Analysis and Redesign of The Rotary Intersection Multi-leg Green Chowk Station Road Durg

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Abstract

Transportation contributes to the economical, industrial, social, and cultural development of any country. In recent years the intense growth of vehicles which caused heavier traffic congestion at intersections, which going to be even worse in peak-hour traffic time. Transportation plays a significant role in the economical, industrial, social, and cultural development of any country. However, the recent increase in the number of vehicles has resulted in heavier traffic congestion at intersections, which is particularly worse during peak hour traffic time.

In India, the number of vehicles is increasing day by day, leading to many problems, especially in cities like Durg, where frequent traffic congestion occurs. This results in delays, loss of time, increased fuel consumption, noise pollution, and frequent interruptions in traffic flow. Green Chowk is one of the busiest rotary intersections in Durg, serving as a junction through which numerous vehicles enter and leave the city. The Indira market and Station Road are very near to the intersection, which further aggravates the traffic problem of the rotary intersection. Thus, the current design of the rotary intersection is not capable of handling the present traffic scenario, let alone the anticipated traffic of the rotary intersection.

This project aims to assess and study the rotary intersection at Green Chowk. This will include site investigation, measuring the present geometry of the intersection, followed by traffic volume count. Based on the above data, we will suggest a new design for the rotary intersection that can handle the present and anticipated traffic scenario at Green Chowk in Durg.

1. INTRODUCTION

1.1 Objective

This project aims to assess and study the rotary intersection at Green Chowk. This will include site investigation, measuring the present geometry of the intersection, followed by traffic volume count. Based on the above data, we will suggest a new design for the rotary intersection that can handle the present and anticipated traffic scenario at Green Chowk in Durg.

Rotary

A rotary is a circular road that consists of a series of merges and diverges. It is similar to entering a freeway from a ramp. On the other hand, a roundabout is a traffic circle consisting of a pair of one-way roads that intersect each other. In between the two pairs of roadways, there is a circular island.

Figure-01 Top View of Green Chowk

Traffic operations in a rotary

As noted earlier, the traffic operations at a rotary are three;

- Diverging
- merging
- weaving

All the other conflicts are converted into these three less severe conflicts.

Diverging:

Diverging is a traffic operation where vehicles moving in one direction are separated into different streams based on their destinations. For instance, if a car is supposed to follow a circular path in a roundabout but instead starts moving outward from the center, then it is considered to be diverging

Merging:
Merging is the ultimate solution for making the traffic flow smoother and faster. By combining vehicles coming from different directions into a single stream, we can reduce traffic congestion, minimize travel time, and enhance road safety.
Weaving:
Weaving involves the combination of merging and diverging movements in the same direction.

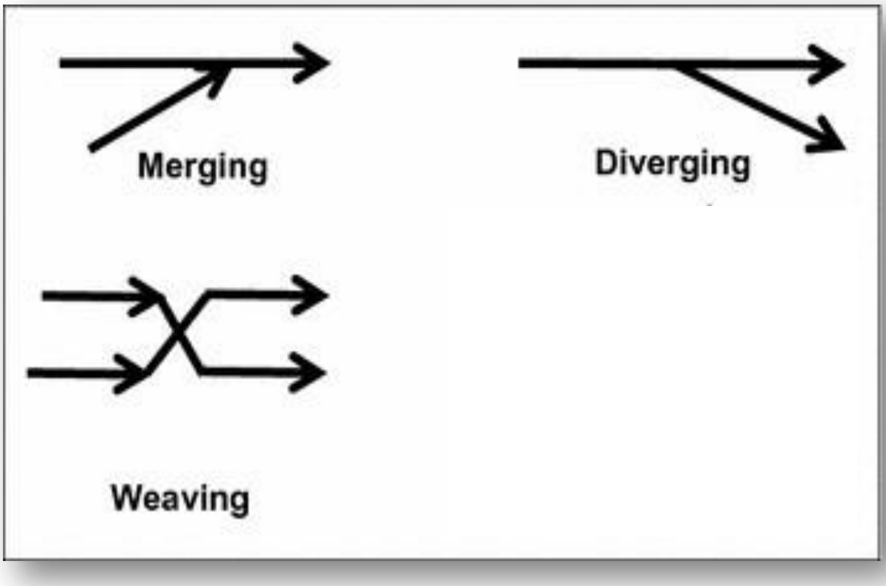


Figure-02 Traffic Operation in Rotary

Design elements

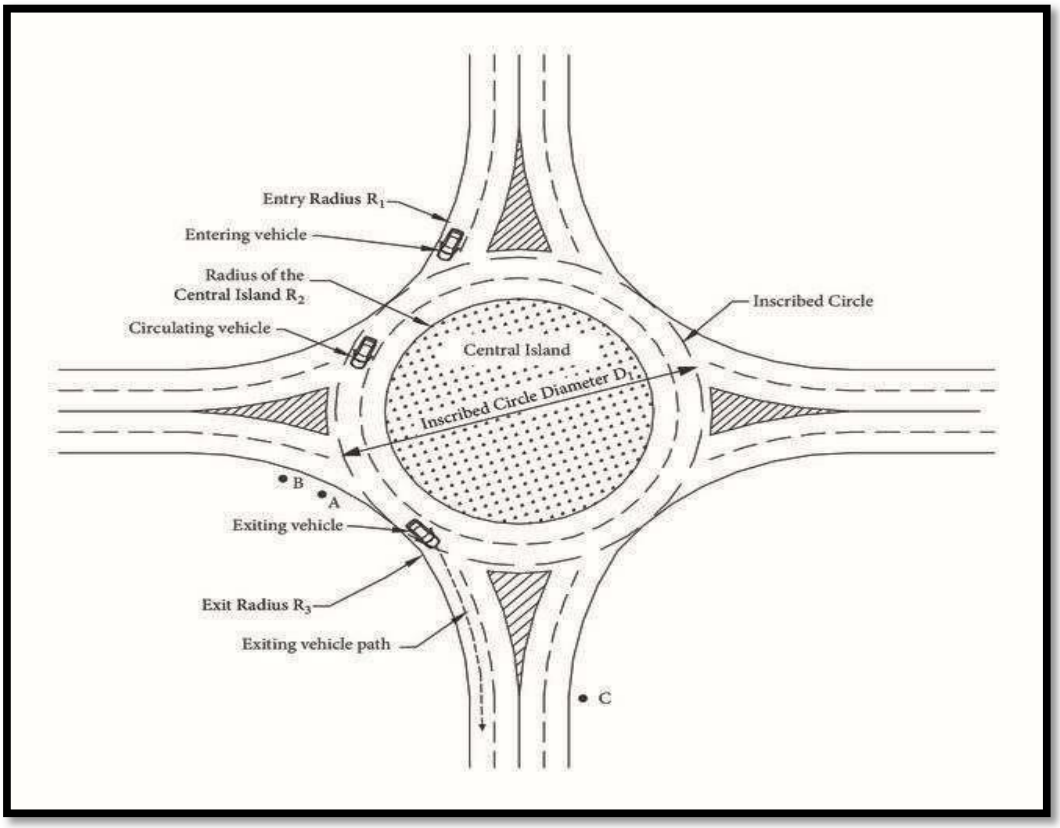
The design of a roundabout includes several key elements, such as the speed at which vehicles should enter and exit, the radius of the central island, the length and width of the weaving area, and the width of the entry and exit points. Additionally, it's possible to calculate the capacity of a roundabout using certain empirical formulas.

All vehicles must reduce their speed when approaching a roundabout. This means that the design speed of a roundabout should be much lower than the speed limit of the roads leading up to it. While it's possible to design a roundabout without reducing speed, this can result in a very large structure that's expensive to build. As a general rule, the design speed for urban and rural areas should be around 30 and 40 Kmph respectively.

Design speed

All vehicles are required to decrease their speed while approaching a rotary. Therefore, the design speed of a rotary is lower than the roads leading to it. Although it's possible to design a roundabout without much speed reduction, the resulting geometry may lead to a very large size, incurring a huge cost of construction. Typically, the design speed is kept at 30 kmph and 40 kmph for urban and rural areas respectively.

Figure-03 Elements of Rotary Intersection



Entry, exit, and island radius

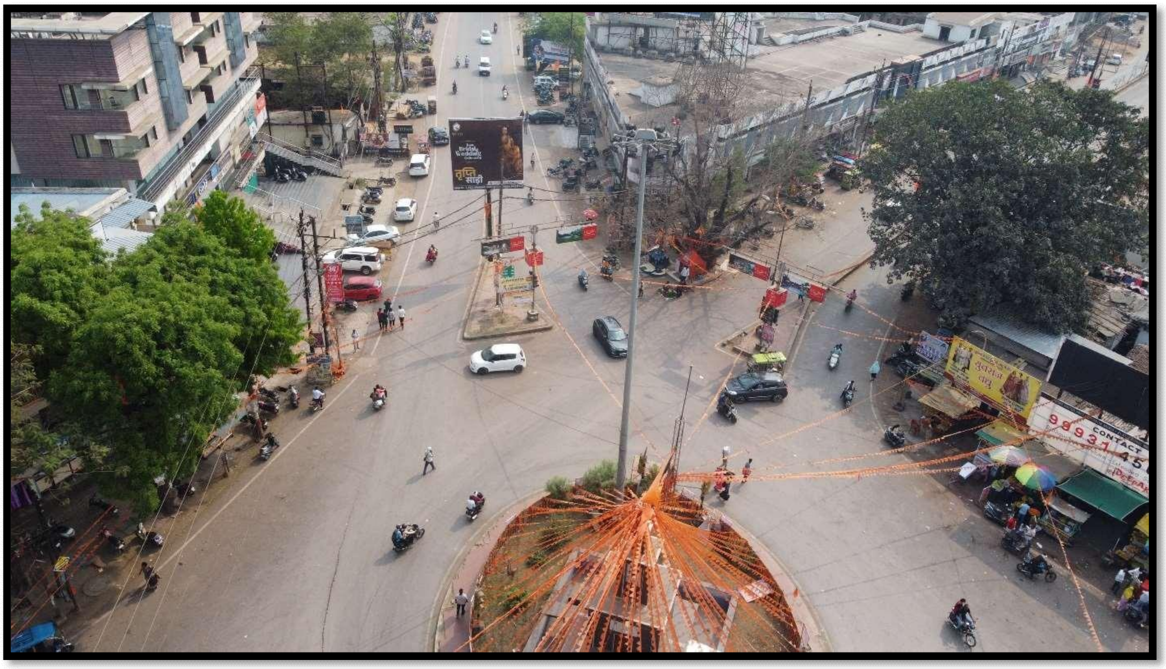
The radius at the entry of a rotary depends on factors such as design speed, super-elevation, and coefficient of friction. To make drivers reduce their speed, a small curvature is introduced at the entry, rather than having it be straight. For urban and rural designs, an entry radius of about 20 and 25 meters respectively is ideal.

The exit radius should be larger than both the entry radius and the radius of the rotary island. This allows vehicles to leave the rotary at a higher rate. Typically, the exit radius should be set to 1.5 to 2 times greater than the entry radius. However, if there is heavy pedestrian movement at the exit approach, the exit radius could be set to the same as the entry radius.

The size of the central island in a roundabout is determined by the design speed and the radius of the entry curve.

Typically, the central island is given a slightly larger radius than the entry curve to prioritize the movement of traffic that is already in the roundabout. A radius that is about 1.3 times larger than the entry curve is sufficient for practical purposes.

Figure-04 Lack of Sight Distance and Sharp Turning



Width of the rotary

The width of the rotary's entry and exit points is determined by the number of vehicles entering and leaving the intersection, as well as the width of the approaching road. To slow down the traffic, the width of the carriageway at the entry and exit points is lower than that at the approaching roads. The International Road Congress (IRC) recommends that a two-lane road with a width of 7 meters should be maintained at the same width for urban roads and reduced to 6.5 meters for rural roads. Additionally, a three-lane road with a width of 10.5 meters should be reduced to 7 meters for urban roads and 7.5 meters for rural roads. The weaving section should be wider than the entry and exit lanes, typically by one lane.

The carriageway width at exit

The width of the road at its exit point is known as the carriageway width. The smoothness of traffic merging and diverging on the road depends on the weaving length. This is determined by various factors such as weaving width, proportion of weaving traffic to non-weaving traffic, and so on. To ensure smooth traffic flow, the ratio of weaving length to weaving width should be high with a minimum suggested value of 4 by the IRC. However, a very large weaving length can be dangerous as it may encourage over-speeding

Capacity

The capacity of a rotary is determined by the capacity of each weaving section. The Transportation Road Research Lab (TRL) proposed the following empirical formula to find the weaving section's capacity.

$$Q = \frac{280w\left(1+\frac{e}{w}\right)(1-\frac{p}{3})}{1+\frac{w}{L}}$$

where:
e = average entry and exit width
w = weaving width
L = length of weaving
P = proportion of weaving traffic to the non-weaving traffic

$$p = \frac{b + c}{a + b + c + d}$$

The proportion of weaving traffic to non-weaving traffic in the rotary is in the range of 0.4 and 1.

PCU (Passenger Car unit):

The PCU equivalent factor may be considered as a measure of the relative space requirement of a vehicle class compared to that of a passenger car under a specified set of roadway traffic, and other conditions

It is a vehicle unit used for expressing highway capacity. PCU as per IRC based on types of vehicles:

Table No.1 Fast-Moving Vehicles

S.NO.	TYPES OF VEHICLES	PCU
1.	Motorcycles and scooters	0.5
2.	Passenger car, Pick-up van and auto-rickshaw	1.0
3.	Agricultural tractor and light commercial vehicles	1.5
4.	Single-unit Truck and Bus	3.0
5.	Truck-trailer and agriculture tractor-trailer	4.5

Table No.2 Slow-Moving Vehicles

3. PROBLEM FORMULATION & PROPOSED WORK

3.1 Introduction

S.NO.	TYPES OF VEHICLES	PCU
1.	Pedal Cycle	0.5
2.	Cycle Rickshaw	2.0
3.	Hand Cart	3.0
4.	Horse-drawn vehicle	4.0
5.	Bullock Cart	8.0

The Green Chowk Roundabout is a busy area, but its current layout is not conducive to the smooth flow of vehicles. There is a lack of signboards, and the road is inadequately designed for present conditions. Moreover, there is no drainage facility, leading to stagnant water accumulation during rainy days, impairing road visibility and causing traffic disruptions.

3.2 Problem Statement

1. The Green Chowk Roundabout is an important junction that connects to the Durg junction, Market Road, and National Highway 53. However, due to its high traffic volume, it is also a hotspot for road accidents. A recent survey revealed that the roundabout's current design is not conducive to smooth traffic flow.
2. The roundabout houses a waiting room for buses in the weaving section between the bridge and Station Road, which reduces the width of the carriageway. This, in turn, leads to critical conditions and an increased number of conflict points on the road, causing disruptions in other parts of the roundabout.
3. Moreover, there is a lack of signboards to warn drivers to slow down when entering the roundabout. According to IRC 65:2017 guidelines, vehicles should not exceed a speed of 40km/h when navigating the roundabout. However, vehicles frequently break this rule.
4. The Analysis of Passenger Car Unit (PCU) data and road dimensions, islands, central islands, entry and exit widths, weaving lengths, weaving widths, etc. indicates that the road is inadequately designed for current conditions.
5. Additionally, insufficient visible sight distance between two turning legs results in the formation of sharp turns within the roundabout section. In summary, the absence of drainage facilities in Green Chowk Roundabout leads to inconvenience during rainy days, with stagnant water accumulation in low camber areas, impairing road visibility, and causing traffic disruptions.

3.3 Proposed Work

Needs Assessment:

Understand the current challenges and limitations of existing multileg rotary systems in civil transportation, including traffic flow, safety concerns, and capacity issues.

Research and Analysis:

Conduct research on innovative designs, materials, and technologies relevant to multileg rotary systems, considering factors like traffic patterns, pedestrian access, and environmental impact.

Redesign according to IRC:

According to IRC standards, we have redesigned the rotary, determining new dimensions based on current traffic flow conditions and also exploring new capacity.

4. METHODOLOGY

1. Upon arriving at the rotary intersection, we engaged in a discussion about the accidents that have been occurring there recently. Subsequently, we measured the current dimensions of the road, splitter islands, and central islands, as per the Indian Road Congress (IRC) standards.
2. After that, we calculated the Passenger Car Units (PCU) of the rotary during three shifts: morning, afternoon, and evening, each lasting an hour, for a week.

3. By comparing the rotary intersection's capacity, based on the dimensions of the road and the manually calculated PCU data, we can assess its effectiveness.
4. Based on the comparison, we discovered that the actual capacity of the rotary intersection exceeds its design capacity. Following this analysis, we proceeded to redesign the rotary, taking into account the new PCU and considering future traffic growth.
5. The redesign involved widening of lanes, adjusting entry and exit points, and optimizing island placements to accommodate the increased traffic demand.

5. RESULT & DISCUSSION

5.1 Calculation

The capacity of the rotary based on the present dimension

$$Q = \frac{280w\left(1+\frac{e}{w}\right)(1-\frac{p}{3})}{1+\frac{w}{L}}$$

Note: Assume the proportion of weaving ratio = 0.8

- **Bridge to Station**

$$Q_1 = \frac{280(16\cdot3)\left(1+\frac{12\cdot8}{16\cdot3}\right)\left(1-\frac{0.8}{3}\right)}{1+\frac{16\cdot3}{34\cdot6}} = 4061.7273$$

- **Station to Gurudwara**

$$Q_2 = \frac{280(14)\left(1+\frac{10.5}{14}\right)\left(1-\frac{0.8}{3}\right)}{1+\frac{14}{42.4}} = 3781.9196$$

- **Guredwara to Indira market**

$$Q_3 = \frac{280(13)\left(1+\frac{9.5}{13}\right)\left(1-\frac{0.8}{3}\right)}{1+\frac{13}{16}} = 2548.9655$$

- **Indira Market to Bridge**

$$Q_4 = \frac{280(13.1)\left(1+\frac{9.6}{13.1}\right)\left(1-\frac{0.8}{3}\right)}{1+\frac{13.1}{41.8}} = 3548.8631$$

5.1.1 Calculation of PCU

Table no.03 Morning PCU Value

	Number Of PCU				
	Morning				
	Incoming	Outgoing-Left	Outgoing-Right	Outgoing-Straight	Total Outgoing
Road Name/Time	10am-11am	10am-11am	10am-11am	10am-11am	10am-11am
Gurudwara Road	517.5	112.625	112.625	225.25	450.5
Station road	427	96.125	96.125	192.5	384.5
Indiramarket Road	697	186.25	186.5	372.5	745
Bridge road	720	190.5	190.5	381	762
Total	**2361.5**				**2342**

Table no.04 Afternoon PCU Value

	Number of PCU				
	Afternoon				
	Incoming	Outgoing-Left	Outgoing-Right	Outgoing-Straight	Total Outgoing
Road Name/Time	1 PM-2 PM	1 PM-2 PM	1 PM-2 PM	1 PM-2 PM	1 PM-2 PM
Gurudwara road	977	232.5	232.5	465	930
Station road	685	172	172	344	688
Indira market road	1085	186.5	186.5	372.5	745.5
Bridge road	1194	308.5	308.5	617	1234
TOTAL	**3941**				**3957.5**

Table no.05 evening PCU value

	Number of PCU				
	Evening				
	Incoming	Outgoing-left	Outgoing-right	Outgoing-straight	Total outgoing
Road Name/Time	5 PM-6 PM	5 PM-6 PM	5 PM-6 PM	5 PM-6 PM	5 PM-6 PM
Gurudwara road	1110	275.5	275.5	551	1102
Station road	951	196.5	196.5	393	786
Inderamarket road	1180	250.5	250.5	501	1002
Bridge road	1695	386.75	386.75	773.5	1547
TOTAL	**4936**				**4437**

CAPACITY OF ROTARY BASED ON PRESENT TRAFFIC FLOW

Note: According to the traffic flow different weaving section has different proportion ratios.

Rotary capacity $(Q) = \frac{280w\left(1+\frac{e}{w}\right)(1-\frac{p}{3})}{1+\frac{w}{L}}$

- **Bridge to Station**

$$Q_1 = \frac{280(16\cdot3)\left(1+\frac{12\cdot8}{16\cdot3}\right)\left(1-\frac{0.746}{3}\right)}{1+\frac{16\cdot3}{34\cdot6}} = 4161.4242$$

- **Station to Gurudwara**

$$Q_2 = \frac{280(14)\left(1+\frac{10.5}{14}\right)\left(1-\frac{0.733}{3}\right)}{1+\frac{14}{42.4}} = 3897.0962$$

- **Gurudwara to Indra Market**

$$Q_3 = \frac{280(13)\left(1+\frac{9.5}{13}\right)\left(1-\frac{0.767}{3}\right)}{1+\frac{13}{16}} = 2587.2000$$

- **Indramarket to Bridge**

$$Q_4 = \frac{280(13.1)\left(1+\frac{9.6}{13.1}\right)\left(1-\frac{0.738}{3}\right)}{1+\frac{13.1}{41.8}} = 3648.8760$$

NOTE : We have compared the data regarding the "Capacity of the roundabout based on present dimensions" with the "Capacity of the roundabout based on present traffic flow".

Based on this analysis, we have concluded that the roundabout's dimensions are insufficient to accommodate the current traffic conditions.

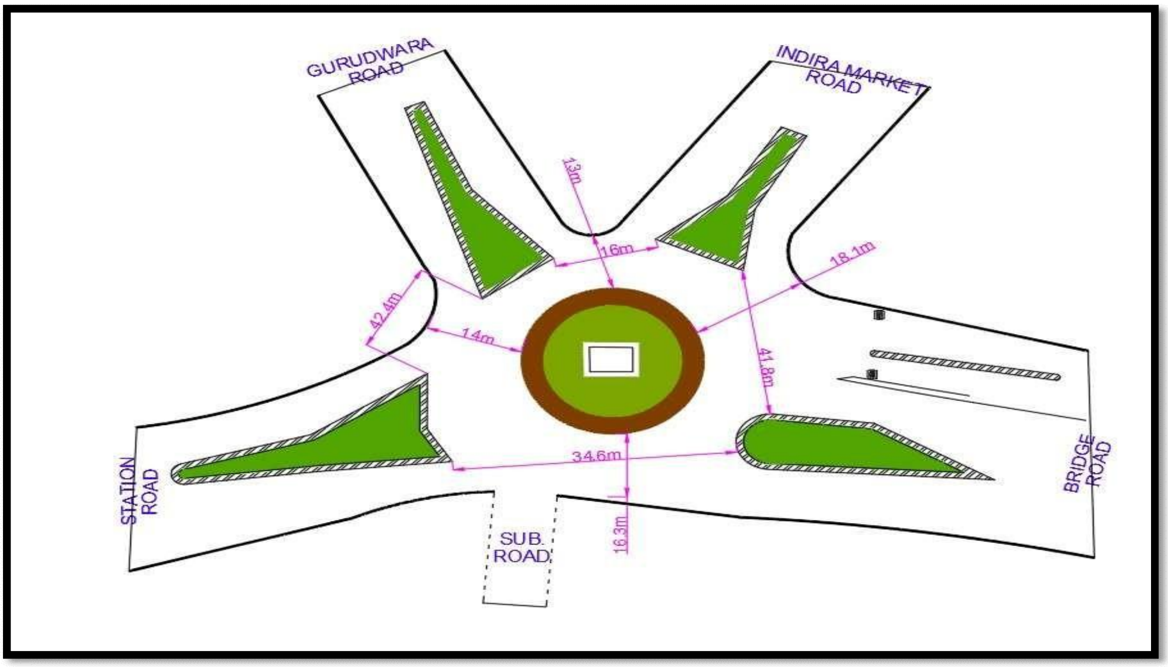


Figure.05 Present Condition of Rotary

Therefore, need a rise store design the roundabout and determine all the Requirements.

5.2 NEW CALCULATIONS

According to the Indian Road Congress (IRC), the ratio of weaving width to weaving length of the rundabout should fall within the range of 0.12 and 0.4.

For the maximum traffic condition, we consider the value of **0.4**.

$$\frac{w}{L} = 0.4$$

Relation between entry and exit radius with width of weaving section:

$$W = \frac{e_1+e_2}{2} + 3.5$$

Relation between average width and entry-exit width:

$$e = \frac{e_1+e_2}{2}$$

where :

e_1 = entry radius

e_2 = exit radius

W = width of weaving section

L = length of weaving section

We assume that the future PCU data will increase w.r.t. the present data Hence, The new value of capacity will be calculated as follows, considering an increase with an average rate of 5%.

Q_1= 4300,Q_2= 4100,Q_3= 2800 and Q_4= 4000

- **Bridge to Station**

$$\frac{280\,w\left(1+\frac{w-3.5}{w}\right)\left(1-\frac{0.746}{3}\right)}{1+0.4} = 4300$$

$w = 16.057$ m

L = 40 m

- **Station to Gurudwara**

$$\frac{280\,w\left(1+\frac{w-3.5}{w}\right)\left(1-\frac{0.733}{3}\right)}{1+0.4} = 4100$$

$w = 15.392$ m

L = 38.481m

- **Gurudwara to Indira Market**

$$\frac{280\,w\left(1+\frac{w-3.5}{w}\right)\left(1-\frac{0.767}{3}\right)}{1+0.4} = 2800$$

w = 11.154

L = 27.886 m

- **Indira Market to Bridge**

$$\frac{280\,w\left(1+\frac{w-3.5}{w}\right)\left(1-\frac{0.738}{3}\right)}{1+0.4} = 4000$$

w = 15.012

L = 37.531 m

5.3 Result

Based on collected data, we have obtained the following results through measurements and calculations:

Present Dimensions (according to the physical data collection) –

- Bridge Road –
  - W = 16.3
  - L = 34.6
  - e = 12.3

- Station Road –
  - W = 14
  - L = 42.4
  - e = 10.8
- Gurudwara Road –
  - W = 13
  - L = 16
  - e = 9.5
- Indira Market Road –

- W = 13.1
- L = 41.8
- e = 10

Calculated Dimensions (according to the increased capacity) –

- Bridge Road –
  - W = 16.06
  - L = 40
  - e = 12.56
- Station Road –
  - W = 15.39
  - L = 38.48
  - e = 12.56
- Gurudwara Road –
  - W = 11.5
  - L = 27.87
  - e = 7.65
- Indira Market Road –
  - W = 15.01
  - L = 37.53
  - e = 11.51

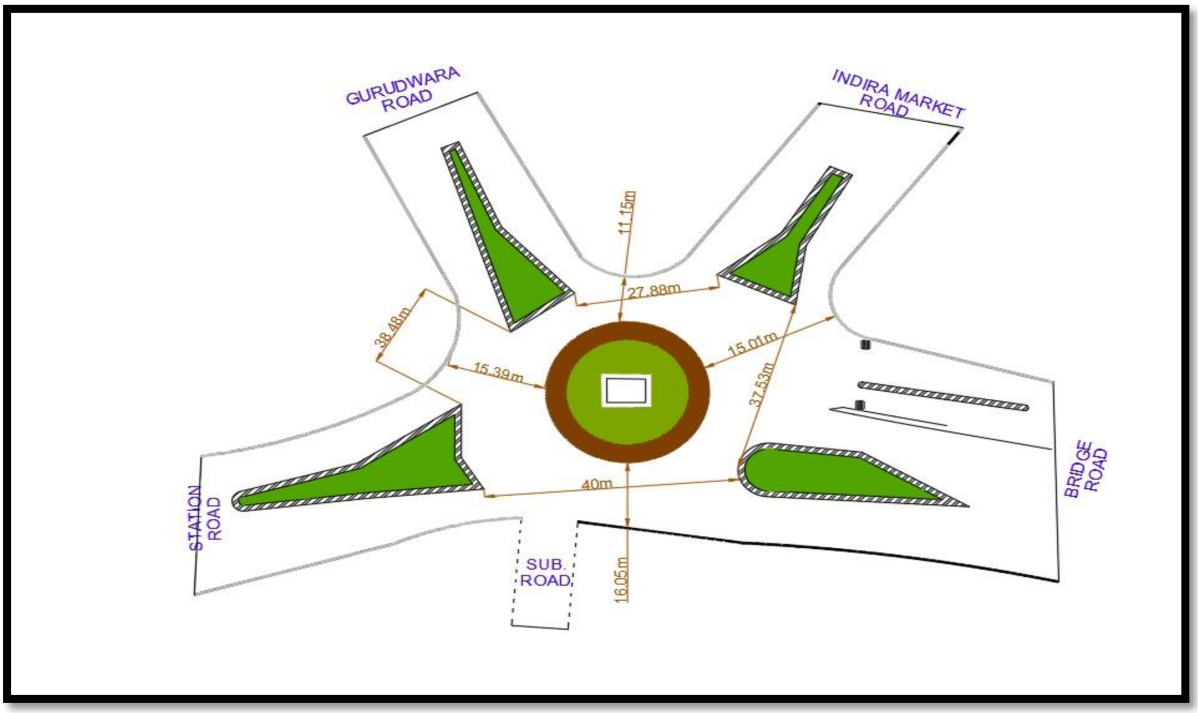


Figure. 06 Recommended Design of Rotary

These are the recommended values that should be considered based on the current traffic flow at the roundabout.

6. CONCLUSION

1. The current capacity of the rotary has been increased by 5%.
The present capacity is as follows:
Q1 = 4161.4242,
Q2 = 3897.0962,
Q3 = 2587.2000, and
Q4 = 3648.8760.
The recalculated capacity, which has been increased by 5% for future scope, is as follows:
Q1 = 4300,
Q2 = 4100,
Q3 = 2800, and
Q4=4000.
2. If there is a plan to make changes in the dimensions (width, length, CID, ICD, etc.) of the rotary due to future traffic increases, it should be noted that there is no space available for such alterations.

7. FUTURE SCOPE OF PROJECT

1. We suggest moving the street vendor's carts to a new complex along Indira Market Road. This will help free up space on the rotary carriageway and address the issue of vehicles blocking the carriageway due to roadside parking.
2. The upcoming construction of IIT Bhilai is expected to increase traffic flow along Bridge Road, which is the shortest route connecting Station Road and IIT Bhilai. Therefore, it is essential to redevelop the bridge to accommodate the anticipated rise in traffic volume.
3. The passenger waiting room within the weaving length of the rotary carriageway, serving as a bus stop, contributes to road blockages. We recommend eliminating the rotary bus stop since there is a bus stand nearby. This will alleviate congestion and ensure smoother traffic flow.
4. Implementing smart traffic management systems, such as intelligent signaling, dynamic lane allocation, and real-time traffic monitoring, can optimize traffic flow and minimize congestion.
5. To promote safer and more accessible pedestrian movement within and around the rotary, it is recommended to enhance pedestrian crossings, sidewalks, and pedestrian-friendly amenities.

8. ACKNOWLEDGEMENT

Our project was a great success, thanks to the outstanding mentorship provided by Mrs. Deepa Sahu. As a faculty member in the Department of Civil Engineering at Bhilai Institute of Technology, Mrs. Sahu's remarkable personality, guidance, and encouragement were the driving force behind our progress. We are extremely grateful to her and cannot thank her enough for her timely and invaluable advice. Her contributions have been invaluable to this project, and we are fortunate to have had her as our mentor.

9. LITERATURE REVIEW

9.1 ASSESSMENT STUDY AND DESIGNING OF ROTARYINTERSECTION AT BAJAJ SQUARE WARDHA

Mohan R. Wake, Dr Bharati Sunil Shete, Prof. Ashish Bijawe.

Article from International Research Journal of Engineering and Technology (IRJET).

Bajaj Square is one of the busiest intersections in Wardha, serving as a junction through which several vehicles enter and leave the city. However, due to the high volume of traffic passing through the square, it faces numerous problems such as collisions, long queues leading to traffic jams, pedestrian traffic issues and improper handling of traffic during peak hours. The ongoing construction activity near the square has exacerbated the problem of traffic congestion. The nearby Bhaji market and bus stand add to the traffic volume, making it difficult for the present design of the rotary intersection to handle the current traffic scenario, let alone any future increase in traffic.

9.2 DESIGN OF A ROTARY FOR AN UNCONTROLLED MULTI-LEGINTERSECTION IN CHENNAI, INDIA
S. Vasantha Kumar, Himanshu Gulati (VIT University), ShivamArora (Roorkee)
IOP Conference Series Materials Science and Engineering

A roundabout or rotary intersection is a type of intersection that is used to control traffic at busy intersections. This type of intersection requires all vehicles to move around a central island in a clockwise direction. The purpose of this study is to design a rotary for an uncontrolled multi-leg intersection located in Royapetah, Chennai, India. The intersection has five approach roads with two-way traffic in all the approach roads, and currently, there is no signal or traffic police to control the traffic, which leads to traffic chaos during peak hours. In order to design the rotary, traffic volume information from the approach roads is essential. To collect the traffic volume information, video data was collected for eight hours on a typical working day using a handy cam from the terrace of an apartment building located near the intersection. During the data extraction stage, each five-minute traffic volume was extracted for all the five classes of vehicles considered and was converted to passenger car units (PCU). The analysis of traffic data showed that during peak hours, from 4.45 pm to 5.45 pm, the proportion of weaving traffic, i.e., the ratio of the sum of crossing streams to the total traffic on the weaving section was found to be 0.81. According to Indian Road Congress (IRC) guidelines, this proportion can take any value between 0.4 and 1, and in the present study, the calculated value is found to be within the prescribed range. Using the calculated values of the average entry width of the rotary and the width and length of the weaving section, the practical capacity of the rotary was found to be 3020 PCUs, which is well above the observed traffic volume of 2665 PCU's. Well above the observed traffic volume of 2665 PCUs. Choose our rotary design for an efficient and safe traffic solution at your busy intersection.

9.3 DESIGN OF ROTARY INTERSECTION IN TUMAKURU CITYPrakash J, Supriya C B, Dr. T V Mallesh, Dr. B H Manjunath.
Department of Civil Engineering
S.S.I.T, SSAHE University, Tumakuru, Karnataka, India
This paper discusses the design study of a rotary intersection situated at Kunigal Circle on the Tumakuru ring road. This road provides connectivity between Ring Road circle NH-206 and Kyatsandra toll gate NH-48. During peak hours, traffic increases by 50% than normal regular traffic, making the regulation of traffic at this circle very difficult.

To ensure safe traffic movement, it is necessary to provide a suitable intersection, which may be a rotary intersection, a signalized intersection, or a grade-separating intersection. However, in this circle, a rotary intersection is deemed the most suitable option. The practical capacity of a rotary intersection obtained is 4746 PCU/Hr, and this intersection can bear a value of up to 5000 PCU/Hr. The selected intersection is suitable for a roundabout.

9.4 NEW CONCEPT OF TRAFFIC ROTARY DESIGN AT ROADINTERSECTIONS S.K. Mahajan, Anshul Umadekar, Kruti Jethwa
Department of Civil Engineering
RCET, Khoka, Bhilai 491001, Chhattisgarh, India

With the rapid growth of traffic, it has become necessary to implement a special form of grade change of lanes to channel the movement of vehicles in one direction around a central traffic island known as a Traffic Rotary at road intersections. Widening of roads and providing flyovers have also become necessary to resolve major conflicts at intersections, such as collisions between through and right turn movements.

By implementing a Traffic Rotary, major conflicts are converted into milder ones like merging and diverging. As vehicles enter the rotary, they are gently forced to move in a clockwise direction. They then weave out of the rotary in the desired direction. To avoid crossing conflicts, all vehicles are allowed to merge into a stream around the rotary and then diverge out to the desired radiating road, thus eliminating crossing conflicts and converting them into weaving maneuvers or merging/diverging operations.

9.5 STUDY AND DESIGN OF ROTARY INTERSECTION AT SBI JUNCTION, YAVATMAL
Prof. S.R. Raut, Deep Korde, Yash Taywade, Prajkta Kamble, Vishal Durwe
Research paper from International Research Journal of Modernization in Engineering Technology and Science.

The project studied and designed a rotary intersection at SBI Chowk in Yavatmal, where five roads intersected. Previously, no rotary intersection existed at the site. The aim was to propose a hypothetical design for future construction, considering the worsening traffic congestion due to increased vehicle growth. Instead of relying on traffic signals and stop signs, the project aimed to improve traffic flow and safety by implementing a rotary island. Rotary intersections facilitate one- way traffic flow around a central island, with vehicles yielding to those already in the circle before exiting. They have the potential to reduce accident frequency and severity, contingent upon proper design, implementation, and driver understanding of road signs and traffic rules, along with engineers' planning and execution.

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