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Performance Analysis of Rivers State University Roundabout Under Heterogeneous Traffic Condition

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ABSTRACT
This study evaluates the capability of the rotary intersection at Rivers State University in order to address the traffic issues by studying the traffic at the intersection. At the intersection, traffic volume was counted manually and analyzed. The results were converted to equivalent Passenger Car Unit per hour (PCU/hr). According to the analysis, the intersection pulls a traffic volume of 4097PCU/hr, with a practical rotary capacity of 2351PCU/hr. These capacities are approximately 36.56% higher and 27.6% lower than the maximum allowable capacity of 3000PCU/hr provided by the Indian Road Congress (IRC), making the intersection insufficient and unable to handle the current traffic conditions which consequently causes traffic issues. For the North, East, South, and West approaches, further examination of the four intersecting legs indicated that they are undersaturated, with degrees of saturation of 0.41, 0.26, 0.42, and 0.44, respectively. This is within the permissible range of the advised traffic demand. Therefore, based on on-the-ground observations, the traffic situation at Rivers State University roundabout was caused by the volume of pedestrian crossings and business activities, the lack of a pedestrian crossing facility, on-street parking, inadequate traffic control by the police, and the behavior of the road users, rather than the flow from the approach legs. The study suggests that the current roundabout be converted to a priority intersection, that a suitable midblock bus stop be designed, that a suitable crossing facility be implemented, and that all on-street parking be eliminated by the introduction of a parking facility surrounding the university.

KEYWORDS: Rotary intersection, Saturation, Congestion, Traffic, Capacity.

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1. INTRODUCTION

Unquestionably, Rivers State government has spent a lot of money trying to improve some major intersections in the state capital as a way of managing traffic because it is now seen as one of the fundamental components of modern society. There are fundamental characteristics that make the search for new control and optimization strategies for vehicular traffic flow necessary. These are fast-increasing volume of vehicular traffic flow, restrictions on expanding the construction of new infrastructure, hazardous environmental impact due to the emission of pollutants, together with unfavorable delays suffered in congested traffic jams. This project would obviously not be substantially finished without developing a full understanding of vehicle dynamics within a mathematical framework. In addition to analytical research, this has motivated traffic engineers to do extensive numerical research in the subject of traffic engineering.

According to Mohan *et al.* (2020), the progress of any society depends on transportation. Even while transportation is crucial for a society's economic growth, it nonetheless faces difficulties including traffic congestion and accidents. Increased levels of urbanization and economic development, which have been observed in all urban centers around the developing globe, have led to an increase in traffic conditions during peak hours, especially at intersections because of a mix of complex flow patterns. The increasing rate of human population and vehicular traffic has been one of the various problems of African cities. Due to their importance in ensuring the safety of traffic movement, intersections are important elements in the geometric design and construction of highways. An intersection is a place where two or more roads merge with the possibility of a route or direction change. Basically, intersections fall into one of three groups: At grade, Grade - separated without ramps, and Grade- separated with ramps intersection (Surender & Ahuja, 2016). AASHTO (2011) recommends not more than four legs at an intersection. This is because the quantity of possible conflict locations at any intersection depends on the volume of approaches, the volume of turning motions, and the nature of the traffic control measures in place. Traffic engineers are very concerned about road intersections because of the conflicting traffic patterns. Mannering *et al.* (2004) stated that major accidents and delays occur at intersections.

The Rivers State University roundabout on Ikwerre Road in Port Harcourt is a four-leg at grade intersection which serves as entry and exit point to the university and leads to Agip, Abuja bypass, and Mile 3 Diobu. This roundabout has been identified by Otto and Awarri (2022) to have serious traffic issues along Ikwerre road. This paper therefore, attempts to give numerical research on the roundabout's capacity and pinpoint causes of delays. Traditionally, the roundabout was designed to control traffic flow in one direction around a central island which gives vehicles already inside the circle priority (circulation flow), save operating expense, and shorten travel time which is normal for every roundabout. The roundabout, however, is no longer able to manage traffic. It is clear that during peak hours, the roundabout is surrounded by jammed-up traffic with high inflow rates, making it extremely unlikely that a significant space gap will open up. This causes other directions to get blocked, therefore causing prolonged queues to emerge up to the university gate. A signalized control technique may perform better in this case because the roundabout's performance is ineffective, according to Otto and Awarri (2022). However, during off-peak hours, there is a significant space gap in the circulating direction, increasing the likelihood of an entrance in the block direction. As a result, the roundabout is more effective. The flow of vehicles entering the roundabout and the number of open spaces have a considerable impact on its efficiency. The fundamental query is: under what conditions does the self-organized control mechanism become ineffective? This question requires an answer. To answer this question, the performance of the roundabout has been analyzed in an effort to gain a better understanding of the problem considering all the factors seen within and around the roundabout and proffer reliable solutions to address the issue in the present and future.

This investigation seeks to propose a practical method for enhancing traffic flow at Rivers State University rotary intersection in Port Harcourt City.

The objectives of this research were to:

i. estimate the amount of traffic at the crossroads, research the current traffic situation;
ii. evaluate the rotary's capacity;
iii. estimate the demand to traffic volume (degree of saturation) for each leg that makes up the intersection;
iv. determine factors responsible for delay.

A rotary intersection is a form of at-grade intersection that is designed to allow traffic to go in only one way around a central island. Converging

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traffic is forced to move in a clockwise or anti-clockwise direction around the central island, weaving out of the intersection to follow their intended routes. This creates a conflict free system. However, because of the merging and diverging traffic, conflicts might be seen at circular intersections (Tom & Krishna, 2007). It is important to note that a rotary intersection provides improved safety when compared to other traffic control arrangements (Sargeant & Christie, 2002). Because head-on and right-angle collisions are virtually eliminated, they lessen the severity of crashes and can manage more traffic with less delay than signalized control junctions. Turn pocket lanes probably take up less space because they are not necessary. In addition, they offer superior energy and require less maintenance than alternative intersection treatments and conventional systems (De-Amico, 2012).

2. MATERIALS AND METHODS

2.1 Materials

A data entry form, a pen, a measuring tape, and a stop-watch were all utilized in the execution of this study project.

2.2 Methods

2.2.1 Design Principles for Rotary Intersection

To have a functional system in the design of rotary intersections according to Ishanya *et al.* (2017), the following components must be taken into consideration:

i. **Design Speed:** When approaching a rotary intersection, all vehicles are required to slow down. A rotary's design speed will be substantially low as a result of this. For urban and rural settings, the design speed is typically maintained at 30 and 40 kilometers per hour respectively according to the Indian Road Congress (IRC) 65 (1976).

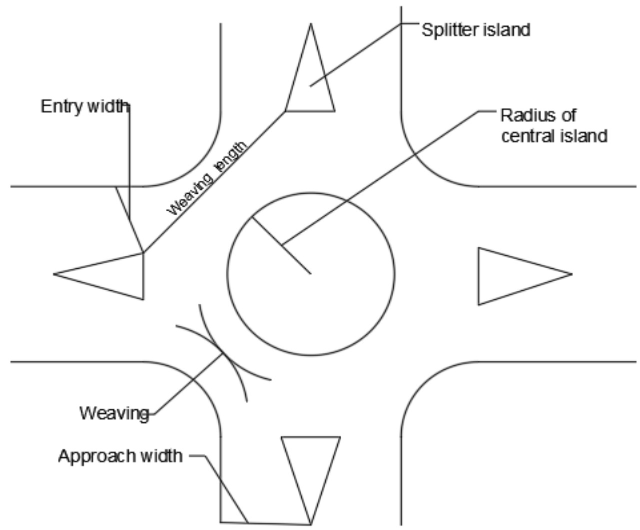

Figure 1: A rotary intersection consisting of its geometric features.

ii. **Rotary Width:** The traffic entering and exiting the intersection, along with the width of the adjacent road, determines the entry and departure widths of the rotary. To enable quicker speeds, the carriageway's width will be reduced at the entry and exit points compared to the width at the approaches. Indian Road Congress (IRC) 65 (1976) stipulates that a two-lane road with a width of 7 m should be maintained at 7 m for urban roads and 6.5 m for rural roads. A three-lane road with a length of 10.5 meters will also be decreased to 7 meters and 7.5 meters for urban and rural roads, respectively. The width of the weaving segment ought to be wider than the width at entry and exit. Typically, this entryway is one lane wider than the norm.

iii. **Weaving Length/Width:** The ease of merging and diverging traffic is governed by it. It depends on a number of variables, such as weaving width, the ratio of weaving to non-weaving traffic, and others. The easiest way to do this is to increase the weaving's ratio of width to length. The ratio

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of four is the minimum value advised by IRC 65 (1976). A very long weaving length is also risky because it may encourage over-speeding (Ishanya *et al.,* 2017).

iv. **Entry, Exit and Island Radius:** Several variables such as design speed, coefficient of friction, and super elevation affect the radius at the entry. The rotary's entry has a slight bend rather than being straight. In order to allow vehicles to exit the rotary at a faster rate, the exit radius should be larger than the entry radius and the rotary's radius. The entry radius should typically be 1.5 to 2 times the exit radius. The design speed and the radius of the entry curve determine the radius of the central island, which in actuality is 1.33 times the radius of the entry curve.

v. **Saturation Flow:** It is a crucial indicator of the flow rate of traffic in terms of road traffic performance. When there is continuous movement, this is the number of cars that will pass the stop line. According to Chang-qiao and Xiao-ming (2012), saturation flow is used as a fundamental parameter to measure an intersection's capacity and timing of signals. The saturation flow values maybe assumed as 1675, 1850, 1990, 2050, 2600, and 2975 PCU per hour for the approach roadway widths of 3.0, 3.5, 4.0, 4.5, 5.0, and 5.5m respectively. While for width above 5.5m, the saturation flow is calculated using Equation 2.1.

$$S = 525w \quad (1)$$

Where, w is the road width.

vi. **Capacity:** The practical capacity of a rotary intersection is directly influenced by the geometric layout and the capacity of each weaving section. The formula is suggested by the Transport and Road Research Laboratory, which has led research on this subject and is a version of the well-known Wardrop's formula (1957) provided by;

$$Q_w = \frac{280w\left[1+\frac{e}{w}\right]\left[1-\frac{p}{3}\right]}{1+\frac{w}{L}} \quad (2)$$

Where:
e is the average entry and exit width of weaving
w is the weaving width
L is the weaving length

$$P = \frac{b+c}{a+b+c+d} \quad (3)$$

Where:
p is the proportion of weaving traffic to the non-weaving traffic
a and d are the non-weaving traffic
b and c are the weaving traffic.
In the following diagram, a and d represent non-weaving traffic while b and c represent weaving traffic. It depicts four different sorts of motions at a weaving section.

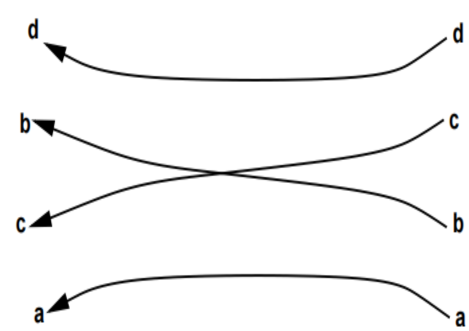

Figure 2: Flow pattern for weaving and non-weaving traffic.

As a result, when designing a rotary intersection, the intersection's traffic volume must be considered. A key indicator of how much traffic is present on a route at any one time is the traffic volume. It is specified in terms of vehicles per hour. However, it is normal practice to convert mixed traffic with a variety of vehicle types into an equal passenger car unit (PCU) by employing certain equivalency factors listed in the Highway Capacity Manual (2010).

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To calculate the volume of traffic, a manual counting method was used in this study. To do this, the number of vehicles at the intersection were counted through field observation of the traffic flow. The observed traffic volume, which included vehicles mostly classified as cars, trucks, and buses were recorded. Based on suggested conversion factors, this was noted and translated to comparable Passenger Car Units per hour (PCU/hr). This information was gathered over the course of one (1) year at the Rivers State University roundabout and its approach legs twice daily between the hours of 7:00am and 9:00am and 3:30pm and 6:00pm. The schedule and day selection are perfect because they coincide with this intersection's busiest times. Similar to this, the weaving width, weaving length, entry width, exit width, and radius of the central island of the roundabout were all measured with tapes, and the values were recorded.

Using the Wardrop's formula found in Equations 2 and 3, the intersection's practical capacity was determined. Equation 3.1, as presented in Govind *et al*. (2020), was used to calculate the degree of saturation for each leg, which is a measure of the demand to traffic volume ratio.

$$\text{Degree of Saturation} = \frac{\text{Actual Flow}}{\text{Saturation Flow}} \quad (4)$$

3. RESULTS AND DISCUSSION

The findings of the traffic study are displayed below. The intersection's current geometric features are represented by the data in Table 1.

Table 1: Existing Geometric Features of Rivers State University Intersection

Parameter	Approach			
	South	North	West	East
Entry width, e_1 (m)	6.66	7.47	8.05	7.6
Exit width, e_2 (m)	9.49	7.02	7.63	8.1
Weaving length, l (m)	17.4	17.4	17.4	17.4
Approach width (m)	10.2	10.2	10.2	10.2
Central island radius (m)	12.64	12.64	12.64	12.64

Table 2 provide the intersection's converted traffic volume count in Passenger Car Units per hour (PCU/hr) during the morning session. Data indicates that the total volume of traffic entering the intersection during the morning session is 4097 PCU/hr with the North bound leg having the highest traffic flow (1295 PCU/hr) and the West bound leg having the lowest volume of traffic (738 PCU/hr) observed. The above data is presented in a bar chart to give a pictorial view of traffic flow as shown in Figure 3.

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Table 2: Traffic Flow at Rivers State University Intersection (Morning)

Parameter	Flows (PCU/hr)			Total
	Left Turning	Straight Ahead	Right Turning	Flow
North (from Agip Road)	180	451	664	**1295**
East (from Abuja bypass Road)	221	482	122	**825**
South (from Mile 3 Road)	465	561	213	**1239**
West (from RSU Road)	231	182	325	**738**
Total	**1097**	**1676**	**1324**	**4097**

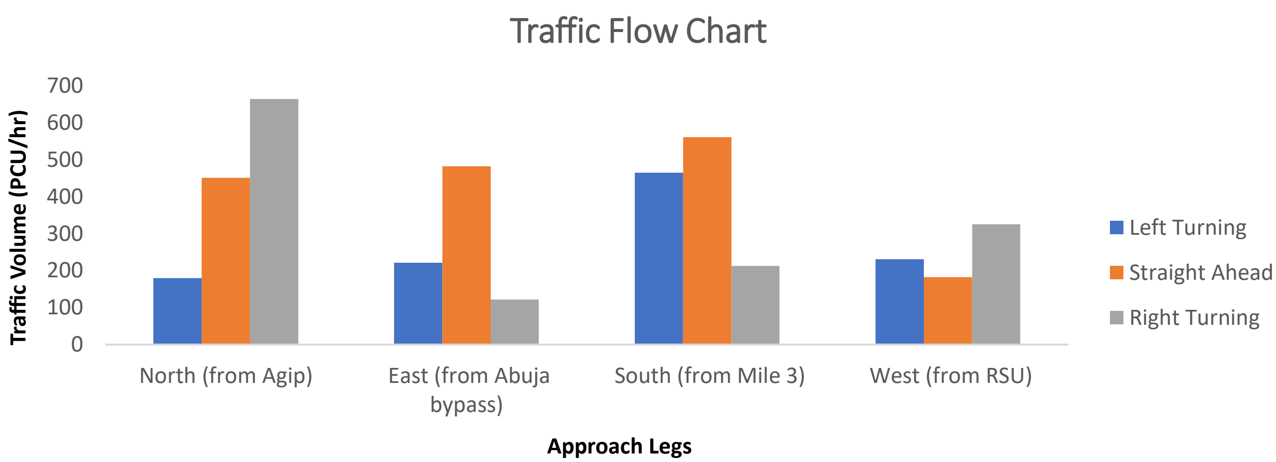

Figure 3: Traffic flow chart for Rivers State University intersection

The converted traffic volume count in Passenger Car Units per hour (PCU/hr) during the evening session is given in Table 3, and the total volume of traffic entering the intersection is 3566 PCU/hr with the West bound leg having the highest traffic flow (1377 PCU/hr) and the lowest volume of traffic (567 PCU/hr) observed at the North bound leg. As shown in Figure 3, the aforementioned information has been programmed into a bar chart to provide a visual representation of traffic movement

Table 3: Traffic Flow at Rivers State University Intersection (Evening)

Parameter	Flows (PCU/hr)			Total
	Left Turning	Straight Ahead	Right Turning	Flow
North (from Agip Road)	152	320	95	**567**
East (from Abuja bypass Road)	121	64	528	**713**
South (from Mile 3 Road)	82	721	106	**909**
West (from RSU Road)	418	331	628	**1377**
Total	**773**	**1436**	**1357**	**3566**

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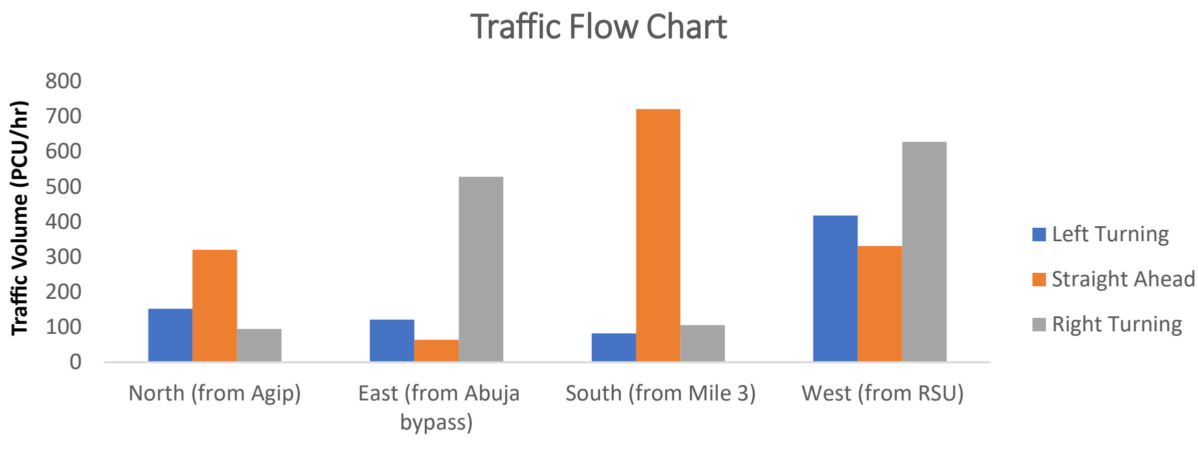

Figure 3: Traffic flow chart for Rivers State University intersection

A description of the in-flow and out-flow of each intersecting approach is shown in Plates 3 and 4. The data shows that there are lots of movements on the West approach to the Rivers State University intersection. The South approach came next, then the North approach, and finally the East approach.

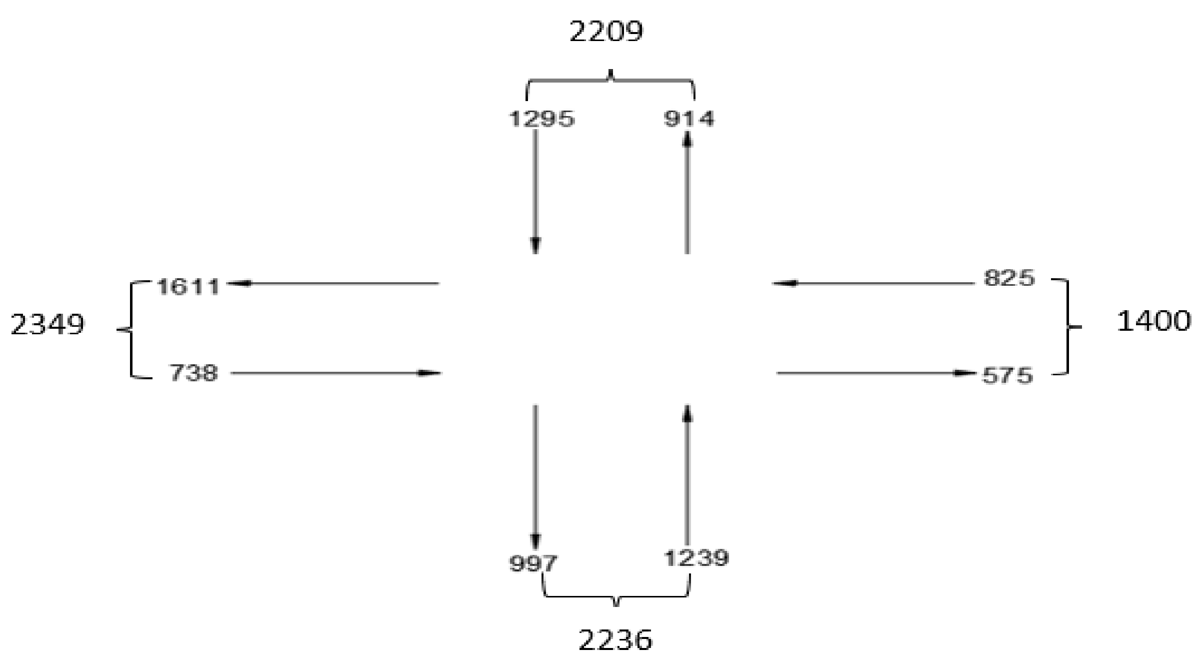

Figure 4: Traffic flow in and out of the Rivers State University intersection

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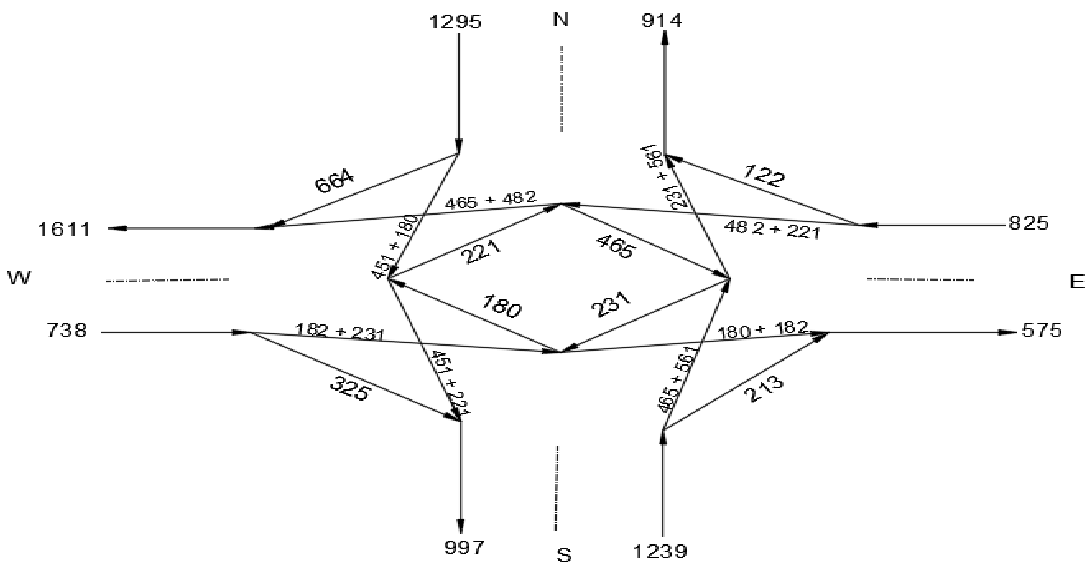

Figure 5: Traffic flow distribution at Rivers State University rotary intersection

Equation 2 and Equation 3 were used to assess the intersection's usefulness as shown in Table 4 below. The North-East section, which had a capacity of 2351PCU/hr from the computed capacity of sections and had a weaving to non-weaving ratio of 0.72, was chosen as the intersection's practical capacity. This is so because the practical capacity is the lowest of all the sections as recommended by the Indian Road Congress (IRC) 65 (1976). The intersection can no longer support the current traffic when compared to the observed capacity of 4097PCU/hr. The observed capacity is 74.26% greater than the intersection's practical capacity. A rotary intersection may only operate at a maximum permissible capacity of 3000PCU/hr as recommended by the Indian Road Congress (IRC) 65 (1976). The results from the features of the existing roads demonstrate that the practical and observed capacities are 27.6% lower and 36.56% higher than the allowable capacity respectively. According to the intersection's practical capacity and allowable capacity under typical traffic conditions, there should not be any congestion. The congestion experienced is as a result of a major disadvantage of rotary intersection which is high pedestrian crossing. The Indian Road Congress (IRC) 65 (1976). has stated it clearly that intersections with high pedestrian movement does not require a rotary. That is to say, at an intersection where the volume of pedestrian crossing is very high, rotary intersection cannot perform effectively. The Rivers State University rotary intersection has a lot of pedestrian crossing as a result of students, lecturers, traders within the intersection and bus stop location 5m away from the intersection.

Table 4: Practical Capacity of the Weaving Sections

Section	Weaving Ratio (P)	Capacity, Q (PCU/hr)
North-East	0.72	2351
East-South	0.75	2390
South-West	0.68	2526
West-North	0.64	2681

The effectiveness of the leg's capacity is displayed in Table 5. Using Equation 3.1, the outcome shows that the North, East, South, and West routes have saturation degrees of 0.41, 0.26, 0.42, and 0.44 respectively with the West approach (RSU road) having the greatest degree at 0.44 (44%). Since these numbers are within the permissible limits, the approach legs are capable of supporting the requisite capacity. This was also seen in a study carried out by Otto and Simeon (2022) when studying the capacity of Slaughter rotary intersection in Port Harcourt. In this study, inability of the rotary intersection to meet up the present-day traffic volume, poor parking facility, road side market, absence of pedestrian crossing facility, road user characteristics and poor traffic control are all variables contributing to the delay experienced at the intersection.

Table 5: Degree of Saturation of the Approach Legs

Approach	Actual Flow (PCU/hr)	Saturation Flow (PCU/hr)	Degree of Saturation	Result
North (from Agip Road)	2209	5355	0.41	< 0.85 OK
East (from Abuja bypass Road)	1400	5355	0.26	< 0.85 OK
South (from Mile 3 Road)	2236	5355	0.42	< 0.85 OK
West (from RSU Road)	2349	5355	0.44	< 0.85 OK

4. CONCLUSION

Based on the research's findings and in accordance to its aim and objectives, the following conclusions were reached:

i. At the intersection, 4097PCU/hr of traffic is seen entering and exiting. The practical capacity of the rotary intersection has been exceeded by 74.26%.

ii. The rotary's capacity is 2351PCU/hr, which is the lowest of all the intersection's weaving sections.

iii. The demand for traffic volume at the intersecting legs was 0.41, 0.26, 0.42, and 0.44 respectively, from saturation. Consequently, it falls within the specified range of 0.85, which is acceptable (Govind *et al,*2020).

iv. The intersection's inability to handle the current volume of traffic, the volume of pedestrian crossing as a result of the university and other business activities, lack of pedestrian crossing facility, on-street parking, poor traffic control by police, and the behavior of the road users (public transport drivers) are all contributing factors to the delay experienced at the intersection.

It is crucial to make the following recommendations in light of the results and conclusions reached:

i. The intersection should be changed to a priority intersection by restricting cross movement and introducing road markings as shown in Figure 6.

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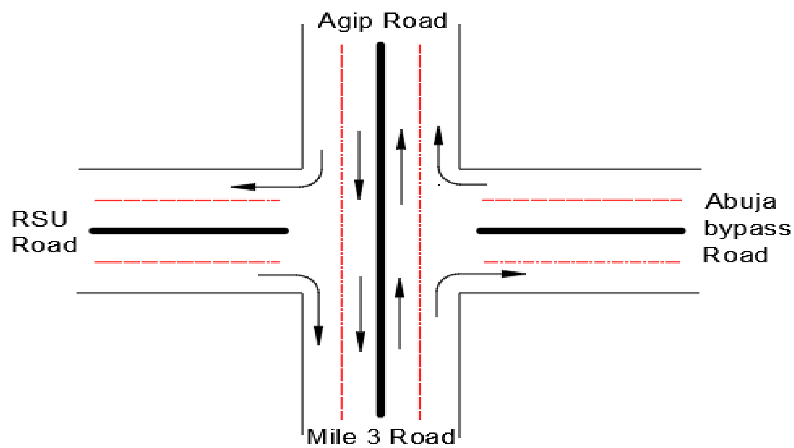

Figure 6: Traffic Movement of a Priority Intersection

ii. A proper midblock bus stop should be designed.
iii. A suitable overhead crossing facility should be introduced.
iv. All on-street parking along Rivers State University (Ikwerre Road) should be eliminated by the introduction of a parking lot facility around the university-Mile 3 area to encourage pedestrian movement within the area.

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