained from Bisra Chowk, Rourkela. The result obtained is shown in Fig 5.5.



Conclusions

A study concerning capacity and performance of roundabouts in India was conducted to check the efficiency of roundabout in terms of capacity. The capacity was taken as an outcome for drivers' behaviour and flow conditions at the site. From the work done so far, the following facts could be concluded:

I. From the detail study, it was observed that the driver behaviour varied from site to site with the change in traffic composition, like the headways were larger when the number of heavy vehicles were more. The critical headways thus, were found to be affected by the number of vehicles entering a roundabout from an approach leg.

II. Critical gap was computed using three methods namely, Raff, Wu and Maximum likelihood method. For the sites considered the values of critical gap obtained from these three methods changed with a standard deviation of 10-23%.Regarding the traffic flow, the entry flow of roundabouts was found to vary exponentially with the circulating flow when plotted using one minute interval data.

III. When validating the model, the critical gap obtained using the equilibrium of probabilities (Wu) method gave a good fit for the data in most of the cases, as it neither underestimated nor overestimated the capacity. This proved the method to be the most suitable for Indian conditions.

IV. The developed model provided good fit for moderate valued circulating flow, while overestimated in case of lower circulating flows. This might be due to consideration of only saturated flows in developing the model.

V. The variations in the results might be due to the fact that only a few sites were used for developing a model. To modify the developed model and form more robust model, more data is to be used.

VI. The comparative study with two existing models, HCM 2010 and German, showed that in maximum cases the HCM 2010 model underestimated the capacity, whereas the German model overestimated when compared to valued obtained by developed model.

REFERENCE

1. Akçelik, R., E. Chung, and M. Besley (1999), "Roundabouts: Capacity and Performance Analysis", Research Report ARR No. 321, 2nd ed. ARRB Transport Research Ltd, Australia, 1999.
2. Akcelik, R(2011), "Evaluating Roundabout Capacity, Level of Service and Performnce",
3. Akçelik, R(2011), "A Roundabout Case Study Comparing Capacity: Estimates from Alternative Analytical Model", 2nd Urban Street Symposium, Anaheim, California, pp.1-20.
4. ARR 321, Roundabouts: Capacity and Performance Analysis, ARRB Transport Research, 1998.
5. Ashalatha, R. and S. Chandra (2011), "Critical Gap through Clearing Behavior of Drivers at Unsignalised Intersections", *KSCE Journal of Civil Engineering*, No: 15(8), pp. 1427-1434.
6. Brilon, W., R. König, R. Troutbeck (1997), " Useful Estimation Procedures for Critical Gaps",*rd.*
7. *Proceedings of the 3 International Symposium on Intersections without Traffic Signals*, Portland
8. Oregon, pp. 71 – 87, July 1997.
9. Brilon, W., R. Koeniga, and R. J. Troutbeck, (1999), "Useful estimation procedures for critical gaps", Transportation Research Part A 33, pp. 161-186.

10. Chandra, S, R. Rastogi (2012), “Mixed Traffic Flow Analysis on Roundabouts”, Journal of the IRC, Volume-73-1, 2012, pp. 69-77.
11. ERSOY, M, H. B. ÇELİKOĞLU (2014), “Capacity Analysis on Multi-Lane Roundabouts: An Evaluation with Highway Capacity Manual 2010 Capacity Model”, Pamukkale University Journal of Engineering Sciences, 20(6), 225-231, 2014.
12. Gavulová, A (2012), “Use of Statistical Techniques for Critical Gaps Estimation”, *Proceedings of the 12th International Conference “Reliability and Statistics in Transportation and Communication” (RelStat’12), 17–20 October 2012, Riga, Latvia, p. 20–26.*
13. Hakkert, A. S., D. Mahalel, and S. A. Asante, (1991), “A Comparative Study of Roundabout Capacity Procedures”, *Proceedings of an International Workshop, 18–19 July, 1991 in Bochum*, Germany, pp 93-106.
14. Hagring, O., (2000), “Derivation of Capacity Equation for Roundabout Entry with Mixed Circulating and Exiting Flows”, *Transportation Research Record , No. 01-2081.*
15. IRC 65: Recommended Practice for Traffic Rotaries, 1976, *Indian Road Congress.*
16. Jie, C., Y. Xinmiao, D. Wei and H. Xin (2008), “Driver’s Critical Gap Calibration at Urban Roundabouts: A Case Study in China”, *Tsinghua Science and Technology*, Vol 13(2) pp237-242.
17. Kimber, R. (1980), “The Traffic Capacity of Roundabouts”, *Laboratory Report 942*, U.K. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1980.
18. Kusumaa, A., and H. N. Koutsopoulos (2011), “Critical Gap Analysis of Dual Lane Roundabouts”,
19. *Procedia Social and Behavioral Sciences 16*, pp. 709–717.
20. Lindenmann,H.P.(2006) “Capacity of Small Roundabouts with Two-Lane Entries”, Transportation Research Record: Journal of the Transportation Research Board, No. 1988,2006, pp. 119–126.
21. Mauro. R (2010), “Calculation of Roundabouts: Capacity, Waiting Phenomenon and Reliability”.
22. Mereszczak, Y., M. Dixon, M. Kyte, L. Rodegerdts, and M. Blogg, (2006), “Including Exiting Vehicles in Capacity Estimation at Single-Lane U.S. Roundabouts”, *Transportation Research Record: Journal of the Transportation Research Board*, No. 1988, pp. 23–30.
23. NCHRP Synthesis 264: Modern Roundabout Practice in the United States, *Transportation Research Board*, 1998.
24. NCHRP Web-only Document 94: Appendixes to NCHRP 572: Roundabout in United States,
25. Transportation Research Board, 2006.
26. NCHRP 672: Roundabouts: An informational Guide, Second Edition, *Transportation Research Board*, 2010.
27. Polus, A. and S. Shmueli, (2011), “Analysis and Evaluation of the Capacity of Roundabouts”,
28. *Transportation Research Record 1572*, No: 97011.
29. Ruijun, G (2010), “Estimating Critical Gap of Roundabouts by Different Methods”, *The Sixth Advanced Forum on Transportation of China.*