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Empirical Evaluation And Geometric Optimization Of The TGB Circle Rotary Intersection, Surat City

Mayuri J. Patel[1,*], Dixit N. Patel[1], Nirav D. Parmar[1], Mayank A. Patel[2], Urvesh N. Barot[2]
[1]Assistant Professor, Civil Engineering Department, Dr. S. & S. S. Ghandhy Government Engineering College, Surat, Gujarat, India.
[2]Assistant Professor, Applied Mechanics Department, Dr. S. & S. S. Ghandhy Government Engineering College, Surat, Gujarat, India.
[*]Corresponding author. E-mail addresses: patelmayuri254@gmail.com

ABSTRACT
This study presents a detailed assessment of traffic congestion and safety conditions at the TGB Circle rotary intersection in Surat city. Surat is a city which is rapidly expanding its urban center and experiencing increasing traffic demand. Comprehensive traffic volume surveys were carried out on all four approaches of the rotary during peak hours, and the collected data were converted into Passenger Car Units (PCU) in accordance with Indian Roads Congress (IRC) guidelines to ensure consistency and accuracy in analysis. Traffic movement characteristics, including directional distribution and weaving proportions, were systematically examined to understand operational performance at the intersection.
In addition, detailed measurements of the existing geometric elements such as entry width, weaving width, and central island dimensions—were undertaken to evaluate their adequacy with respect to prevailing traffic conditions. The practical capacity of the rotary was estimated using IRC's empirical capacity equations and was found to be sufficient to accommodate the current peak-hour traffic volumes. Despite adequate capacity, the findings reveal operational and safety concerns arising from geometric limitations and traffic behaviour. The study therefore emphasizes the need for selective geometric redesign and operational improvements to enhance traffic efficiency, minimize conflicts, and improve overall safety at this important urban junction.
Keywords: *Rotary Intersection, Roundabout Design, Traffic Flow Analysis, Traffic Congestion, Urban Intersection, Passenger Car Unit (PCU).*

1. INTRODUCTION

Urbanization and rapid economic growth in Indian cities have led to a dramatic increase in vehicular traffic, resulting in frequent congestion and heightened safety risks at major intersections. Surat, one of Gujarat's fastest-growing metropolitan areas, exemplifies these challenges due to its thriving textile, diamond, and industrial sectors, which attract significant migration and daily commuter flows. The city's expanding population and rising vehicle ownership have placed considerable pressure on its transportation infrastructure, particularly at key junctions such as the TGB Circle rotary intersection.

The TGB Circle, located at the convergence of four major arterial roads—Adajan, Pal Gam, Star Bazar, and L.P. Savani—serves as a critical node in Surat's urban road network. This intersection experiences substantial traffic volumes throughout the day, with pronounced peaks during morning and evening rush hours. As shown in the attached schematic, the intersection accommodates complex traffic movements, including right, left, and straight maneuvers from each approach, with directional flows often exceeding 1,000 vehicles per hour in multiple arms during peak periods. Despite its importance, the TGB Circle currently lacks traffic signals and active police regulation, further exacerbating congestion and increasing the risk of collisions.

According to the World Health Organization's Global Status Report on Road Safety, major causes of urban traffic collisions include speeding, failure to yield, and improper turning maneuvers—issues that are particularly acute at unsignalized, high-volume intersections like TGB Circle. At such locations, the cumulative delay for all users increases, as vehicles are forced to slow down and negotiate the intersection, regardless of actual demand. The absence of a well-designed control system or rotary geometry can lead to inefficient traffic flow, increased conflict points, and elevated accident rates.

To address these challenges, the Indian Roads Congress (IRC) provides comprehensive guidelines for the design and analysis of rotary intersections (IRC-65:1976), recommending the use of circular or elliptical rotaries with appropriate geometric features to facilitate safe merging, diverging, and weaving of traffic streams. The design and capacity assessment of a rotary require accurate data on traffic volumes, movement patterns, and the physical dimensions of the intersection. For this study, detailed traffic counts were conducted at TGB Circle using videography and manual observations over an eight-hour period, capturing all vehicle classes and movement directions in 15-minute intervals. Field measurements established the intersection's geometric properties, including a circular central island with a 9.5 meter radius, entry and exit widths of 8.5 meters, a weaving width of 15 meters, and a weaving length of 38 meters.

The primary objective of this research is to analyze the current operational performance of the TGB Circle rotary, quantify its capacity using IRC recommended empirical methods, and propose geometric and operational improvements to enhance traffic safety and efficiency. By converting observed traffic volumes to Passenger Car Units (PCU) and evaluating the proportion of weaving traffic, the study aims to determine whether the existing rotary can accommodate present and projected demand, and to identify design modifications that can mitigate congestion and reduce accident risk. The findings are intended to inform urban traffic management strategies in Surat city and provide a model for similar intersections in other rapidly urbanizing cities.

2. LITRATURE REVIEW

Rotary intersections have been widely adopted as an effective form of at-grade intersection control due to their ability to reduce conflict points, regulate vehicular speeds, and improve overall safety and operational efficiency. Standard design and evaluation procedures for rotary intersections are primarily guided by national and international manuals such as **IRC:65–1976[1]**, **IRC:65–2017[2]**, and the **Highway Capacity Manual (HCM 2010)[3]**.

Studies conducted in Indian cities such as Vadodara, Chennai, Ahmedabad, and Surat highlight that inadequate geometric design and increased traffic demand often lead to congestion, reduced entry capacity, and excessive delays at rotaries. Capacity evaluation based on **IRC guidelines** and **weaving section analysis** has shown that parameters such as entry width, weaving length, circulating width, and proportion of weaving traffic significantly influence rotary performance[4]. These studies stress the need for redesign or geometric optimization to accommodate current and future traffic volumes.

Several researchers have compared different **roundabout capacity estimation methods**, including empirical models, gap-acceptance models, and simulation-based approaches. Comparative studies reveal that commonly used models such as IRC, HCM, SIDRA, and RODEL often overestimate capacity, especially for multi-lane roundabouts, while their accuracy varies with local traffic and geometric conditions[5][6]. Calibration using field data is therefore essential for realistic capacity prediction.

Under heterogeneous traffic conditions, modifications to standard HCM equations have been proposed to account for reduced critical gaps and follow-up times caused by mixed vehicle types. Such calibrated models have been found more suitable for Indian traffic conditions and are important for geometric optimization and operational evaluation of rotaries[7].

Beyond operational performance, environmental and safety impacts have also been investigated. Studies comparing roundabouts with signalized intersections indicate that although roundabouts generally improve safety and reduce severe conflicts, their environmental performance may vary depending on congestion levels and geometric layout[8] [9]. Advanced designs such as turbo and elliptical roundabouts demonstrate better performance under specific traffic conditions, emphasizing the importance of selecting an appropriate geometry during the design stage.

Studies, such as those conducted at the Anjali roundabout in Ahmedabad [10]and Simada Naka in Surat[11], utilize classified traffic volume counts and PCU (Passenger Car Unit) conversions to estimate entry capacity and evaluate the level of service under heterogeneous traffic conditions. These evaluations are essential for planners to decide between maintaining a roundabout or implementing alternative traffic management solutions.

Vasantha Kumar [12]designed a rotary for an uncontrolled multi-leg intersection in Chennai using IRC-based geometric and capacity analysis. Their findings revealed that proper geometric design, especially adequate weaving width and length, can significantly improve traffic operations at complex intersections.

Overall, the literature indicates that **effective evaluation and geometric optimization of rotary intersections require an integrated approach**, combining field data, calibrated capacity models, and simulation techniques. Such an approach is particularly crucial in urban areas with heterogeneous traffic to ensure improved capacity, reduced delay, enhanced safety, and lower environmental impacts.

3. METHODOLOGY

The methodology for analyzing and designing the rotary intersection at TGB Circle, Surat, involved a systematic, multi-step approach in accordance with IRC guidelines and best practices in traffic engineering. The process began with the selection of the study area, focusing on TGB Circle due to its high traffic volumes and strategic importance in Surat's urban road network. An initial site reconnaissance was conducted to understand the intersection's geometry, traffic patterns, and operational issues.

Traffic data collection was performed using both manual counting and videography to ensure accuracy and comprehensive coverage. Surveys were conducted during both morning and evening peak hours on a typical working day, with data recorded in 15-minute intervals. The data collection focused on all four approaches—Adajan, Pal Gam, Star Bazar, and L.P. Savani capturing vehicle movements in right, left, and straight directions. Vehicles were classified into two-wheelers, three-wheelers, cars, and heavy vehicles.

Simultaneously, field measurements of the intersection's geometric features were taken, including the radius of the central island, entry and exit widths, weaving width, and weaving length. This ensured that the subsequent design would be grounded in the actual site conditions.

The recorded vehicle counts were then extracted and processed, with all movements and classes tabulated for each approach and direction. Using IRC recommended Passenger Car Unit (PCU) conversion factors, raw counts were standardized for analysis. The peak hour was identified by analyzing the time intervals with the highest traffic volumes.

Next, a detailed analysis of traffic movements was conducted, identifying the proportions of merging, diverging, and weaving traffic for each approach. The proportion of weaving traffic (p) was calculated using the IRC formula, which is critical for capacity analysis.

The practical capacity of the rotary was then estimated using the IRC empirical formula, incorporating the measured geometric parameters and the calculated weaving proportion. The estimated capacity was compared against the observed peak hour demand to assess the adequacy of the existing or proposed design.

Finally, based on the findings, rotary design recommendations were formulated, including geometric improvements, signage, and operational enhancements to ensure safe and efficient movement at the intersection.

4. DATA COLLECTION

4.1. Study Location

The selected study area is the TGB Circle rotary intersection in Surat city, Gujarat, India. This is a major four-legged intersection where four arterial roads converge: Adajan, Pal Gam, Star Bazar, L.P. Savani.

The intersection is characterized by high traffic volumes, especially during peak hours, and currently operates without traffic signals or police regulation, making it an ideal case for rotary design improvement.

Figure 1. TGB Circle Intersection (Source: Google Maps)

4.2. Data Collection Methodology

a) Survey Timing and Approach

Date & Time: Data was collected on a typical working day during both morning and evening periods to capture peak traffic conditions.

Duration:

Morning: 7:00 am to 12:00 pm, Evening: 6:00 pm to 10:00 pm, Peak Hour Focus: Detailed analysis was performed for the peak hour (10:15 am to 12:15 pm).

Technique:

Videography: A mobile camera was set up at a vantage point near the intersection to record continuous traffic movement.
Manual Counting: Supplementary manual counts were performed to validate video data.

b) Vehicle Classification

Traffic was classified into five categories, as per IRC guidelines: Two-wheelers (2W), Three-wheelers (3W), Passenger Cars, Light Commercial Vehicles (LCV), Heavy Vehicles (HV),

c) Data Extraction

Interval: Traffic volumes were extracted in 15-minute intervals for all approaches and turning movements.
Directions: All 18 possible movement directions (right, left, straight for each approach) were considered.
Conversion: Raw vehicle counts were converted to Passenger Car Units (PCU) using IRC-recommended factors: 2W = 0.5 PCU, 3W = 1.0 PCU, Car = 1.0 PCU, HV = 3.0 PCU.

d) Field Measurements

Manual field measurements were taken to record the geometric features of the intersection:
Shape: Circular
Central island radius: 9.5 m
Average entry/exit width: 8.5 m
Weaving width: 15 m
Weaving length: 38 m
3. Collected Traffic Data (Peak Hour Sample)

A. Pal Gam to Adajan

Table No. 1 Pal Gam to Adajan traffic movement

Movement	2W	3W	Car	HV	Total
Right	243.5	19.5	63	9	335
Left	89	11	37	3	140
Straight	379	36.5	112	5.5	533

B. Star Bazar to L.P. Savani

Table No 2 Star Bazar to LP Savani Traffic Movement

Movement	2W	3W	Car	HV	Total
Right	336	23	63	3	425
Left	129	39	23	3	194
Straight	440	199	195	33	867

C. Adajan to Pal Gam

Table No 3 Adajan to Pal Gam traffic movement

Movement	2W	3W	Car	HV	Total
Right	106	134	182	5	427
Left	789	118	274	4	1185
Straight	211	176	122	3	512

D. L.P. Savani to Star Bazar

Table No 4 LP Savani to Star Bazar

Movement	2W	3W	Car	HV	Total
Right	184.5	19.5	63	9	276
Left	89	11	37	3	140
Straight	185	36.5	112	5.5	339

5. SUMMARY OF DATA COLLECTION PROCESS

Traffic data was systematically collected for all approaches and turning movements at TGB Circle. The use of both videography and manual counting ensured high accuracy and reliability. Data extraction in

15-minute intervals allowed identification of true peak hour conditions. Vehicle classification and PCU conversion enabled standardized analysis as per IRC recommendations. Field measurements of geometric features provided necessary input for rotary design calculations. The procedure for design of such rotaries having only four legs intersecting at right angles is simple and straightforward as given in IRC guidelines. According to Indian Road Congress (IRC) guidelines (IRC-65, 1976), a rotary can be of either circular, elliptical, oval, rectangular shape with four approach roads/legs or it can be of complex intersection with many approaches.
In the present study design the for leg rotary intersection at TGB circle Surat city. Videography carried out at the junction for the current traffic volume data and field measurement manually. The data collection was carried out for a duration of eight hours from 7:00 am to 12 am morning and 6:00 pm to 10:00 pm in the evening on a working day using a mobile camera from appropriate location near the TBG intersection. Every 15 minutes, traffic volume was extracted for all the five classes of vehicles considered, namely, two-wheeler, three-wheeler, passenger cars, light commercial vehicles (LCV) and heavy commercial vehicles (HCV). A total of 18 directions of traffic movements were considered while extracting the 15 minutes traffic volume data. The class-wise traffic volumes observed from videography were converted to passenger car units (PCU) using the PCU factors suggested in IRC guidelines.
Field measurement was done manually for the actual dimension of the TGB Circle. The dimension of the intersection is in the circular shape rotary with 9.5 m radius, average entry and exit width 8.5 m, width of weaving section 15 m, length of weaving section 38 m.

6. DATA ANALYSIS

At intersections like TGB Circle, traffic consists of a mix of vehicle types two-wheelers, three-wheelers, cars, and heavy vehicles. Each vehicle type affects traffic flow differently due to its size, speed, and maneuverability. To analyze and design intersections accurately, these mixed vehicle counts are converted to a common unit called the Passenger Car Unit (PCU), following IRC guidelines.

A. Pal Gam to Adajan

Table 5. Pal Gam to Adajan with PCU

Movement	2W PCU	3W PCU	Car PCU	HV PCU	Total PCU
Right	121.75	19.5	63	27	231.25
Left	44.5	11	37	9	101.5
Straight	189.5	36.5	112	16.5	354.5

Total PCU for Pal Gam to Adajan = 231.25 + 101.5 + 354.5 = 687.25

B. Star Bazar to L.P. Savani

Table 6. Star Bazar to LP Savani

Movement	2W PCU	3W PCU	Car PCU	HV PCU	Total PCU
Right	168	23	63	9	263
Left	64.5	39	23	9	135.5
Straight	220	199	195	99	713

Total PCU for Star Bazar to L.P. Savani = 263 + 135.5 + 713 = 1,111.5

C. Adajan to Pal Gam

Table 7. Adajan to Pal Gam

Movement	2W PCU	3W PCU	Car PCU	HV PCU	Total PCU
Right	53	134	182	15	384
Left	394.5	118	274	12	798.5
Straight	105.5	176	122	9	412.5

Total PCU for Adajan to Pal Gam = 384 + 798.5 + 412.5 = 1,595

D. L. P. Savani to Star Bazar

Table 8. LP Savani to Star Bazar

Movement	2W PCU	3W PCU	Car PCU	HV PCU	Total PCU
Right	92.25	19.5	63	27	201.75
Left	44.5	11	37	9	101.5
Straight	92.5	36.5	112	16.5	257.5

Total PCU for L.P. Savani to Star Bazar = 201.75 + 101.5 + 257.5 = 560.75

Sum Total PCU at Intersection (Peak Hour)

Pal Gam to Adajan: 687.25, Star Bazar to L.P. Savani: 1,111.5, Adajan to Pal Gam: 1,595, L.P. Savani to Star Bazar: 560.75,

Grand Total PCU (Peak Hour): 687.25 + 1,111.5 + 1,595 + 560.75 = **3,954.5 PCU/hr**

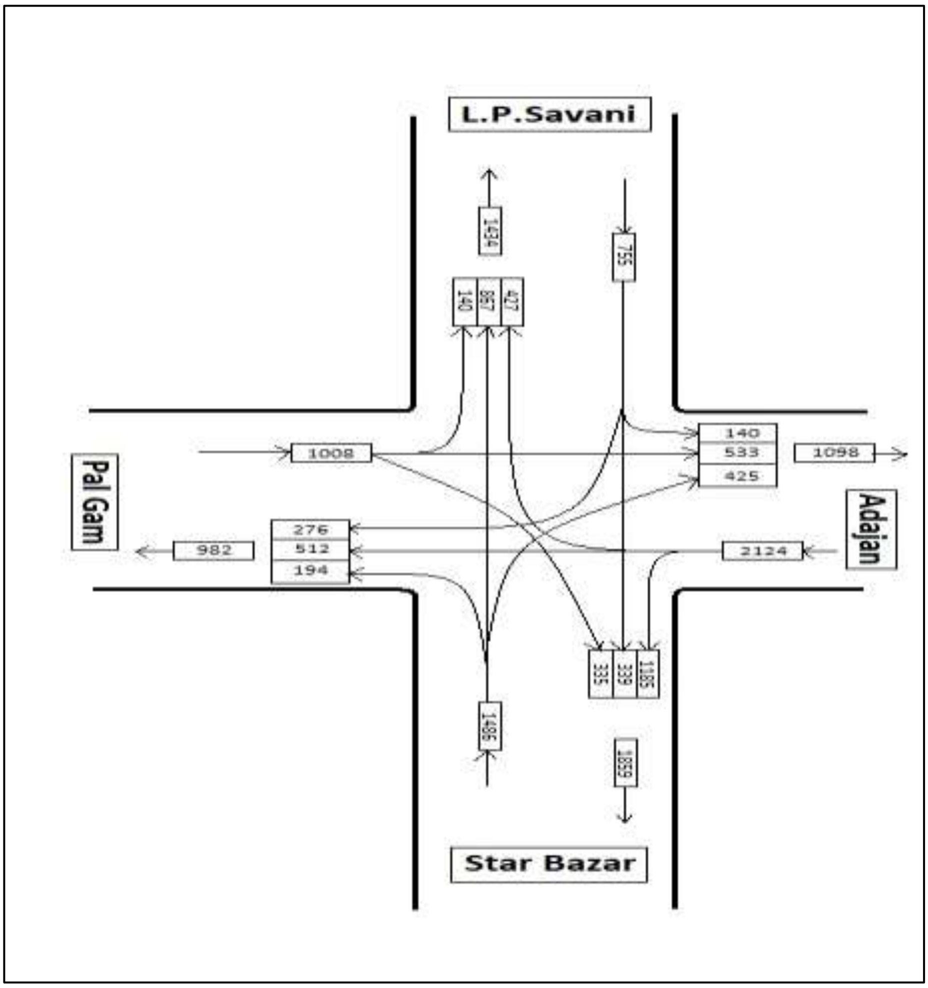

Figure 2 PCU wise movement at TGB Junction

6.1. Directional Flow Analysis

The attached Figure 2 shows the intersection with labeled traffic flows for each direction. The north-south direction (Star Bazar to L.P. Savani and vice versa) and east-west direction (Pal Gam to Adajan and vice versa) both carry substantial volumes, but the highest flows are observed in the north-south direction. This is consistent with field observations and the numerical data.

Peak Hour and Movement Patterns

Peak Hour Identified: 10:15 to 11:15 am, when the total volume approaches 3,954.5 PCU/hr.

Movement Patterns

Straight movements have the highest volumes on all arms, especially from Star Bazar to L.P. Savani (867 vehicles/hour) and Adajan to Pal Gam (512 vehicles/hour). Right and left turns are significant but lower than straight movements.

Vehicle Mix

Two-wheelers and cars dominate the traffic, reflecting typical Indian urban traffic composition.

6.2. Interpretation and Implications

High Traffic Volume: The intersection handles nearly 4,000 PCU/hr during the peak hour, indicating a high level of demand and potential for congestion.

Directional Imbalance:

The north-south axis (Star Bazar to L.P. Savani) sees the highest flows, suggesting that any geometric or signal improvements should prioritize these movements.

Weaving Traffic:

The mix of right, left, and straight movements leads to significant weaving within the rotary, which is a critical factor for capacity and safety analysis.

Design Adequacy:

According to the IRC rotary capacity formula, the calculated capacity (using geometric parameters and weaving proportion) is slightly above the observed demand, but only with a small buffer. This suggests the intersection is operating near its design limits during peak periods.

Proportion of Weaving Traffic (p):

The proportion of weaving traffic is calculated as per IRC:

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

Where,

a, d = non-weaving flows, b, c = weaving flows

From the study and data, the maximum p = 0.71 (as per the L.P. Savani approach).

Rotary Capacity Calculation (IRC Formula):

IRC Empirical Formula:

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

Where,

w = weaving width (m) = 15

e = average entry width (m) = 12

L = length of weaving section (m) = 38

p = proportion of weaving traffic = 0.71

Plug in the values:

$$Qp = \frac{280*15\,(1+\frac{12}{15})(1-\frac{0.71}{3})}{1+\frac{15}{38}}$$

$$Qp = \frac{5771.6}{1.3947} = 4139.3$$

Rotary Capacity (Qp): ≈ 4,139 PCU/hr

7. CONCLUSION

1) Peak Hour Demand: 3,954.5 PCU/hr

This value represents the total volume of traffic (converted to Passenger Car Units, or PCU) entering the rotary from all approaches during the busiest one-hour period of the day. It reflects the maximum load the intersection must handle to avoid congestion and excessive delays.

2) Rotary Capacity: 4,139 PCU/hr

This is the maximum volume of traffic that the rotary can safely and efficiently accommodate in one hour, based on its geometric design (entry/exit widths, weaving width and length, etc.) and traffic movement patterns. This value is calculated using the Indian Roads Congress (IRC) empirical formula, which considers the rotary's physical dimensions and the proportion of weaving traffic.

3) The Comparison: Capacity > Demand:

The rotary's capacity (4,139 PCU/hr) is greater than the observed peak hour demand (3,954.5 PCU/hr).

4) Buffer: There is a buffer of about 185 PCU/hr (4,139 - 3,954.5 = 184.5), meaning the rotary can handle slightly more traffic than currently observed without becoming overloaded.

5) Operational Implication: Under current conditions, the rotary should function efficiently, with manageable delays and minimal congestion during peak times.

6) Future Consideration: Since the buffer is not very large, any significant increase in traffic (due to urban growth, new developments, or modal shifts) could push the rotary beyond its capacity, leading to congestion, longer delays, and increased risk of accidents.

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