# Performance Analysis of 4-legged Intersection Under Heterogeneous Traffic Condition

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**Abstract** - In the modern era, India is experiencing significant economic development, and the field of traffic engineering plays a crucial role in shaping this progress. As India endeavors to build smart cities, efficient traffic management becomes paramount. The seamless flow of traffic is of utmost importance to ensure optimal functioning within these smart cities. Consequently, the focus of this research paper is to identify and address the challenges present in the traffic systems of Indian cities.

Specifically, this study centers around a 4-legged intersection located at Engineering College Chauraha in Lucknow. This intersection holds great significance in Lucknow as it serves as a vital connection between Sitapur and Ayodhya. By examining this particular intersection, we aim to shed light on the issues faced in its traffic system.

Data collection involved conducting observations during weekday peak periods from 5:30 pm to 6:30 pm. To classify the traffic accurately, video recordings were utilized, categorizing vehicles into three distinct types: light vehicles, heavy vehicles, and bicycles. The operational performance analysis of the intersections was subsequently carried out using the powerful SIDRA INTERSECTION software.

The findings reveal that the intersection is operating close to its maximum capacity, yet it fails to provide an adequate level of service (LOS) considering the high volume of traffic it handles. The analysis of the volume to capacity (v/c) ratio indicates that the intersection is in an unstable state. In summary, the results strongly indicate the necessity for improvements to enhance the intersection's performance.

***Key Words***: *Heterogeneous traffic, Capacity, Level of service, SIDRA Intersection Software*

## 1.INTRODUCTION

The core objective of my research is to investigate the optimal design and performance characteristics of roundabouts. To accomplish this, I employed the advanced SIDRA INTERSECTION software, enabling me to simulate and evaluate various roundabout design configurations. By considering essential factors such as traffic volume, vehicle types, and geometric measurements, I aim to derive valuable insights into the design principles and performance indicators of roundabouts. The findings from this research will serve to enhance transportation planning and traffic management strategies, ultimately contributing to more efficient and effective traffic systems.

Roundabouts represent specialized at-grade intersections that facilitate the smooth flow of vehicles by guiding them in a unified direction around a central island, allowing them to exit toward their desired destinations [1]. While roundabouts have long been established in Europe and Australia, their adoption has extended to countries like India and beyond. Roundabouts offer an efficient alternative to traditional traffic lights, particularly in intersections with lower traffic volume, leading to decreased delays, enhanced management of left turns, reduced accidents, and moderated vehicle speeds. Moreover, roundabouts offer benefits such as cost-effective maintenance and the potential for incorporating landscaping features within their central islands [2].

However, it is crucial to highlight that the design of roundabouts often overlooks vital elements such as swept path analysis, which holds significant importance in intersection design, including roundabouts. Unfortunately, improper design of intersections and roundabouts has resulted in a distressing average of 415 daily fatalities in India, as reported by the Ministry of Road Transport and Highways [3]. In order to achieve sustainable infrastructure objectives that prioritize environmental protection and resource conservation, roundabouts can play a pivotal role. By obviating the need for energy-intensive traffic lights and reducing accidents, roundabouts contribute to a more efficient flow of traffic. It is evident that implementing roundabouts can help create a safer and more sustainable transportation network[4].

Previous research indicates that both roundabouts and 3-4 leg intersections exhibit unstable operational performance when operating at maximum capacity, primarily due to the substantial influx of traffic into the roundabout [5]. Consequently, it becomes imperative to conduct a thorough analysis of roundabout junction capacity and perform swept path analysis. Several factors need to be taken into account, including traffic delays, operational costs, level of service, accident rates, and environmental impact [6]. Consequently, roundabouts are increasingly replacing conventional intersections, and critical considerations such as alignment, swept path analysis, and sight distance significantly influence the geometric design of roundabouts [7].

In a recent study conducted by Abdul Awwal and Aarish Khan (2020), the performance of a roundabout and a 3-leg intersection in Aligarh city underwent meticulous analysis utilizing the advanced SIDRA INTERSECTION software. The study findings uncovered significant shortcomings in terms of maximum capacity and level of service (LOS) when faced with high traffic volumes. Both the intersection and roundabout exhibited an unstable volume to capacity (V/C) ratio, suggesting a pressing need for substantial improvements and optimization measures.

In a comprehensive analysis conducted by Young-Joo Lee, Wonho Suh, et al. (2018), the capacity of roundabouts was thoroughly examined using mathematical modeling and microscopic simulation techniques with VISSIM. The study revealed that the capacity of roundabouts is closely tied to the gap acceptance model. The results, derived from simulations and mathematical models, demonstrated that the Highway Capacity Manual 2010 (HCM2010) underestimates the approach capacity for turnaround rates ranging from below 500 veh/hr to 800 veh/hr, depending on the minimum gap time. Conversely, it overestimates the approach capacity for flow volumes exceeding 700 to over 900 veh/hr, depending on the selected minimum allowable gap. Furthermore, the research team discovered that the approach capacity for turnaround time was also overestimated.

In a comprehensive analysis conducted by Md Sameer Sohail et al. (2020), the performance of a 4-legged roundabout intersection in Hyderabad was rigorously examined using the advanced SIDRA INTERSECTION software. The study identified that the roundabout experiences significant traffic volume during both peak and off-peak hours, leading to an unstable level of service (LOS) that ranges from C to F at the arrival legs. Based on these compelling findings, the research team recommended a redesign of the roundabout, underscoring the crucial significance of incorporating thoughtful considerations of geometric design and capacity during the redesign process.

In a comprehensive study carried out by Šime Bezina et al. (2019), the objective was to investigate the influence of arrival axis rotation on the design of roundabouts. The researchers examined various theoretical scenarios using different radii values (Rv = 15, 17.5, and 20 m) to determine the relationship between the radius size and the maximum rotation angle. The findings of the study indicated that the maximum rotation angle achievable for the approach axis is dependent on the size of the radius. Specifically, as the radius increases, the potential angle of rotation for the approach axis also increases.

In a study conducted by Shivam Shukla (2017), an evaluation of roundabout capacity was carried out using three distinct roundabout models: the Tanner model, NCHRP model, and German model. The analysis of capacity was based on the gap acceptance method, which was derived from Tanner's implementation of the HCM 2010. The study revealed that roundabouts located in urban and suburban areas of India face significant congestion during peak hours, emphasizing the urgency to reconsider and analyze the geometric design of roundabouts.

The Highway Capacity Manual (HCM) 2016 model holds a prominent position as a widely recognized and authoritative resource for evaluating the capacity and level of service (LOS) of transportation facilities, with a specific focus on roundabouts. Developed by the esteemed Transportation Research Board (TRB), the HCM offers a comprehensive framework and methodology that enables in-depth analysis of the performance of various elements within roadway networks.

Within the realm of roundabouts, the HCM 2016 model presents a methodical approach to evaluate their operational characteristics, traffic flow efficiency, and overall effectiveness. It offers a set of guidelines and procedures specifically tailored for estimating the capacity, delay, queuing, and level of service (LOS) of roundabouts. These assessments take into account crucial factors such as geometric design, traffic volume, and other relevant parameters. By employing the HCM 2016 model, transportation professionals can obtain valuable insights and make informed decisions regarding the design and management of roundabouts.

To summarize, the HCM 2016 model is an invaluable tool for assessing the capacity and level of service (LOS) of roundabouts, offering a standardized and dependable methodology for evaluating their performance. By utilizing this model, transportation professionals can effectively analyze roundabouts and make informed decisions in their design and planning processes. This, in turn, enables the creation of roundabouts that can efficiently cater to the demands of traffic, leading to safer and more efficient transportation systems overall.

Hence, it is of utmost importance for road authorities and relevant organizations to prioritize comprehensive capacity and delay studies for each roundabout. This diligent approach allows them to acquire invaluable data and insights regarding the performance of these intersections, thereby facilitating the identification of any existing issues or potential areas for enhancement. Through a meticulous analysis of capacity and delay, appropriate and effective solutions can be devised to tackle traffic congestion and elevate the overall efficiency of roundabouts. By undertaking these measures, transportation systems can be optimized, ensuring smoother traffic flow and improved travel experiences for all road users.

Through strategic investments in capacity and delay studies, road authorities can equip themselves with valuable insights to make informed decisions. These studies empower them to allocate resources effectively, implement appropriate design modifications, and prioritize future infrastructure projects. By taking this proactive approach, authorities can optimize the performance of roundabouts, resulting in reduced travel times, enhanced safety, and an overall improvement in the quality of transportation networks. The valuable data and analysis obtained from capacity and delay studies enable road authorities to identify areas of improvement, implement targeted measures, and ensure that roundabouts operate efficiently, meeting the evolving needs of road users. Ultimately, this investment leads to a more seamless and reliable transportation system, benefiting both commuters and the broader community.

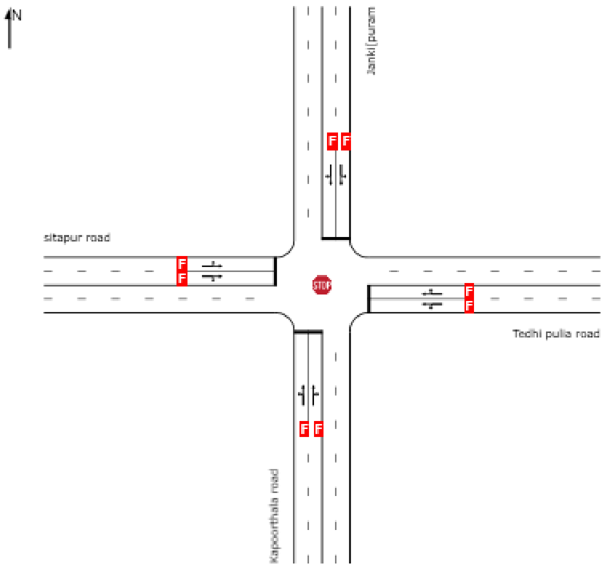


Figure 1 Intersection Layout

## 2. METHODOLOGY

Lucknow, the capital city of the Indian state of Uttar Pradesh, is renowned for its rich culture and heritage. With a significant population and growing traffic congestion issues, it becomes imperative to address the traffic flow challenges effectively. One potential solution is to enhance the capacity of intersections by transforming them into roundabouts. To achieve this, it is essential to collect pertinent geometric and peak hour traffic data at the chosen intersections, selected based on their representation of the target population regarding size and number. While Lucknow is home to numerous intersections, the focus lies on a specific 4-leg, two-way traffic intersection. It is worth noting that many of these intersections were constructed years ago, and it is now necessary for drivers to adhere to modern roundabout traffic rules. By adopting a comprehensive approach and implementing modern roundabout principles, it is possible to alleviate traffic congestion and enhance the overall efficiency and safety of the intersection network in Lucknow.

To gather relevant information about the intersections, data related to gap acceptance or rejection, follow-up time, and free-flow speed were manually collected from recorded videos. Special attention was given to observe any unusual driver behaviour, such as gap-forcing, right-of-way violations, or overly cautious driving. This data collection process aimed to provide a comprehensive understanding of the existing peak hour traffic conditions at the intersections.

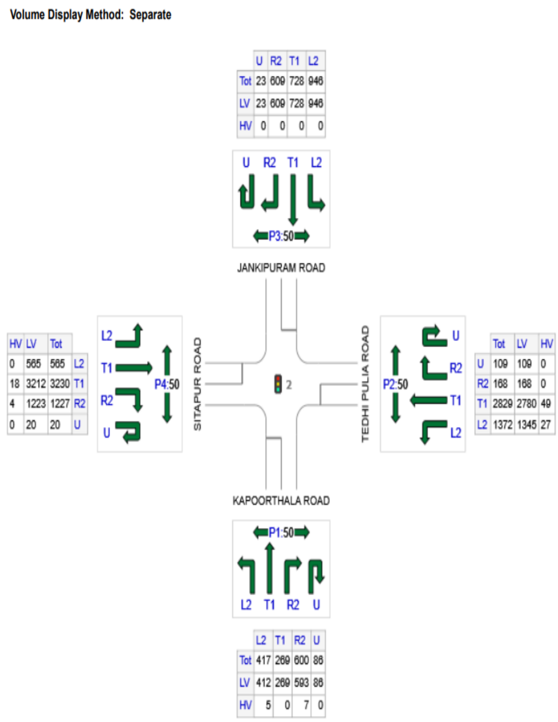


Figure 2 Traffic Movement

## 3.RESULT & DISCUSSION

### A. Traffic volume

Table 3 and Table 4 provide insights into the volume of traffic entering the roundabout and the 4-legged intersection, respectively. The data from Table 3 indicates that the dominant category of vehicles entering both the roundabout and the intersection is light vehicles. These include cars, motorcycles, and other similar vehicles. The share of light vehicles in the total vehicle inflow is significantly higher compared to other categories.

On the other hand, the presence of heavy vehicles such as buses and trucks is relatively low, accounting for approximately 1% of the total vehicle inflow into both the roundabout and the intersection. It is worth noting that heavy vehicles typically occupy more space and require special considerations in terms of manoeuvring at intersections.

Interestingly, non-motorized vehicles, particularly bicycles, have a noticeable presence at the roundabout and the intersection. They constitute a significant portion of the total vehicle inflow, surpassing the share of heavy vehicles. This emphasizes the importance of accommodating non-motorized modes of transportation and ensuring their safety and accessibility in urban areas.

Understanding the composition of vehicle types entering the roundabout and the intersection is crucial for designing appropriate infrastructure and implementing effective traffic management strategies. By considering the dominance of light vehicles and the presence of non-motorized vehicles, planners can tailor their approaches to enhance the safety, efficiency, and overall functionality of these intersections, promoting sustainable and inclusive transportation systems.

The data indicates that when the design of the 4-legged intersection is transformed into a 4-legged roundabout, there is an observed increase in the traffic volume capacity. This change in design allows the roundabout to accommodate a higher volume of vehicles compared to the previous intersection configuration.

By converting the intersection into a roundabout, the capacity to handle traffic flow improves due to the efficient and continuous movement of vehicles around the central island. The roundabout design facilitates better traffic distribution and reduces congestion, enabling a larger number of vehicles to navigate the intersection within a given time frame. The higher effective volume capacity of the 4-legged roundabout implies that it can accommodate a larger number of vehicles compared to the 4-legged intersection without experiencing significant congestion or delays. This finding highlights the advantages of roundabouts in effectively managing traffic and increasing the overall capacity of an intersection.

By implementing a roundabout design, road authorities can optimize the intersection's performance, mitigate congestion issues, and enhance the traffic flow experience for drivers. These benefits contribute to improved transportation efficiency and a more sustainable and safer road network.

This increase in traffic volume capacity is attributed to the unique characteristics of roundabouts, such as the absence of traffic signal delays and the utilization of yield-based priority rules. These features enhance the flow of traffic, leading to smoother operations and higher throughput.

The findings highlight the benefits of transforming traditional intersections into roundabouts, especially in areas with high traffic demands. By adopting a roundabout design, road authorities can effectively manage and accommodate the increased volume of vehicles, resulting in improved traffic flow, reduced delays, and enhanced overall transportation efficiency.

Table 3 Effective volume capacity for 4-legged intersection

| | |
|---|---|
| Demand Flows (Total) | 10448 veh/h |
| Percent Heavy Vehicles (Demand) | 1.3 % |
| Degree of Saturation | 5.263 |
| Practical Spare Capacity | -84.8 % |
| Effective Intersection Capacity | 1985 veh/h |

Table 4 Effective volume capacity for 4-legged roundabout

| | |
|---|---|
| Demand Flows (Total) | 8769 veh/h |
| Percent Heavy Vehicles (Demand) | 1.3 % |
| Degree of Saturation | 2.420 |
| Practical Spare Capacity | -64.9 % |
| Effective Intersection Capacity | 3624 veh/h |

### B. Degree of Saturation

Table 5 and 6 clearly demonstrate a notable difference in the degree of saturation between the 4-legged intersection and the 4-legged roundabout. The degree of saturation refers to the level of traffic congestion or the proportion of the intersection's capacity that is utilized by vehicles during a given time period.

In this specific case, the data shows that the degree of saturation for the 4-legged intersection is higher compared to the degree of saturation for the 4-legged roundabout at Engineering College Chauraha. This indicates that the 4-legged intersection is operating closer to its maximum capacity, leading to a higher level of traffic congestion and potentially longer delays for vehicles.

On the other hand, the lower degree of saturation observed for the 4-legged roundabout suggests that it has a higher effective volume capacity in handling the traffic demands at the intersection. The roundabout's design and operational characteristics allow for smoother traffic flow and efficient utilization of available space, resulting in reduced congestion and improved traffic movement.

Table 5 Degree of Saturation for 4-legged Intersection

| | Approaches | | | | Intersection |
|---|---|---|---|---|---|
| | South | East | North | West | |
| Degree of saturation | 5.20 | 3.74 | 5.14 | 5.26 | 5.28 |

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 Impact Factor: 8.176 ISSN: 2582-3930

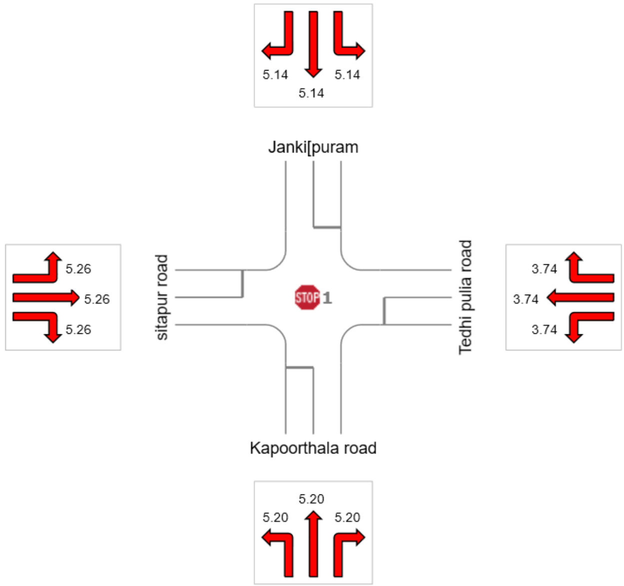


Figure 3 Degree of saturation for 4-legged intersection

Table 6 Degree of Saturation for 4-legged roundabout

| | Approaches | | | | Intersection |
|---|---|---|---|---|---|
| | South | East | North | West | |
| Degree of saturation | 1.53 | 1.87 | 1.32 | 2.42 | 2.42 |

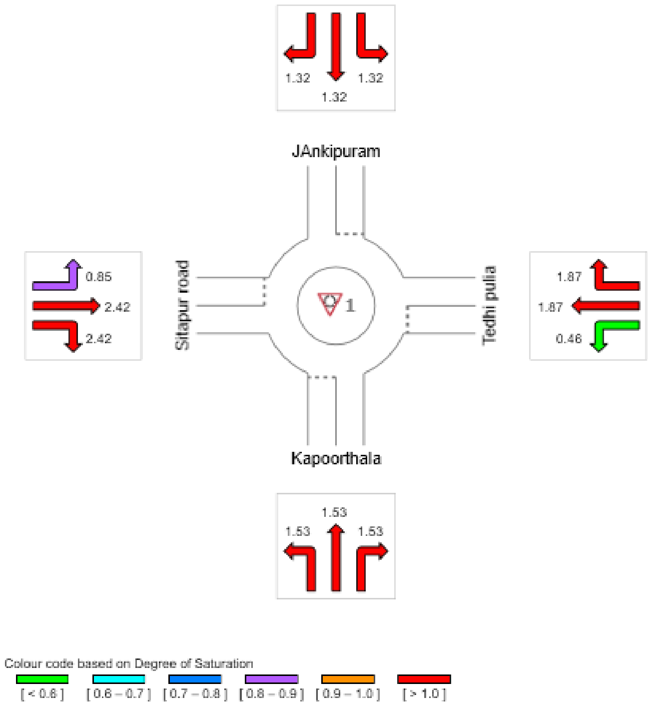


Figure 4 Degree of Saturation for 4-legged roundabout

## 4. Conclusion

The present study aimed to assess and compare the operational performance of a 4-legged roundabout and a 4-legged intersection at the Engineering College Chauraha in Lucknow. The findings revealed that both the roundabout and the 4-legged intersection were operating under unstable conditions. However, it was observed that the effective volume capacity of the 4-legged roundabout exceeded that of the 4-legged intersection.

The level of service, which indicates the quality of traffic flow and operational conditions, was found to be unsatisfactory for both the roundabout and the 4-legged intersection. This suggests that both types of intersections were experiencing congestion, delays, and reduced efficiency in accommodating the traffic demand at the location.

However, a significant difference emerged when comparing the degree of saturation between the two types of intersections. The degree of saturation quantifies the extent to which the intersection's capacity is utilized by vehicles. In this study, it was evident that the operational condition of the 4-legged intersection was much worse than that of the 4-legged roundabout. The degree of saturation for the 4-legged intersection indicated higher congestion levels and a greater strain on its capacity, leading to increased delays and traffic queues.

On the other hand, the 4-legged roundabout exhibited a comparatively lower degree of saturation, implying a more efficient utilization of its available capacity. This suggests that the roundabout design facilitated smoother traffic flow and better traffic management, resulting in reduced congestion and improved traffic movement.

Overall, the findings highlight the advantages of implementing a 4-legged roundabout over a traditional 4-legged intersection at the Engineering College Chauraha in Lucknow. The roundabout demonstrated a higher effective volume capacity and a more favorable operational performance, offering the potential to alleviate congestion, improve traffic flow, and enhance the overall level of service at the intersection. These results underscore the importance of considering roundabout designs as effective solutions for optimizing the performance of intersections in urban areas.

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