A COMPARATIVE ANALYSIS OF ROUNDABOUTS AND SIGNALIZING INTERSECTIONS IN ROURKELA CITY

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Abstract: At grade intersection are one of the vital element in any road network. At grade intersections like Roundabouts take part a remarkable role in the level of delay experienced by vehicles on the road network. Roundabout control and traffic signals are the most common type of at grade intersection control. The aim of this research is to propose the changing of roundabout intersections into the signalizing intersection in the Rourkela city by using VISUM macro simulation software. The empirical work considered five major roundabouts in Rourkela city on outer ring road that is operated under different traffic congestion levels and different traffic distribution percentage. Various parameters like the level of service, effective size, cost, safety, operations, etc. were compared in this study. This study indicated that roundabouts suggested for low traffic volume while traffic signals are proven to be more suitable for large traffic volumes. In this study, the results showed that in Rourkela city the roundabouts should be upgraded to signalized intersection.

Index terms: *Roundabouts, signalized intersection, cost, safety, operations, VISUM, Rourkela city*

1. INTRODUCTION

Traffic congestion is one of the major problems in many cities around the world. Local agencies try to often propose some solutions to reduce traffic delays at intersections. Some of the proposed solutions included changing roundabout intersections to signalized intersection.

Usually, urban planners cannot propose the utilize of a roundabout or replacing one of them at an intersection without consulting traffic engineers. Traffic engineers usually use software programs to analyze whether the intersection should be implemented with a signalized intersection or a roundabout intersection. Then based on an average delay in each case, a decision can be made.

Even though there are plenty of commercial traffic design software programs available, choosing between a roundabout or a signalized intersection is not a straight forward decision. The reasons behind that are; firstly, the software programs are not always affordable or available. secondly, urban planners need traffic engineers to run the software analysis is time-consuming, while findings and hiring a traffic engineer might be cost-intensive.

The study area of this research is Rourkela. Rourkela is a steel city situated in the state of Odisha with population 552,970(census-11) and more traffic problems. Many industries, industrial plants, Educational institutions are there. The city has well-planned transportation infrastructure but nowadays the population increased rapidly so traffic is increasing. The congestion is one of the serious problems in the metropolitan area, up-gradation of the roundabout intersections to signalized intersections is one of the best solutions. In this study preparing a model about the existing roundabouts, of a two-lane & single-lane roundabouts corridor in VISSIM using the existing field data and the various parameters have compared of roundabout intersection and signalized intersection like; the effects of roundabouts on fixed location and Evaluation of level of service, fraction of two-wheeler and four-wheeler, effective size of the roundabout intersection, etc.

•The objective of the study is providing some guidelines on the suitability of replacing a roundabout with a signalized intersection based on the traffic volume and choosing the best alternative for the existing traffic flow condition.

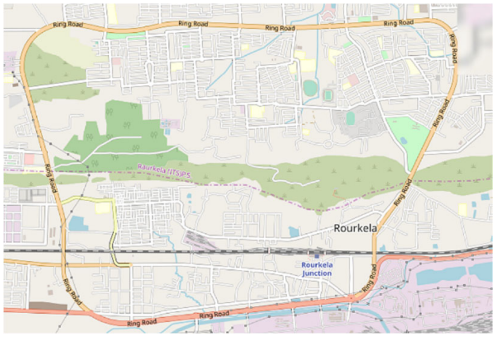

Fig.1Rourkela city Map

2. LITERATURE REVIEW

The various study conducted on the roundabout and signalized intersection show that the entry gap distribution is different from circulating gaps; entry of the vehicle velocity is smallest; the vehicle characteristics are mostly the same in different lanes. (C. Fisk.et al.1991). It used to draw an animation of a double-tracked roundabouts (SWITZERLAND) and analyzed the interesting scenario maximum traffic volume where no or just a few vehicles have to wait, in such case traffic volume of single tracked allows 3500 vehicles per hour whereas the double-tracked roundabout in TCS-mode has a capacity 5700 vehicles per hour .(Bernhard and Portmann 2000) Mean speed, turning angle and delays are the main contributing factor of four-lane intersections under yield control, two ways and four ways stop control and signal control for various traffic conditions(Sisiopiku and Oh 2001).

A case study of Greek road to investigate the performance of roundabout intersection combined of a traffic signal control corridor under enlarge traffic demand condition. This paper demonstrates the four relatively new alternative types of the roundabout and suggested that the standard roundabout gives the best performance than other roundabouts(Fromme 2010). It focuses on the performance of roundabout with traffic signals and analyzed that signal setting with alternative phasing can be provided the intersection capacity of about lane arterial (McNulty 2013).There some parameters performances of different vehicle types on circulating lane and weaving section which includes, gap distribution, velocity distribution and distance distribution of lane changing(Rajeswaran and Rajasekaran 2013). Developed an accident prediction model, which is necessary for statistical safety evaluation of roundabout(Ambros et al. 2016).

Evaluated and compared the performance of typically roundabout with turbo roundabouts by the approach of travel time, delay time, length of the queue created in the entering, by using VISSIM software(Izadi et al. 2016). A macroscopic simulation proposal was developed using VISUM and proceed to evaluate the environmental effect of converting four three lanes roundabouts to the signalized intersection along a heavily congested urban corridor (Kumar and Sivanandan 2018).

3. METHODOLOGY

The aim of this study is to analyze the existing roundabouts, of a two-lane and single-lane roundabout corridor by using VISUM software. VISUM is a macroscopic, time step and behavior-based simulation model for realistic modeling of the city. This software can give the accurate behavior of transportation network planning. VISUM software using for junction layout comparison, transport development planning, capacity analysis, etc. VISUM solves the many problems of the urban transport system. Here trying to show the realistic behavior of the present traffic flow condition at the peak hour on the selected roundabout in Rourkela city. Manually collected data are used for the simulation. All the location trying to show realistic behavior. In this study, the simulation results and parameters evaluation gives the best preference to improve the existing traffic flow condition of the two-lane and single-lane roundabout corridor.

4. STUDY AREA

The study area of this research is Rourkela, nowadays there is huge traffic congestion on the ring road mostly near the roundabout. The length of the ring road is 16 km which connects 19 sectors, on this ring road many roundabouts have existed and for analysis five major roundabouts are selected. The selected roundabouts are sector-2 chowk, Ambagan chowk, Bishra chowk, sail chowk, plant side chowk.

• Sector 2 chowk is going on locality in Rourkela city.it has situated on the ring road and nearer to the NIT campus (around 2km). In Evening hours (4:00-5:00) and morning hours (8:00-9:00) optimum no. of vehicles are there. and it noticed the maximum no of heavy vehicles appears morning hours because of their bus stand.

• Sail chowk is an important segment in Rourkela city. It has also situated on the ring road.it is near to the steel plant .it is a very polluted area because of the steel plant.it contributes to the maximum no. traffic volume.it occurs more crowed during the peak hour.

• Ambagan chowk is in front of the ISPAT market. And it is an outer area from the factory sail. It is using for marketing purposes because of the market.

It's around 5km from the NIT campus. Huge no. of two-wheelers and four-wheelers demands are there.

• Traffic gate chowk is near about to the main market road and Railway station also.it contributes largely no. of traffic volume.it also on the ring road. Generally, this chowk is using for commercial purposes. Land acquisition cost is high compared to other places. Large nos. of auto, two-wheeler, and four-wheeler demands in that chowk because of the main market and railway stations.

Fig 2 Map on ring road in Rourkela city

5. DATA COLLECTION AND ANALYSIS

All the data is collected by manually and with the aid of a video camera. The traffic data is collected for one hour or 60 minutes' duration at peak hour traffic condition. The collected data is entry and exist volume of each leg, in all the five roundabouts. According to High Way Capacity manual all the data have converted into the Passenger Car Unit(PCU). The empirical analysis focuses on the various parameters. All the parameters are done by the Highway capacity manual(HCM). VISUM macro simulation software is using existing field data.

Fig. 3 Roundabout in Rourkela city

Table.1: Location of Studied Roundabouts and time of Collection

ROUNDABOUTS	TIME OF COLLECTION
Sector-2 Chowk	4:00pm to 5:00pm
SAIL Chowk	5.00pm to 6.00pm
Ambagan Chowk	9.00am to 10.00am
Plant Side Chowk	8.30am to 9.30am
Bishra Chowk	4.30pm to 5.30pm

Table.2: Conversion to Passenger car units

Vehicle Type	PCU
Motor cycle	0.5
bicycle	0.5
Private car	1.0
Bus, tractor, truck	3.5

The movement of on the approaches or legs and the traffic volume in term of passenger car unit and these data necessary for the analysis. As explained in the passenger car equivalent factors are used to convert the number of vehicles to passenger car equivalent

Table .3 Summarized vehicles volume on intersections at peak hour.

Roundabout	Heavy Vehicles	Light Vehicles			Total Veh	Total Traffic
		Cars, Autos	Motor, Bicycles	Total		
Sector-2 Chowk	131	921	2150	3071	3202	2455
SAIL Chowk	328	1124	3826	4950	5278	4181
Ambagan Chowk	185	1087	2468	3309	3462	2970
Plant Side Chowk	303	1352	2460	3812	4115	3648
Traffic Gate Chowk	257	1320	3024	4094	4309	3732

6. EVALUATIONS OF PARAMETERS

- Level of service
- The effective size of the roundabout
- The fraction of two-wheelers and four-wheeler
- Compare of present traffic flow versus existing traffic flow

Level of service

This estimation of the level of service is based on the delay model derived from studies conducted on multilane roundabouts of varying diameter by taking into account the delay experienced by the vehicle from the entry point of the roundabout. The delay model empirical equation

$$Y=0.8*e0.001x$$

Y=Vehicular delay in seconds

X=Total approach traffic flow on the vehicle per hour

As mentioned earlier, based on the observed overall vehicular delay at the roundabout and prevailing traffic flow, the level of service has been established by using the clustering technique to represent the quality of traffic flow on roundabout. If the volume to capacity V/C ratio of a lane exceeds 1.0, regardless of the delay, the level of service of the roundabout if defined as the level of Service-F.

Table 4: level of service based on overall vehicular delay

Level of service (LOS)	Level of service (LOS)
A	≤ 5
B	$6 \leq d \leq 15$
C	$16 \leq d \leq 20$
D	$21 \leq d \leq 35$
E	$36 \leq d \leq 65$
F	>65

Highway capacity manual (HCM 2012-2017) are suggested passenger car unit, critical gap and follow-up time of different diameters of roundabout, entry capacity model for varying diameters of roundabouts.

6.1 According to the highway capacity manual estimated level of service

6.2 Level of Service

According to the High way capacity manual have calculated level of service at the fixed location in the Rourkela city. Observed that the sector-2 chowk of the level of service is good and located the very worst condition of the sail chowk. The rest of the other three locations' conditions are also not good

Figure 4: Level of Service Analysis

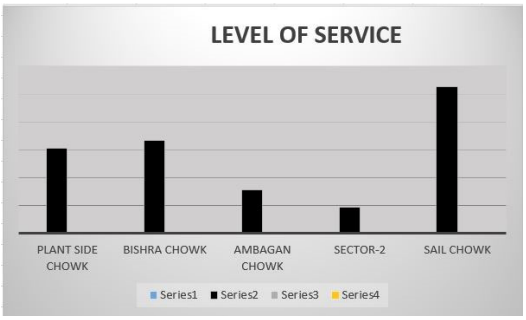

Table 5: Data Analysis

According to highway capacity manual(HCM 2012-2017) Suggestad passenger car units (PCU)										
		MOTORIZED TRAFFIC						NON-MOTORISED TRAFFIC		
ROUNDABOUTS	DIAMETER IN MM	two wheeler	autos	small car	big cars	LCVs	heavy vehicles	cycle	cycle ricks	ADV
sector-2	29	0.32	0.83	1	1.4	1.88	3.65	0.18	1.12	4
Traffic gate chowk	60	0.32	0.83	1	1.4	1.46	3.05	0.28	1.74	4
sail chowk	51	0.32	0.83	1	1.4	1.46	3.05	0.28	1.74	4
Ambagan chowk	30	0.32	0.83	1	1.4	1.65	3.45	0.21	1.31	4
Plant side chowk	33	0.32	0.83	1	1.4	1.65	3.45	0.21	1.31	4

CRITICAL GAP AND FOLLOW-UP TIME FORDIFFERENT DIAMETERS OF ROUNDABOUTS			
roundabouts	diameter(M)	critical gap(sec)	follow-up time(sec)
sector-2	29	2	1.5
Traffic gate chowk	60	1.6	1.2
Sail chowk	51	1.6	1.2
Ambagan chowk	30	1.9	1.4
plant side chowk	33	1.9	1.4

Entry capacity model for varying diameters of roundabout					
round abouts	diameter ,D(m)	critical gap Tc(s)	follow of time Ts(S)	A=3600/Tf	B=(Tc-0.5*Tc/3600)
sector -2	29	2.01	1.51	2384	0.00035
Traffic gate chowk	60	1.61	1.21	2975	0.00028
sail chowk	51	1.61	1.24	2903	0.00029
Ambagan chowk	30	1.87	1.4	2571	0.00032
plant side chowk	33	1.87		25	

6.3 The effective size of the roundabout

Effective size is an important characteristic of roundabouts. In Rourkela city situated all the selected five major roundabouts on the ring road, some of the roundabouts are elliptic in shape and some are circular. The roundabouts are accommodating with different diameters.

From the analysis of Effective size of roundabout we can know that it will have effect on the traffic. If the size of roundabout is too small the congestion will occur, if size is too large for small traffic volume the vehicle users doesn't following the traffic rules as they are crossing the roundabout from wrong direction

calculating effective size of the choosen location

Roundabouts	shape	effective size
plantside chowk	ellipse	1.69
Bishra chowk	circular	5.05
Ambagan chowk	circular	3.17
sector2	circular	3.71
sail chowk	ellipse	7.38

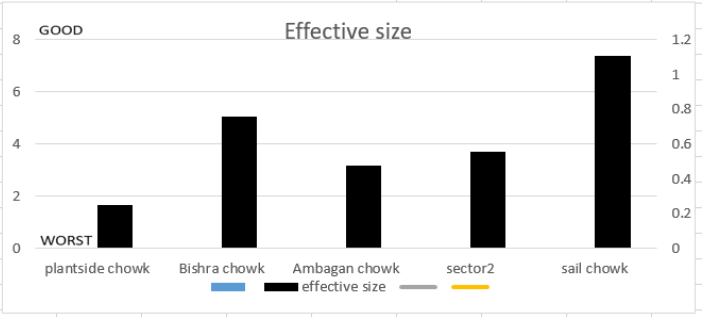

Figure 5: Effective size analysis

Here, this table shows that the effective size of each roundabout

Fig.6 Rule breaking pictures (sector-1)

Here, Figure 4 shows on Sector 1 location in Rourkela city. It shows that nobody does not following the proper direction and all are breaking the of traffic rules. In view of the fact that in particular location the central island of the roundabout is oversized. So effective size of the roundabout plays major role in the design of roundabout.

roundabouts	estimated LOS
Plantside chowk	0.804557195
Bishra chowk	0.80557224
Ambagan chowk	0.80597
Sector2	0.807512908
Sail chowk	0.807587571

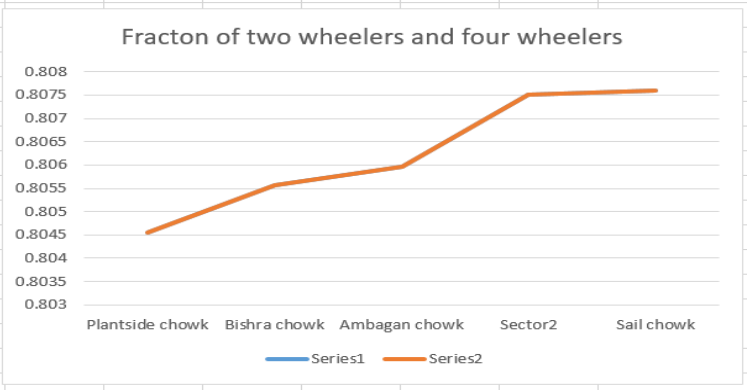

Figure 5: Fraction of two wheelers and four wheeler analysis

Calculated the selected roundabouts of the fraction of two-wheeler and four-wheeler. The fraction of two-wheeler more represents good mobility compare to the four-wheeler. For the reason that four-wheeler taking so much space.

6.3 Compare of present traffic flow versus existing traffic flow

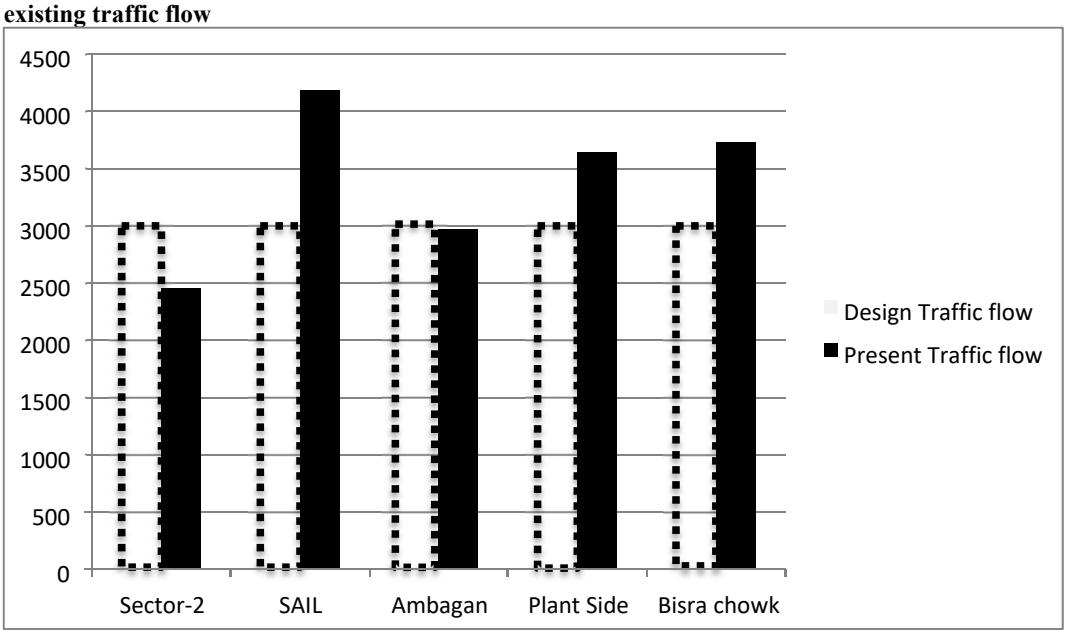

Figure: Design traffic vs present traffic analysis

This table is designed traffic flow versus present traffic flow. According to high way capacity manual(HCM-2017) the design capacity of the roundabout is 3000 vehicles per hour so, the above table shows that the maximum number of vehicles occurs at sail chowk and minimum no of vehicles occurs at sector-2 chowk and most of the roundabout design traffic is crossed, the present traffic is very high the roundabouts at Sail Chowk, Plant Side, Bisra Chowk, Ambagan chowk, Sector-2 chowk.

6.4 Evaluation matrix

A multivariance evaluation process is used to compare both intersections in Rourkela city. Three categories are identified for the evaluation: cost, safety, operations. A total of 12 evaluation criteria – four per category –are applied to compare both intersection treatments and to evaluate which one is best or is it really needs to replace roundabout with a signalized intersection. The valuation process is built for each category; cost, safety, and operations. Therefore, three evaluations matrixes are completed in this study.

• **Cost**

The classification of cost is divided into four criteria: roadway modification cost, construction cost, maintenance cost, and footprint. For roundabout, they already exist so there is no construction cost that will be there for signalized intersections. In the signalized intersection, the cost of maintenance includes traffic signal operation costs. Maintenance of landscaping features will require at a roundabout. the cost associated with the footprint of each intersection treatment including required land acquisition, environmental impact costs, historical impact cost, the impact of utility relocation.in general, a modern roundabout will require more right-of-way than a signalized intersection.

• **Safety**

The classification of safety is divided into four criteria: intersection conflicts, driver expectation, pedestrian and cyclist, crash reduction factors. Traffic signals can move traffic in an orderly manner, reducing potential crash-producing conflicts and reducing the frequency of certain types of a collision so signalized intersections have more safety than a roundabout. Roundabouts are tougher than a signalized intersection for pedestrians with visual and other physical impairments related to accessibility and usability of the facility. The advantage of traffic signals is that they move traffic in an orderly fashion and can interrupt heavy traffic to permit other traffic to cross, such as vehicular or pedestrian traffic.

• **Operations**

The category of operation includes four evaluation criteria: posted speed, capacity, configuration adaptability, and design for larger vehicles. The signalized intersection will require a posted speed of 80 kph and the introduction of advance flashing warnings. The roundabout intersection operation is dependent on the posted speed. However, it is expected that operational speed inside the roundabout is at 50 kph. capacity at roundabouts is generally higher than at signalized intersections. In view of the fact that a roundabout operates on a yield-on entry basis; however, unbalance volumes might result in operational problems.

- **Evaluation criteria**

Based on the above three parameters have compared both roundabout and signalized intersection, given a score to each parameter in general not experimentally, these score refers to which one is better. A higher score intersection is preferred. In this particular study, the score is based on previously experienced in transportation projects.(McNulty 2013). In the evaluation process, score points are assigned to each treatment to compare (in this case, roundabout versus signalized intersections). The total score points are 100, and for each parameter gave some score based on preference for cost-55 points, safety-25 points for operations-20 points, the higher score indicates that it is a good option and lower score indicates that it is not a good option for that parameter.

Table.6 Evaluation matrix

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			SIGNALIZED INTERSECTION	ROUNDABOUT INTERSECTION
CATEGORY	EVALUATION CRITERIA	WEIGHT	SCORE	SCORE
COST	Construction cost	20	15	5
	Roadway modification cost	5	4	1
	Land use cost	15	12	3
	Maintenance cost	15	6	9
	SUB TOTAL	55	37	18
SAFETY	Intersection conflicts	5	3	2
	Pedestrians	5	3	2
	Driver expectations	5	3	2
	Crash reduction factor	10	8	2
	SUB TOTAL	25	17	8
OPERATIONS	Posted speed	5	4	1
	Capacity	5	2	3
	Configuration adaptability	5	4	1
	Design for larger vehicles	5	4	1
	SUB TOTAL	20	14	6
	TOTAL	100	68	32

Above the evaluation matrix table clearly shows that for signalized intersection have more score than the roundabout, so the signalized intersection is best compared to some roundabouts like SAIL Chowk.

6.5 Simulation Result

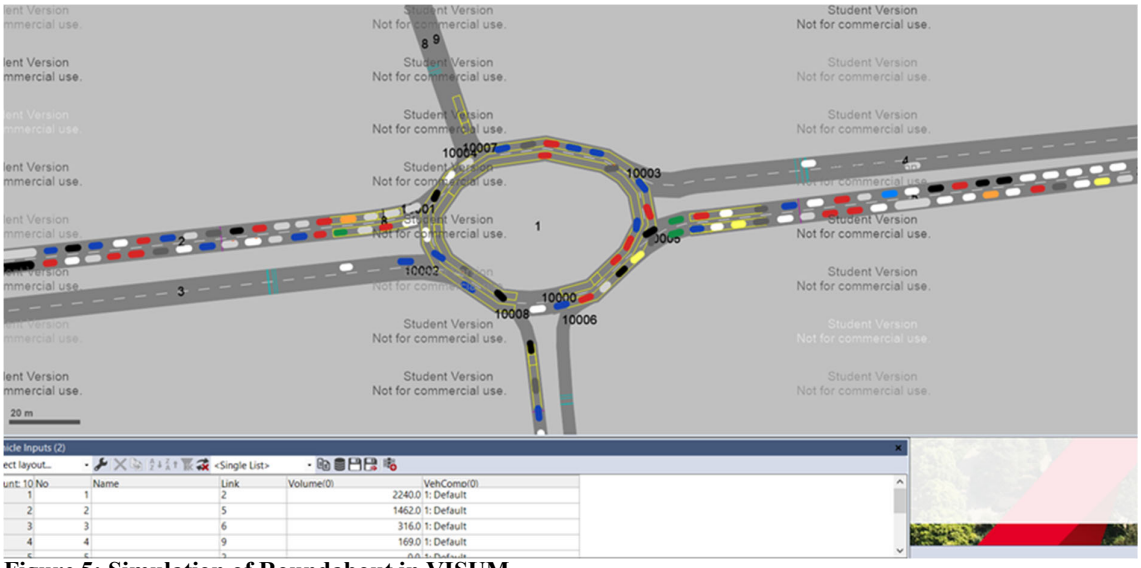

Figure 5: Simulation of Roundabout in VISUM

(Traffic flow condition of the roundabout at Rourkela city)

From the above simulation we can know that the condition of the roundabout at the sail chowk is very poor.

7.DISCUSSION

As general recommendations, the following criteria can be used as a guide for selecting the type of intersection. According to the Highway capacity manual for low traffic volume on the intersection (3000 vehicles per hour), a roundabout is recommended, regardless of the traffic distribution on the approaches. If the traffic volume on the intersection is uniformly distributed (i.e. Equal volume of traffic on all approaches), then a roundabout is recommended in any case of the traffic volumes and the turning percentages. For high traffic volume (more than 3000 vehicles per hour), a traffic signal is recommended for all traffic distributions. Sector-2 chowk traffic volume is 2455 vehicles per hour so the roundabout is within the design traffic so no need to of signalized intersection at Sector-2 chowk. SAIL chowk has a present traffic volume of 4182 vehicles per hour so the roundabout is crossed its design traffic so signalized intersection has to provide at SAIL chowk. Ambagan chowk traffic volume is 2970 vehicles per hour so the roundabout is almost near the design traffic so signalized intersection has to provide. Plant Side chowk has a present traffic volume of 3648 vehicles per hour so the roundabout is crossed its design traffic so signalized intersection has to provide at SAIL chowk. Bisra chowk has a present traffic volume of 3732 vehicles per hour so the roundabout is crossed its design traffic so signalized intersection has to provide at SAIL chowk. Based on the evaluation matrix-like cost, safety, operations, the signalized intersection has a score of 68 and for

roundabout intersection, it is 32. So signalized intersection is best compared to the roundabout.

CONCLUSION

Rourkela roundabouts traffic volume analysis results indicate that most of the roundabouts are in serious problems or over-saturation. Based on observed actual field condition it is necessary to upgrade these roundabouts with signalized intersections. As the study also evaluated some parameters like the level of service, the effective size of the roundabout, the fraction of two-wheelers and four-wheelers, cost, safety and operation in the context of these parameters signalized intersection is best compared to roundabouts. Besides most of the round are built more than 15 years ago so the design capacity of roundabouts expired so up-gradation roundabout is needed. High traffic entry flows at Sail chowk roundabout was found to be 4187vehicle per hour which is more than the design capacity 3000 vehicles per hour, not only sail chowk most of the roundabouts have crossed the design capacity. Simulation performance has also given very congested traffic conditions at the chowk. This traffic is very high to be accommodated by the roundabout, so these roundabouts should be upgraded in Rourkela city.

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