Journal of Engineering, Science, and Technology
ISSN: 2714-2396 | Volume 6, Issue 2

CAPACITY EVALUATION OF SELECTED ROUNDABOUTS IN IBADAN METROPOLIS

Folake O. Akintayo and Fausat M. Agboluaje
(Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria)

ABSTRACT

The Paper determined the capacity and level of operational performance of Ojoo Roundabout and New Garage Roundabout traffic intersections in Ibadan, Oyo State, Nigeria. These Roundabouts were gridlock intersections, where roundabout was introduced to control traffic flow and reduce congestion. As traffic volume increases in Ibadan metropolis, the unsignalised road intersections having roundabouts as control measures also exhibit traffic congestion especially at peak periods. This study analysed the traffic operation and evaluated the capacity for the two selected roundabouts. Geometric data of the roundabouts (entry width, circulatory road width, number of entry and circulatory lanes, and island diameter), traffic movement data with vehicle characteristics and traffic volume data in form of video recordings were collected for the two selected roundabouts at morning and evening peak periods. Empirical analysis technique was adopted to evaluate the capacity for each roundabout. Evaluated results showed that the degree of saturation (DOS) i.e. volume to capacity ratio of 0.78 and 2.49 at morning peak period had equivalent level of service (LOS) of 'C' and 'F' for Ojoo Roundabout and New Garage Roundabout, respectively. Also, at evening peak period the degree of saturation of 0.84 and 0.75 gave a corresponding level of service of 'D' and 'C' for Ojoo Roundabout and New Garage Roundabout, respectively. This study showed that the traffic carrying capacity at peak periods for Ojoo roundabout is operating at an acceptable condition both in the morning and evening peak periods. New Garage Roundabout is operating at near capacity at evening peak period, but operating above capacity at morning peak period, which shows that the present conditions is not adequate for controlling traffic operation.

Keywords: Roundabout, Traffic operation, Capacity, Level of Service, Ibadan Metropolis

1.0 INTRODUCTION

Road network is an important aspect of transportation system in every city as it consists of a system of interconnected paved carriageways which are designed to carry vehicles such as cars, buses and trucks. The road network generally forms the most basic level of transport infrastructure within urban areas, and will link with all other areas, both within and beyond the boundaries of the urban area. The capacity of a network is determined by its roads, and developing a good road network has many positive effects, such as stimulating the development of certain areas. Traffic signals, stop controls, yield controls and roundabouts are traffic control measures commonly used in several at-grade junction in urban areas to maximize traffic efficiency and safety by separating conflicting traffic movements in time. [1]

Traffic congestion is considered one of the main urban transportation problems, particularly in developing countries where vehicle ownership is growing geometrically without corresponding sustainable land use patterns and transportation schemes [2 and 3]. This traffic congestion has negative effect on road user and most of this congestion happens at intersections. Ojoo Roundabout and New Garage Roundabout in Ibadan, Oyo state, Nigeria, also exhibit traffic congestion, which is more noticeable during the peak periods of morning and evening thereby having negative effect on road users. When vehicles stand still in long queues during traffic congestion it results in stress and reduction in the productive hours of road users.

Many intersections in Ibadan do not have sophisticated means of controlling traffic at intersection. Therefore, the services of police and traffic wardens are widely engaged in controlling traffic at intersections in order to reduce congestion. However, where roundabout is used as an alternative

traffic control measures at intersections, the issue of traffic congestion at these roundabouts still draws significant attention each day.

Intersection capacity and other traffic analyses focus on peak hour of traffic volume, because, it represents the most critical period for operations and has the highest capacity requirements. The peak-hour volume, however, is not a constant value from day to day or season to season.

The two principal methods of evaluating the operational performance of roundabouts are gap acceptance method and empirical regression technique. Gap acceptance method is founded on the principle that an individual driver, at a signalized intersection, will wait for a suitable gap in the free flow traffic stream before they enter or cross it. The second method is founded on the principle that the geometric features (approach half width, v; entry width, e; entry radius, r and inscribed circle diameter, D) of any roundabout significantly affect its working performance [4]. This model for estimating the capacity of roundabout by empirical analysis was published by UK Transport and Road Research Laboratory (TRRL) and developed by Kimber [5].

The capacity of roundabout provides the level of service (LOS), which is a quality measure describing the operational conditions within a traffic stream, generally in terms of service measures as speed and travel time, freedom to manoeuver, traffic interruptions, and comfort and convenience [6]. The Level of Service (LOS) is a qualitative concept that has been developed to characterize acceptable degrees of congestion as perceived by motorists [7].

The two roundabouts considered for this study are both unsignalised intersection. Ojoo roundabout has three approach dual carriage roads and it is situated in Akinyele Local Government Area of Ibadan while New Garage roundabout with four approach roads is situated in Oluyole Local Government Area. Fig. 1 shows the location of the two selected roundabouts on the map of Ibadan.

Based on the consideration of exploring roundabout as alternative intersection traffic control method, such a technique is worth conducting study on, in determining the traffic operation and evaluating the entry and exit capacities at morning and evening peak period for Ojoo Roundabout and New Garage Roundabout.

Within the frame work of this study, emphasis was placed on determining the level of service condition for the two selected roundabouts in Ibadan.

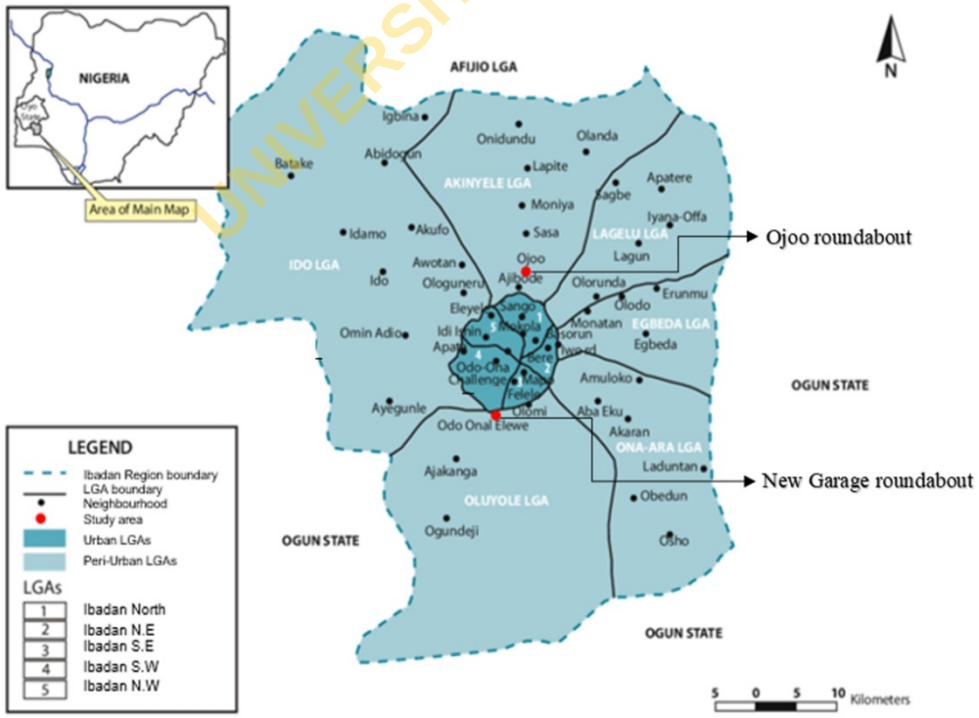

Fig. 1: Location of selected roundabout on Ibadan map
Source: [8]

Journal of Engineering, Science, and Technology
ISSN: 2714-2396 | Volume 6, Issue 2

2.0 METHODOLOGY

The parameters considered to determine the performance of roundabout are generally traffic flow, gap acceptance theory and geometric characteristics. Among those empirical models are regression models based on traffic volumes at entry or exit and circulating flows observed at peak periods.

The reconnaissance carried out offers an opportunity to gather sufficient information to help in decision making regarding further actions to take in the area and to gather information including location, description, traffic flow, nature and condition at the roundabout. The field inventory data of the physical characteristics and geometric feature of the selected roundabouts were collected.

Plate 1 and Plate 2 show the aeriel view of Ojoo Roundabout and New Garage Roundabout respectively.

For the purposes of the study, the approach roads of Ojoo roundabout would be referred to as:

U.I Road = Northbound (NB)
Moniya Road = Southbound (SB)
Express Road = Westbound (WB)

The approach roads of New Garage roundabout would be referred to as:

Podo Road = Northbound (NB)
Orita-Meta Road = Southbound (SB)
Elebu Road = Eastbound (EB)
Toll gate Road = Westbound (WB)

Plate 1: Aeriel view of Ojoo Roundabout Source: [9]

Plate 2: Aeriel view of New Garage Roundabout Source: [10]

Traffic volume study was carried out to get the reliable data at the chosen roundabouts consisting of heterogeneous traffic. Different composition of traffic such as motorcycle, tricycles, cars, buses, trucks, ply these intersections. The traffic volume study was conducted at each roundabout for different days for morning between 7.00 a.m. and 9.00 a.m. also in the evening peak period between 4.30 p.m. and 6.30 p.m.

The Kimber model, an empirical analysis method expresses the entry capacity, Qe using the empirical regression technique for an individual approach as a linear function of the circulating flow. This was adopted for this study to evaluate the roundabout capacity and the variation in the

3

data are carried out by taking into consideration geometric characteristics and traffic volume. Roundabout entry/exit capacity is derived from:

$Q_e = \max \{K [F - f_c\ q_c], 0\}$

The values of K, F, and f_c are determined by:

$K = 1 - 0.00347(ø - 30) - 0.978(1/r - 0.05)$

$F = 303x_2$

$f_c = 0.210t_D (1 + 0.2x_2)$

$$t_D = 1 + \frac{0.5}{1 + \exp^{\frac{D-50}{10}}}$$

$$x_2 = v + \frac{e - v}{1 + 2s}$$

$$s = \frac{1.6 (e-v)}{L}$$

Where:

Q_e = entry/exit capacity

q_c = conflicting circulating traffic (veh/h)

e = entry width (m),

v = approach half width (m),

L = effective flare length (m),

D = inscribed circle diameter (m),

r = entry radius (m),

ϕ = the entry angle (°).

The six level of service (LOS) for Roundabout was estimated using the highway capacity manual (HCM). These are defined in Table 1, which shows the corresponding range of degree of saturation to each level of service (LOS) for roundabouts with the analysis procedures. Letters designate each level, from 'A' to 'F', with LOS 'A' representing the best operating conditions and LOS 'F' the worst. **Table 1**, shows the corresponding range of degree of saturation to each level of service (LOS).

Table 1: Level of service definitions for vehicles based on degree of saturation only [6]

Level of service (LOS)	Degree of saturation (DOS)
A	0 – 0.60
B	> 0.60 – 0.70
C	> 0.70 – 0.85
D	> 0.85 – 0.95
E	> 0.95 – 1.00
F	> 1.00

3.0 Results and Discussion

The two selected roundabouts are unsignalized as at the time of study and common to the roundabouts were the presence of commercial buildings, stalls, and fuel station. Along and on the intersecting roads are hawkers and parking vehicle. Also, services of police and traffic wardens were engaged at peak periods.

Table 2 described the characteristics of the two studied roundabouts.

Table 2: Characteristics of study areas

S/N	Roundabout	No. of intersecting road	Land use characteristics
1	Ojoo	3	Commercial motor parks, commercial centres, stalls, shopping complex, fuel station, police station, market
2	New Garage	4	Commercial motor parks, commercial centres, retail shops, fuel station

The main data used for the traffic data analysis for each roundabout was the varying entry/exit peak hour volume of traffic. The vehicle origin to destination, the anticlockwise circulating movement, the entering movement and the exiting movement for each approach road were retrieved from the captured video recordings.

The morning peak period shows that of all the vehicle types recorded at the two roundabouts, car/small bus had the highest numbers with an average of 6,296 vph (49%), followed by motorcycle with an average of 4,854 vph (38%). Tricycle ranked third with an average of 1,335 vph (10%) while big bus/Trailer came fourth with 357 vph (3%). The evening peak period shows that car/bus had the highest numbers of an average of 5,730 vph (54%) which is followed by motorcycles with an average of 3,281 vph (31%). Tricycle had 1,314 vph (12%) while big bus/trailer also had 226 vph (2%). **Figure 2** shows the traffic composition for morning and evening peak periods at the two roundabouts.

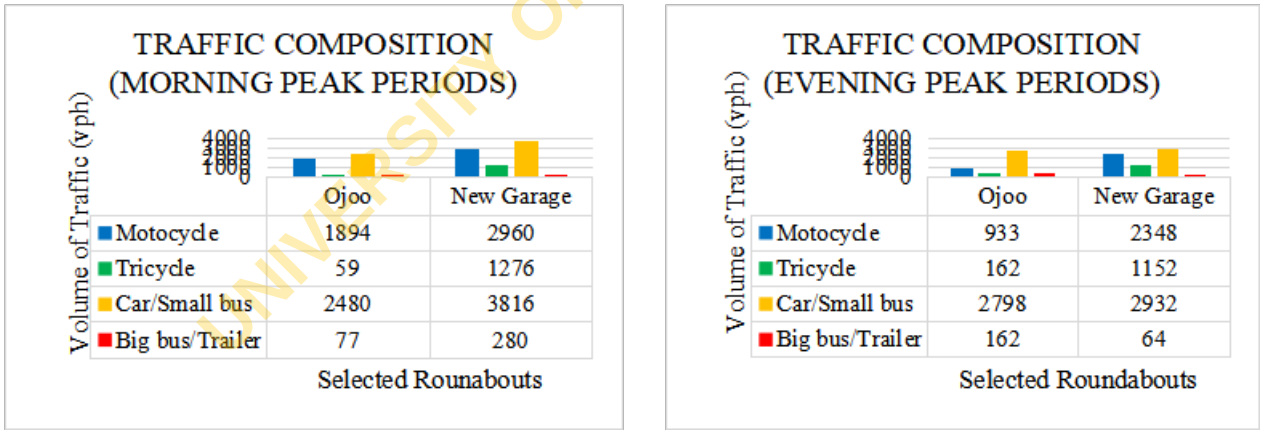

Fig. 2: Traffic composition at the two selected roundabouts

The total summation of all the vehicle types recorded at the two roundabouts is as presented in Figure 3. In the morning peak period, New Garage roundabout recorded the highest volume of traffic with 8,332 vph (65%), while Ojoo roundabout recorded 4,510 vph (35%). Also in the evening peak period, New Garage roundabout has 6,496 vph (62%) and Ojoo roundabout has 4,055 vph (38%).

Journal of Engineering, Science, and Technology
ISSN: 2714-2396 | Volume 6, Issue 2

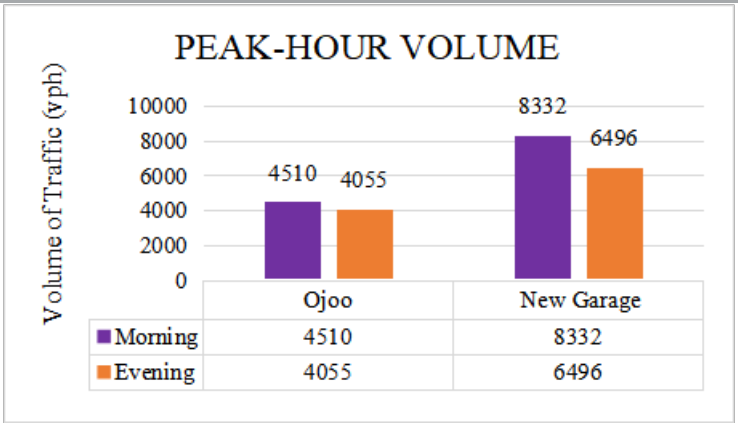

Fig. 3: Traffic volume at the two selected roundabouts

The traffic analysis for this study required the specification of traffic for each approach to roundabout, including the flow rate for each directional movement. The traffic volumes were converted to passenger car vehicle using the passenger car equivalent (PCE), which is expressed in passenger car unit per hour (pcu/hr) for the traffic operational analysis as shown in **Table 3** and **Table 4** for Ojoo roundabout and New Garage roundabout respectively.

A wide range of geometric data were obtained for each roundabout to attain the corresponding operational model developed, using $Q_e = \max \{K [F - f_c\ q_c], 0\}$. This shows the capacity of each entry lane at Ojoo and New Garage roundabouts. The geometric data were the measured value of the existing roundabout geometry features such as the central island diameter, entry/exit lane width, entry radius, inscribed circle diameter.

Table 3: Average volume of traffic conversion to passenger car equivalent for Ojoo roundabout

Time	Approach	Raw turning volumes (vph)				PCE	Adjusted turning volumes (pcu/hr)				Roundabout volumes (pcu/hr)		
		U-turn	Left	Through	Right		U-turn	Left	Through	Right	Circ	Entry	Exit
Morning (AM)	NB approach	124	0	1039	387	**0.804**	100	0	835	311	405	1246	1831
	SB approach	105	355	1629	0	**0.804**	84	285	1310	0	556	1680	1166
	WB approach	44	524	0	306	**0.804**	35	421	0	246	1019	703	632
Evening (PM)	NB approach	420	0	1051	577	**0.915**	384	0	962	528	506	1874	1552
	SB approach	131	377	942	0	**0.915**	120	345	862	0	731	1327	1244
	WB approach	45	334	0	178	**0.915**	41	306	0	163	1466	510	914

Table 4: Average volume of traffic conversion to passenger car equivalent for New Garage roundabout

Time	Approach	Raw turning volumes (vph) U-turn	Left	Through	Right	PCE	Adjusted turning volumes (pcu/hr) U-turn	Left	Through	Right	Roundabout volumes (pcu/hr) Circ	Entry	Exit
Morning (AM)	NB approach	21	210	1364	504	**0.833**	18	175	1137	420	2462	1749	2119
	SB approach	54	127	1270	363	**0.748**	40	95	950	271	1285	1357	2974
	EB approach	167	2168	434	567	**0.815**	136	1768	354	462	1861	2720	780
	WB approach	76	758	217	32	**0.910**	69	690	197	29	3273	985	938
Evening (PM)	NB approach	28	69	898	387	**0.796**	22	55	714	308	1365	1100	1130
	SB approach	72	481	725	1128	**0.709**	51	341	514	800	1393	1707	1315
	EB approach	35	609	412	115	**0.793**	28	483	327	91	1567	928	1534
	WB approach	154	569	738	76	**0.882**	136	502	651	67	1353	1355	1112

Table 5 shows the analysis results with an indicator for the approaches at each roundabout with an average degree of saturation (DOS) for entry and exit at each intersecting road. The estimated DOS value of 0.78 and 2.49 for morning period is equivalent to level of service, LOS 'C' and LOS 'F' for Ojoo roundabout and New Garage roundabout respectively. In the evening period, the average DOS of 0.84 and 0.75 gives Ojoo roundabout and New Garage roundabout an equivalent level of service, LOS 'D' and LOS 'C' respectively. Whereas **Table 6** shows the remarks given based on the situation and the effect of traffic operation at each of the roundabouts.

Table 5: Average DOS (v/c ratio) at the two selected roundabout

S/N	Roundabout	Morning peak Entry	Exit	Average	LOS	Evening peak Entry	Exit	Average	LOS
1	Ojoo	0.62	0.93	**0.78**	C	0.74	0.95	**0.84**	D
2	New Garage	2.34	2.65	**2.49**	F	0.79	0.72	**0.75**	C

Table 6: Peak hour traffic operation remark at the two selected roundabouts

S/N	Roundabout	Remark
1	Ojoo	The traffic operation indicates a severe restriction of speed and freedom to manoeuvre. Small increase in traffic flow generally can causes operational problem.
2	New Garage	Traffic operating conditions at New Garage roundabout is at or near the capacity level. Freedom to manoeuvre within the traffic stream is extremely difficult and only achieved with forceful accomplishment. Minor perturbations within a traffic stream can cause holdup.

IV. CONCLUSION

The study examined traffic congestion problem at Ojoo roundabout and New Garage roundabout in Ibadan and has given the existing intersection geometric data, vehicular traffic information and operations at each of the roundabout. The peak hour traffic volume at Ojoo and New Garage roundabout showed different traffic volume movement with respect to the available capacity of the roundabouts.

This study confirmed that at Ojoo roundabout, the traffic carrying capacity at peak period is operating at a controllable condition. Whereas, New Garage roundabout is operating at near capacity and this shows that the present conditions is not adequate for controlling traffic operation at peak periods.

As growth rate increases in Ibadan, traffic problem such as congestion at road intersection should not be left until it deteriorates.

The existing geometric features of the two roundabouts can be fully optimised by removing all forms of obstruction within the road carriage way at intersections. Where geometric features are inadequate, the roundabout features could be modified. These management approach at these roundabouts will minimise or eliminate the incessant problem of traffic congestion and consequently reduce the engagement services of police and traffic wardens controlling traffic flow at the roundabouts.

REFERENCES

[1] Garber, N. J.and Hoel, N. A. 2015. Traffic and Highway Engineering. Cengage Learning, Stamford, USA.

[2] Olagunju, K., (2015). Evaluating Traffic Congestion in Developing Countries – A Case Study of Lagos of Nigeria: A Paper Presented at 2015 Chattered Institute of Logistics and Transportation (CILT). African Forum: Meru Hotels, Arusha.Tanzania

[3] Akintayo, F. O. 2011. Analysis of traffic flow on selected two-lane highways in Ibadan metropolis, published Ph.D thesis: Department of civil engineering university of Ibadan, Nigeria.

[4] Akçelic, R., Chung, E. and Besley, M. 1996. Performance of roundabouts under heavy demand conditions," Road and Transport Research, vol. 5, no. 2, pp. 36-50.

[5] Kimber, R. M. 1980. The Traffic Capacity of Roundabouts. Laboratory Report LR 942. Transport and Road Research Laboratory, Crowthorne, Berkshire, United Kingdom.

[6] Highway Capacity Manual (HCM) 2016. 6th ed. Transportation Research Board, National Research Council, Washington, D.C., U.S.A.

[7] Liu Y., Guo X., Kong D., and Liang H. 2013. Analysis of Traffic Operation performances at Roundabouts," Procedia - Soc. Behav. Sci., vol. 96, no. Cictp, pp.741–750.

[8] Adelekan, I., Olajide-Taiwo, L., Ayorinde, A., Ajayi, D. and Babajide, S. 2014. Building Urban resilience: Assessing Urban and Peri-urban Agriculture in Ibadan, Nigeria. [Padgham, J. and J. Jabbour (eds.)]. United Nations Environment Progra.m.me (UNEP), Nairobi, Kenya.

[9] Google Earth. 2018. Ojoo Ibadan, 600689.00m E, 825628.00m N.

[10] Google Earth. 2018. New Garage Ibadan, 595807.00m E, 810512.00m N.