ISSN-L: 2223-9553, ISSN: 2223-9944
Vol. 4 No. 2 March 2013

COMPARATIVE ANALYSIS OF TRAFFIC PERFORMANCE OF SMALL AND LARGE CENTRAL ISLAND ROTARIES IN MINNA, NIGERIA

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ABSTRACT

Of recent, the government of Niger state has embarked on the construction of roundabouts with small central island rotaries; this paper compares the performance of large central island rotaries with small central island rotaries. The performance of large central island rotaries compares well to the performance of small central island rotaries. Capacities of rotaries with small islands were found to be higher than capacities of large central island rotaries while the delay for large central island rotaries was found to be higher than that of small central island rotaries. However, both large and small central island rotaries were found to be operating at the same level of service. This study provides recommendations to traffic engineers and/or planners on the conditions under which both central island rotaries perform better and, thus, should be considered.

Keywords: Analysis, Traffic performance, Rotaries, Minna.

INTRODUCTION

The word Rotary is used interchangeably with traffic circle or roundabout to mean a road junction consisting of a circular island around which traffic can flow continuously (Encarta, 2009). The first use of the word 'roundabout' appeared in the UK Ministry of Transport and Planning Institute Circular No.302 in 1929 as cited by (Sisiopiku and Heung-Un, 2001).

This circular was the first to give general guidance for roundabout design. The design allowed a circular or polygon central island shape, depending on the number of legs. The guideline was purposely to improve safety. In US, the first guideline for a roundabout was published in 1942 by the American Association of State Highway officials (AASHO) (Todd, 1991).

The general concept was that large radii gave long weaving sections, on which both high speeds and high capacities could be maintained. The design was intended for vehicle speed not less than 40Km/h and required a central island of at least 23m so that entering vehicles could merge and interweave with those on the circulating roadway. The highest design speed contemplated was 64Km/h, a speed that required a central island radius of 82m or more depending on the super elevation of the circulating roadway

The research on capacities at roundabouts began with the introduction of the yield-at-entry element. As cited by (Sisiopiku and Heung-Un, 2001), delays were studied at minor stream on the basis of gap acceptance models and the analogy of traffic flow to the Poisson distribution, variables were also simplified and equations for the delay to minor traffic were suggested. Impact of geometric factors to delay was studied. From all these works, it was concluded that mean speed and turning angle contributed most to the delay and thus an equation for estimating delays was suggested.

The research conducted by the National Cooperative Highway Research Program (NCHRP Report 572, 2007) analyzed the delay experienced by roundabouts and compared it to the delay experienced by signalized intersections with similar turning volumes. It was found that the roundabout intersection experiences approximately 12 seconds less overall delay than the signalized intersection (MDOT, 2011).

METHODOLOGY

This study considered large and small central island roundabouts. The measures of effectiveness for intersection performance should include volume to capacity (V/C) ratio and delay. The Highway Capacity Manual, 2000 (HCM, 2000) recommends using delay for all intersection alternatives. Therefore, in this study, the average delay was employed to compare the performance of both islands. V/C ratio was also used to compare the performances.

Delay was estimated at each roundabout approach to determine the average delay; the study was conducted during the peak periods using stop time method. Vehicles stopped at the approach were counted for 15sec interval for 15min of morning and evening peak periods. This delay value corresponds to the total delay that an average vehicle experiences directly or indirectly due to the intersection. It includes geometric delay, queuing delay, the acceleration and deceleration delay, and stopped delay. Capacity was calculated in terms of the intersection capacity that corresponds to summation of capacities from all approaches.

RESULTS AND ANALYSIS

Geometric Design Data

Tables 1 and 2 show the Geometric design data of both roundabouts; the geometric design data are those data relating to the actual measurements of roundabout which include the inscribed circle diameter, entry width, approach width, flare and effective lengths.

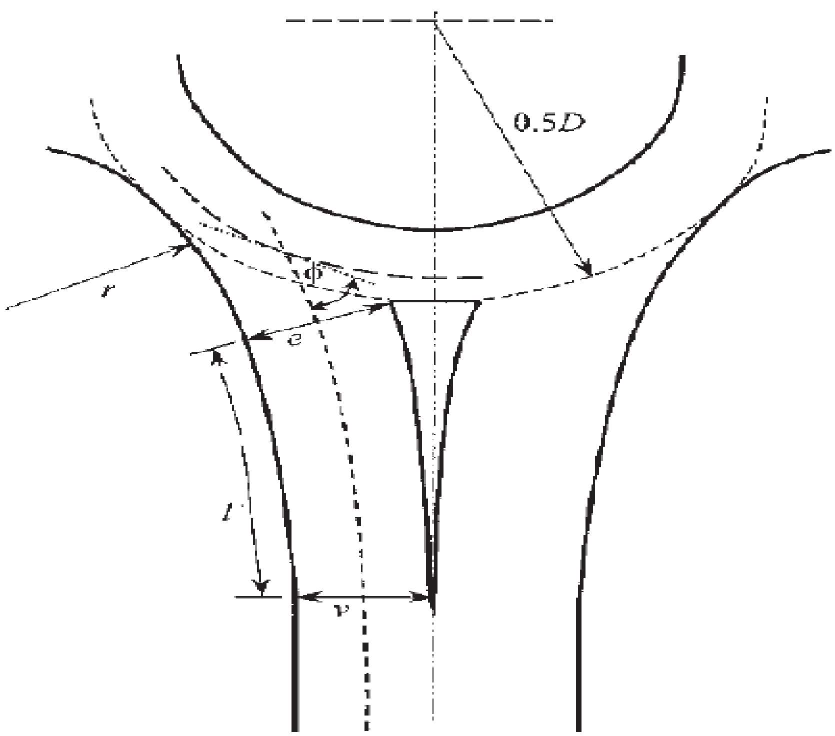

Figure 1. Geometric parameters of Roundabouts (Rogers, 2003)

ISSN-L: 2223-9553, ISSN: 2223-9944
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Where:

e = entry width (meters) – measured from a point normal to the near kerbside

v = approach half-width – measured along a normal from a point in the approach stream from any entry flare

l¢ = average effective flare length – measured along a line drawn at right angles from the widest point of the entry flare

S = sharpness of flare – indicates the rate at which extra width is developed within the entry flare

D = inscribed circle diameter – the biggest circle that can be inscribed within the junction

f = entry angle – measures the conflict angle between entering and circulating traffic

r = entry radius – indicates the radius of curvature of the nearside kerb-line on entry.

Table 1. Measurement of Geometric parameters

Geometric Parameters (N-S)	*Symbol*	*Unit*	*Large circle*	*Small circle*
Entry width	e	m	10.5	9.5
Approach width	V	m	7.7	7.0
Effective Flare length	Li	m	13.25	9.0
Inscribed diameter	D	m	18.34	14.0
Sharpness of flare	S	-	0.339	0.44
Entry angle	Ø	Deg.	39.0	30
Entry radius	R	m	24.02	25.0

Table 2. Measurement of Geometric parameters

Geometric Parameters (E-W)	*Symbol*	*Unit*	*Large circle*	*Small circle*
Entry width	e	m	8.4	10.6
Approach width	V	m	5.1	7.5
Effective Flare length	Li	m	6.0	8.4
Inscribed diameter	D	m	18.340	14.0
Sharpness of flare	S	-	0.88	0.59
Entry angle	Ø	Deg.	39.0	30
Entry radius	R	m	24.02	20.27

The large circle has an inscribed diameter of about 18m while that of the small circle is 14m, even though both circles fall within the same category of rotaries, the difference between them is enough to cause significant effects on their performances.

Volume Study

These data were taken for use to determine the degree of saturation at each rotary. Table 3 summarizes morning, afternoon, and evening peak periods for both roundabouts

Table 3. Morning and Evening Peak Volumes for the Large circle

Approach	*Morning peak (p.c.u)*	*Afternoon peak (p.c.u)*	*Evening peak (p.c.u)*
1	2243.5	2294	2051.0
2	1839.0	2188	1884.0
3	2495.5	1525	1852.5
4	-	-	-

Table 4. Morning and Evening Peak Volumes for the Small circle

Approach	*Morning peak (p.c.u)*	*Afternoon peak (p.c.u)*	*Evening peak (p.c.u)*
1	847.5	1345.5	1217.0
2	1385.5	1544.5	1617.5
3	1186.5	1144.0	1348.5
4	1210.5	1080.0	1835.0

Peak periods indicate higher volume were motorist would have large traffic to pass through but fewer chances of doing so.

Delay Comparison of Large Circle with Small Circle

Delay is an important parameter that is used in the estimation of the level of service at intersection approaches. The Table below provides a comparison for large circle with small circle.

Table 5. Average delays in sec for large circles

	Mon	*Tues*	*Wed*	*Thurs*
Am	22	29	20	21
Aft	17	14	15	19
Eve	27	36	21	18

Table 6. Average delays in sec for small circles

	Mon	*Tues*	*Wed*	*Thurs*
Am	27	26	23	20
Aft	16	16	13	20
Eve	27	38	19	19

The results show that both circles provide similar average delays for the entire range of total entering flow values studied. Both roundabouts where observed to experience maximum

ISSN-L: 2223-9553, ISSN: 2223-9944
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delays of 36sec/veh, and 38sec/veh respectively and minimum delays of 14sec/veh and 13sec/veh respectively for large and small circles. In other words, during the morning periods,

Both roundabouts operate at a level of service E which represents the level at which the capacity of the highway has been reached. Traffic flow conditions are best described as unstable with any traffic incident causing extensive queuing and even breakdown.

Levels of comfort and convenience are very poor and all speeds are low if relatively uniform and B at the evening periods which also represent reasonable free-flow conditions. Comfort and convenience levels for road users are still relatively high as vehicles have only slightly reduced freedom to maneuver.

In summary, large central island rotaries do not show considerable advantage over small central island rotaries in terms of delay. Either of the two intersection alternatives could replace the other without any burden on existing traffic

Comparison of Capacities for Large and Small Circle

The capacity analysis and LOS calculation for road junctions (intersections and roundabouts) are based on the analysis of peak hour data for traffic flow entry calculated using kimbers equation [3]:

$$Q_C = K\{F - F_C Q_e\}, F_C Q_C \leq F \quad (1)$$

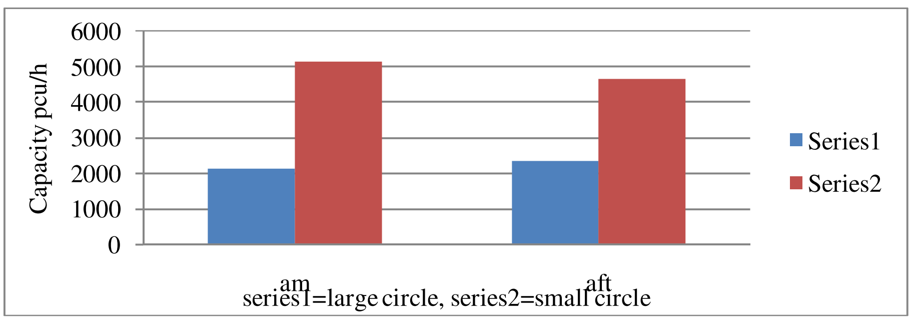

Figure 1. Comparison of capacities for small and large circles

The result of the capacity shows result of the capacity calculations using kimbers equation.

It was observed that small circle has about twice the capacity of large circle which is attributed to the increased circulating width, in other words, the more the circulating width, the more the maximum flow rate.

Comparisons of Volume-To-Capacity Ratio for Large and Small Circles

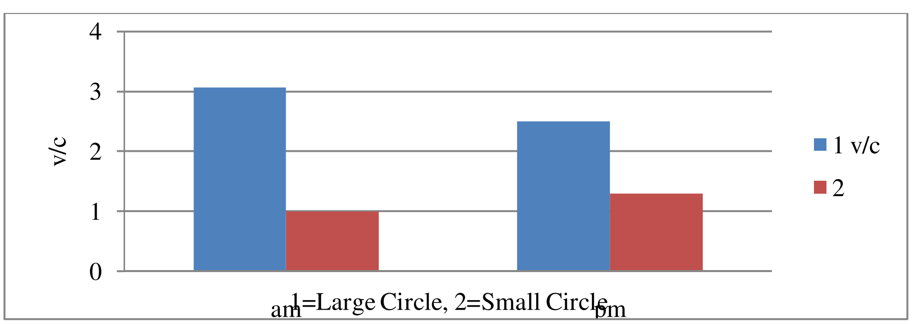

Figure 2. Comparison of V/C ratios

The results of the roundabout analysis indicate that the critical volume/capacity ratios are greater than 1.00 i.e. saturated, which implies that there is need to perform an overall review of geometrics until the v/c ≤ 1.00.

CONCLUSION

The performance of large central island rotaries was evaluated in terms of delay and capacity in comparison to the performance of small central island rotaries. In summary, the following conclusions were drawn from this study.

1. Roundabout geometrics have the most significant effect on the capacity of roundabouts
2. Small Central Island rotaries have higher capacities and lower V/C ratios, hence should be adopted.
3. The increased capacities in small circles is as a result of the increase in circulating widths
4. For any proportion of traffic volume, both roundabouts exhibit similar average delays at peak periods

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