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Research Paper

The Qualitative Performance Analysis of Arowomole Rotary Intersection, Ogbomosho Nigeria.

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ABSTRACT:
This study analyzed the qualitative performance of the Arowomole round-about in Ogbomosho metropolitan city, Oyo State, Nigeria. A rotary intersection is a form of channelized intersection, where vehicles are guided into a one-way circulatory road about a central island. The movement of the vehicles were observed and traffic counts were carried out manually, at 15 minutes intervals for 12 hours (6:30 am-6:30 pm) daily for seven (7) days, from Monday, June 18 th to Sunday, June 24 th, 2018. The qualitative performance of a roundabout is necessary as it is directly related to the measurement of delays, queues, level of service, accident, operation cost of vehicles and environmental issues, are measured to determine the Arowomole roundabout, in qualitative performance of Ogbomosho Nigeria. Results show that, the five (5) working days (Monday-Friday), have the highest traffic volume counts and were selected for the analysis. The peak hour factors (PHF) for the peak and off-peak periods for the five days traffic were computed and used to convert the movement demand volumes to flow rates. The qualitative performance analyses were carried out based on the 12-step approach for the performance analysis of a roundabout outlined by the Highway Capacity Manual. Approach, and entry capacities were determined as a mathematical function of critical headway and follow-up headway, using the Gap-Acceptance parameters (Analytical approach). The degree of saturation, delay, and queue length used in estimating the performance of a roundabout were also determined at the roundabout. The relation between the roundabout performance measure and capacity was expressed in terms of degree of saturation (Volume – Capacity ratio), and hence the levels of service (LOS) for each approach and the entire roundabout were estimated. The general performance of the roundabout ranged between a level of service A – E, and an increase in the entry lane width on Approach 3 was recommended to ensure continuous and smooth flow.
KEYWORDS: Delay, volume of Traffic, Round-about, Pavement Markings, Splitter Island

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I. INTRODUCTION

A rotary intersection (roundabout) is a form of channelized intersection in which vehicles are guided onto a one-way circulatory road about a central island. Entry to the intersection is controlled by give-way-markings and priority is given to vehicles circulating (anti-clockwise in Nigeria) on the roundabout. They are circular intersections with specific design and traffic control features. These features include yield control of all entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 50 km/h. Thus; a roundabout is a subset of a wide range of circular intersection forms (Rodegerdts et al., 2010).

Qualitative performance analysis of a roundabout is very important since it is directly related to delay, queues, level of service, accident, operation cost, and environmental issues. For more than three decades, modern roundabouts have been used successfully throughout the world as a junction control device. Nigeria also has its share of roundabouts. Three performance measures are typically used to estimate the performance of a given roundabout design: These are degree of saturation, delay and queue length. Each measure provides a unique perspective on the quality of service at which a roundabout will perform under a given set of traffic and geometric conditions (Rodegerdts et al., 2010).

The main objective of a roundabout design is to secure the safe interchange of traffic between crossing traffic streams and the minimum delay. The operating efficiency of a roundabout depends on entering drivers accepting headway gaps in the circulating traffic streams. Since traffic streams merge and diverge at small angles and low relative speeds, accidents between vehicles in a roundabout rarely have fatal consequences (O'Flaherty et al., 2006).

1.1 Problem Statements

There are three legs; four legs; and five legs roundabouts at different locations in Ogbomoso, Oyo State of Nigeria, and most of them have served for more than 20 years. Little or no attention has been paid to the design, capacity and performance evaluation of most of these roundabouts, and the knowledge of their capacities or level of performance is not available. The qualitative performance analysis of the Arowomole roundabout will, therefore, be suitable for inclusion in traffic assignment models which explicitly represent traffic conflicts at intersections or in a stand-alone analytically based computer programs which analyses a double lane roundabout. It can also be implemented into a travel forecasting model. The results from the analysis will also aid the relevant authorities in determining whether, where and how to construct additional multi-lane roundabouts in the future.

1.2 Aim and Objectives of Study

The aim of this study is to analyze the qualitative performance at Arowomole Roundabout, in the Ogbomoso metropolis.

The objectives of the study are to;

(i) carry out traffic studies on the Arowomole roundabout and select the appropriate methodology for evaluating the capacity of the roundabout,

(ii) compute the capacity of Arowomole roundabout using the Analytical (Gap-Acceptance) method and determine the degree of saturation, delay, and queue lengths at the roundabout,

(iii) determine the qualitative performance of Arowomole roundabout, and make recommendations.

1.3 Significance of Study

These have resulted to more cars, poor facility management, and poor practices on the side of the road users. The poor facility management is as a result of the relevant authorities paying little attention to the fact that the road facilities need to be upgraded to meet the demand of the ever-growing number of vehicles, which most often leads to a total breakdown of the facility and hence delivering at very low level of service. There is, therefore the need to determine the qualitative performance analysis of Arowomole Roundabout. The qualitative performance analysis can be used to identify the legs of the roundabout which are in critical condition and appropriate measures will be taken to mitigate the problem.

1.4 Study Area

The case study of this research work is the Arowomole Round-about in Ogbomoso, Oyo State. It is located on longitude N 8^{o}29'39.2316'' and latitude E 4^{o}35'39.9192'' in the Arowomole area of Ogbomoso metropolitan city. The north-bound leg (or approach) is the Kolara, the east-bound is the Arada Road, the south-bound approach is the Sunsun road and the west-bound approach is the Maternity Way. The area comprises of administrative, commercial and residential activities.

1.5 Methodology in Brief

The Arowomole roundabout has four approaches namely; Kolara Road, Arada Road, Ogbomoso South local Government secretariate Road and Maternity Way. For each arm, traffic data were collected manually at 15 minutes intervals, 12 hours (6:30 am-6:30 pm) daily for seven (7) consecutive days, from Monday, June 18th to Sunday, June 24th 2018. During the course of the count, it was observed that the highest volume of vehicles was recorded between 7:30 am and 8:30 am, and the lowest vehicular volumes were recorded between 12:00 pm and 1:00 pm. From the seven-day count, the five (5) working days (Monday to Friday) which produced the highest counts recorded were selected for the analysis. The entry capacities were determined using the Gap-Acceptance parameters (Analytical approach), based on the Transportation Research Board Highway Capacity Manual (2010). The qualitative performance analysis was analyzed also using the HCM (2010).

1.6 Limitation of the Study

The blueprint for the Arowomole rotary intersection design was not readily available; hence most of the parameters used in the determination of the capacity were made on assumption with reference to limitations set by the United Kingdom Empirical Roundabout capacity equation. Since the regression or empirical method totally depends on the geometric elements of the roundabout, the capacity estimations using the UK empirical approach may be compromised due to inadequate data. The empirical formulation has some drawbacks, for example, data has to be collected at over saturated flow (or at capacity) level. It is a painstaking task to collect enough amounts of data to ensure reliability of results, and this method is sometimes inflexible under unfamiliar circumstances, especially when the value is far out of the range of regressed data. The performance analysis was therefore evaluated with the analytical gap-acceptance method prescribed by the HCM (201

II. LITERATURE REVIEW

2.1 Preamble

Transport Research Laboratory (TRL) of England first introduced modern roundabout facilities in the early 1960s in the United Kingdom (Mark, 2003). These facilities were introduced in order to solve the problems of the existing rotaries and traffic circles, using the principle that entering traffic yields to circulating traffic, or the "give way" rule, and almost all city planners soon accepted it. Above all, improvement in safety is the most distinct advantage of roundabouts. Most areas that implement roundabout rules experienced an impressive reduction impact on their accident numbers. Due to this reputation, some countries have converted many ordinary intersections into roundabouts. Norway and Ireland were the first countries to follow England. The first roundabout in Norway was built in 1971(Mark, 2003). For instance, France built almost 1500 roundabouts in a year. The Netherlands, in the late 1980s, built about 400 roundabouts over a period of six years (Thaweesak, 1998).

Since 1960, different types of methodologies have been developed in order to determine roundabout capacity, and hence its performance analysis. The different approaches or theories on which these methodologies are based are discussed in the following sections.

2.2 Types of Roundabouts

The main types of round-about are Mini, Compact, Normal, Grade-Separated, Signalized and Double Roundabouts (the last being a combination of Mini, Compact or Normal Roundabouts).
Rotary intersections normally have a minimum of three legs, with some having up to six legs. The legs can have a single or multiple lanes. The roundabout may also have a single or multi-circulatory widths; all subject to the size of the roundabout (DMRB, 2007).

2.2.1 Normal round-abouts

A Normal Roundabout has a kerb central island at least 4 meters in diameter as shown in Figure 2.1. Its approaches may be dual or single carriageway roads. Usually, a Normal Roundabout has flared entries and exits to allow two or three vehicles to enter or leave the roundabout on a given arm at the same time. Its circulatory carriageway therefore, needs to be wide enough for two or three vehicles to travel alongside each other on the roundabout itself (DMRB, 2007).

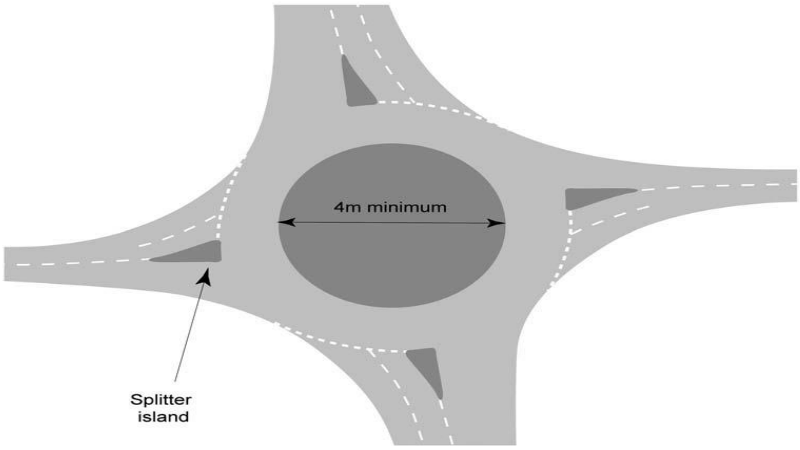

Figure 2.1: Normal Roundabout. (Source: DMRB, 2007)

If a Normal Roundabout has more than four arms, it becomes large with the probability that higher circulatory speeds will result. Either a Double Roundabout or a Signalized Roundabout is a potential solution in these circumstances (DMRB, 2007).

2.2.2 Compact round-abouts

A Compact Roundabout shown in Figure 2.2 has single lane entries and exits on each arm. The width of the circulatory carriageway is such that it is not possible for two cars to pass one another. On roads with a speed limit of 65 km/h or less within 100 m of the give way line on all approaches. Compact Roundabouts may have low values of entry and exit radii in conjunction with high values of entry deflection. This design has less capacity than that of Normal Roundabouts, but is particularly suitable where there is a need to accommodate the

movement of pedestrians and cyclists. The non-flared entries/exits give the designer more flexibility in sitting pedestrian crossings.
On roads with speed limits exceeding 65 km/h, the design of Compact Roundabouts is similar to that for Normal Roundabouts, but the single-lane entries and exits are retained (DMRB, 2007).

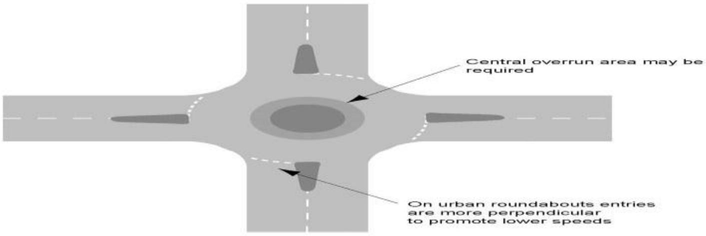

Figure 2.2: Compact Roundabout. (Source: DMRB, 2007)

2.2.3 Mini-roundabouts

A mini-roundabout is an intersection design form that can be used in place of stop control or signalization at physically constrained intersections to help improve safety and reduce delays. Typically characterized by a small diameter and traversable islands, mini-roundabouts are best suited to environments where speeds are already low and environmental constraints would preclude the use of a larger roundabout with a raised central island. Figure 2.3 presents the characteristics of a mini-roundabout.

Mini-roundabouts operate in the same manner as larger roundabouts, with yield control on all entries and counterclockwise circulation around a central island. Due to the small footprint, large vehicles are typically required to travel over the fully traversable central island, as shown in Figure 2.3. To help promote safe operations, the design generally aligns passenger cars in such a way as to naturally follow the circulatory roadway and minimize running over of the central island to the extent possible (Rodegerdts et al., 2010).

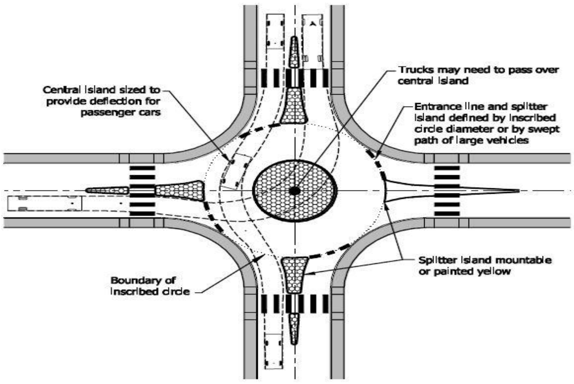

Figure 2.3: Mini-roundabout. (Source: Rodegerdts et al., 2010

2.2.4 Grade separated roundabouts

A Grade Separated Roundabout has at least one approach coming from a road at a different level. This type of roundabout is frequently employed at motorway junctions, but can also be used to link underpasses, flyovers and other multiple level intersections (DMRB, 2007).

2.2.5 Signalized roundabouts

A Signalized Roundabout has traffic signals on one or more of the approaches, and at the corresponding point on the circulatory carriageway itself. Installing traffic signals, with either continuous or part-time operation, at some or all of the entry points can be appropriate where a roundabout is naturally not self-regulated. This may be for a combination of reasons such as;
(a) a growth in traffic flow;
(b) an overloading or an unbalanced flow at one or more entries;
(c) high circulatory speeds; and
(d) significantly different flows during peak hour operation.
In some cases, it may be possible to achieve the desired result by making suitable changes to the layout and this should be checked using suitable software before installing traffic signals, as this may be cheaper and more effective (DMRB, 2007).

2.3.1 Major geometric features of modern roundabouts

Since some methodologies like the United Kingdom - regression capacity analysis, depend totally on roundabout geometric features or elements, and it is therefore necessary to identify and clearly understand the geometric features or elements of roundabouts. According to the capacity study of roundabouts in the UK, geometric elements of roundabouts play an important part in the efficiency of roundabouts operational performance. Good geometric design will improve not only capacity but also safety, which is a major concern for road design. Basic elements for design consideration of roundabouts (Figueroa, 2012) are:

(i) Design vehicle
(ii) Design speed
(iii) Deflection
(iv) Central island
(v) Circulating width
(vi) Inscribed circle diameter
(vii) Entry and exit width
(viii) Splitter island
(ix) Super elevation and drainage
(x) Pavement markings
(xi) Signage
(xii) Lighting, and

2.8 Summary

Based on the literature reviewed, different approaches have been used for Capacity Analysis, by different researchers, but can be categorized into two. These are (i) Empirical Method which is totally roundabout geometry dependent and (ii) Analytical (or Gap-Acceptance approach) Method that incorporates driver behavior

and familiarity, type of vehicle, the circulating and entering splits and conflicting circulating flow.

Although traffic circles and roundabouts use a circular design, they operate very differently. Traffic circles are very large and are designed for high-speed vehicle operation. Roundabouts are designed as small as possible, 4 to 60 m wide, and operate at 24 to 40 km/h. The design of roundabouts forces drivers to slow down as they approach them, then limits drivers' circulating and exit speed. It is difficult to pass through a well-designed roundabout above these design speed.

Since the regression or empirical method totally depends on the geometric elements of the roundabout, it is sometimes difficult to find the necessary geometric features (elements) on existing roundabouts-the case study roundabout (Fate Roundabout) inclusive, which may be a problem during evaluation. Besides, the analytical method is more realistic than empirical method since it includes the traffic environment (Akcelik, 2003). Therefore, the Analytic method is preferred for this research work using Highway Capacity Manual (2010) Gap-Acceptance Parameters approach.

III. METHODOLOGY

3.1 Data Collection

Traffic data were collected manually for 12 hours (6:30 am - 6:30 pm) at 15 minutes intervals, daily for a period of seven (7) days (Monday, 18/6/2018 – Sunday, 24/6/2018). The traffic counts were conducted to capture the peak and off-peak periods for the vehicular movements in order to achieve the objective of the study. Skilled persons were employed to carry out the traffic count and measurement of the roundabout's existing dimensions on all approaches. The five working days (Monday - Friday) were identified to have the highest traffic volume and were then chosen for analysis.

3.2 Geometric Data

The geometric parameters measured on the Arowomole roundabout are presented in Figure 3.1

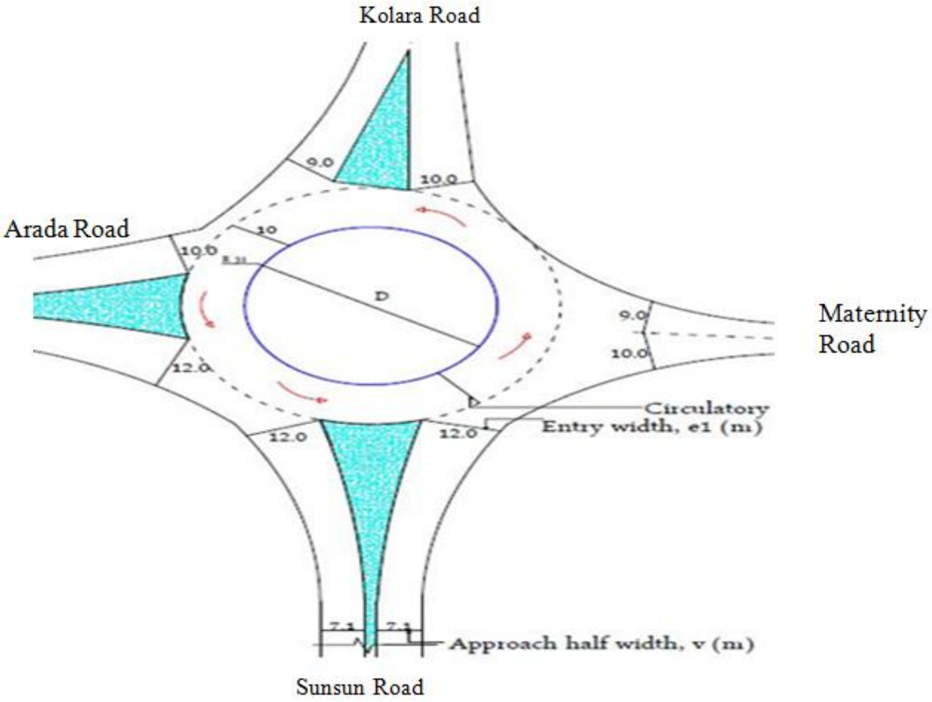

Figure 3.1: Schematic diagram showing the geometric features of the Arowomole Roundabout

Approach 1 (Kolara road)	**Approach 2 (Arada road)**	**Approach 3 (Sunsun road)**	**Approach 4 (Maternity Road)**
Inscribed circle **diameter, D = 62 m**	Inscribed circle diameter, D = 62 m	Inscribed circle diameter, D = 62 m	Inscribed circle diameter, D = 62 m
Entry width, e_1 = 9 m	Entry width, e_1 = 9 m	Entry width, e_1 = 12 m	Entry width, e_1 = 12 m
Circulatory width, e_2 = 10m	Circulatory width, e_2 = 10 m	Circulatory width, e_2 = 10m	Circulatory width, e_2 = 10 m
Approach half width, v = 5 m		Approach half width, v = 7.1 m	Approach half width, v = 7.1 m

The data and information of vehicle movements were obtained and recorded for the pre-determined peak hours on each approach. The capacity and performance analysis computation were then carried out using analytical method.

3.3 Capacity and Performance Analysis computation using HCM (2010) Gap-Acceptance parameters (Analytical approach)

The HCM (2010) described a 12- step approach for the performance analysis of a roundabout as discussed in section 2.6. Based on the stated steps, the capacity and performance of the Arowomole Roundabout were then computed and analyzed for the five working days (Monday - Friday) with the highest traffic volumes.

IV. Results Analysis and Discussions

4.1 Analysis of Results

As much as possible, the traffic data collected were indicative of the existing peak and off-peak hour traffic conditions for the Arowomole rotary intersection.

4.1.1 Volumes on each of the approaches

The peak and off-peak hours for Day 1 on approach 1 are 7:30 – 8:30 am and 12 – 1 pm, respectively.
Tables 4.1 and 4.2 present the data and information on the movement of vehicles during peak and off-peak hours, respectively on Approach 1 (Day 1), while the data for the other Approaches are shown in Appendix A.

Table 4.1: Movement of vehicles on Approach 1 (Day 1- peak period)

Time	Left Turns (LT)				Through Turns (TT)				Right Turns (RT)				
	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	**TOTAL**
7:30-7:45	53	0	0	11	50	0	0	9	25	0	0	5	**153**
7:45-8:00	49	1	0	15	40	0	0	10	17	1	0	11	**144**
8:00-8:15	41	1	0	10	47	0	0	7	15	0	0	6	**127**
8:15-8:30	36	0	0	22	52	0	0	11	20	0	0	18	**159**
TOTAL	179	2	0	58	189	0	0	37	77	1	0	40	**583**
Adjusted	224	3	0	73	236	0	0	46	96	1	0	50	**729**

Table 4.2: Movement of vehicles on Approach 1 (Day 1- Off peak period)

Time	Left Turns (LT)				Through Turns (TT)				Right Turns (RT)				
	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	**TOTAL**
12:00-12:15	28	1	1	10	44	2		18	11			9	**124**
12:15-12:30	28			8	30	1		9	23			13	**112**
12:30-12:45	32	1		9	36	2		11	15			11	**117**
12:45-1:00	36	1		11	35			6	16			7	**112**
TOTAL	124	3	1	38	145	5	0	44	65	0	0	40	**465**
Adjusted	143	4	1	44	167	6	0	51	75	0	0	46	**537**

The raw volume counts were adjusted with a factor of 1.25, since for every 15mins count; 3minutes were used for the recording process, leaving 12 minutes for the count, hence the adjustment factor needed to account for the 3 minutes was $\frac{15}{12} = 1.25$ (Traffic Monitoring Handbook, 2007), which was multiplied by the raw volume counts to give an adjusted volume (Peak periods). Similarly for the off-peak period, adjustment factor was $\frac{15}{13} = 1.15$, as 2 minutes were used for recording process.
The peak and off-peak traffic volumes used for the analysis for all approaches for the 5 working days (Monday-Friday) are presented in Appendix B

Table 4.3: Day 1 (Peak Period) [Monday]

Time	Left Turns (LT)				Through Turns (TT)				Right Turns (RT)				
	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	**TOTAL**
7:30-7:45	53	0	0	11	50	0	0	9	25	0	0	5	**153**
7:45-8:00	49	1	0	15	40	0	0	10	17	1	0	11	**144**
8:00-8:15	41	1	0	10	47	0	0	7	15	0	0	6	**127**
8:15-8:30	36	0	0	22	52	0	0	11	20	0	0	18	**159**
TOTAL	179	2	0	58	189	0	0	37	77	1	0	40	**583**
Adjusted	224	3	0	73	236	0	0	46	96	1	0	50	**729**

Table 4.4: Day 1 (Off-Peak Period) [Monday]

Time	Left Turns (LT)				Through Turns (TT)				Right Turns (RT)				
	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	Car	SUT or Bus	TwT	Bike	**TOTAL**
12:00-12:15	28	1	1	10	44	2	0	18	11	0	0	9	**124**
12:15-12:30	28	0	0	8	30	1	0	9	23	0	0	13	**112**
12:30-12:45	32	1	0	9	36	2	0	11	15	0	0	11	**117**
12:45-1:00	36	1	0	11	35	0	0	6	16	0	0	7	**112**
TOTAL	124	3	1	38	145	5	0	44	65	0	0	40	**465**
Adjusted	143	4	1	44	167	6	0	51	75	0	0	46	**537**

4.1.2 Capacity and performance analysis computation

The results of traffic movements of Tables 4.1 and 4.2 show that the Arowomole roundabout is mostly busy on working days (Monday – Friday). Therefore, the results of the five working days were used for the analysis.

The capacity and performance analysis computation were carried out using the analytical method. The peak hour factors (PHFs) for the roundabout are shown in Table 4.3. The PHFs were computed from Equation 2.19 and an example for the computation of the PHF for Approach 1 (Day- 1 Peak period) from record of Table 4.1, is given as follows:
From Table 4.1, vehicle volume during peak 15 min of the peak hou, P_{15} = 159 vehicles.

Vehicle volume during peak hour, P_h = 583 vehicles
Hence, using equation 2.20

DAY	APPROACH	Entry Flow Rates (Peak period)				Entry Flow Rates (Off peak period)			
		L	**T**	**R**	**TOTAL**	**L**	**T**	**R**	**TOTAL**
1	1	326	310	159	**795**	206	240	126	**572**
	2	209	339	259	**807**	158	267	182	**607**
	3	197	423	320	**940**	171	304	267	**742**
	4	298	346	318	**962**	197	220	230	**657**
2	1	328	370	143	**841**	224	191	132	**547**
	2	210	330	266	**806**	154	263	225	**642**
	3	260	476	346	**1082**	154	294	220	**668**
	4	384	431	349	**1164**	211	224	224	**659**
3	1	356	339	196	**891**	217	223	164	**604**
	2	269	321	277	**867**	183	214	233	**630**
	3	222	395	347	**964**	161	258	225	**644**
	4	266	290	250	**806**	211	230	198	**639**
4	1	340	307	162	**809**	221	227	133	**581**
	2	229	282	252	**763**	170	261	176	**607**
	3	176	378	286	**840**	174	223	223	**620**
	4	204	328	354	**886**	148	257	166	**571**
5	1	289	266	185	**740**	176	181	175	**532**
	2	223	300	246	**769**	170	184	118	**472**
	3	189	323	275	**787**	165	181	186	**532**
	4	148	239	258	**645**	175	180	175	**530**

$PHF_{11} = \frac{Ph}{P15 \times 4} = \frac{583}{4 \times 159} = 0.917$

Where;
PHF_{11} = peak hour factor for Approach 1 on Day 1
Table 4.5 presents the PHF for all the approaches during the five-day analysis period
Table 4.10: Entry Flow Rates for the Arowomole Roundabout

Compute the Average Delay for each entry lane
The average delay was computed using Equation (2.22).
The average control delay was computed taking values from Table 4.9 and 4.10; entry lane capacities and degree of saturation respectively. The average delay for Approach 1 (Day 1-peak period) is thus given; C_i= 1227 (pc/h), x = 0.647, T = 1 hour, hence;

$d = 9\ s\ /\ veh$

For Day 1: Peak period

$$d_{intersection} = \frac{\sum(9\ x\ 795) + (11x807) + (15x940) + (14x962)}{\sum(795 + 807 + 940 + 962)} = 12\ s/veh$$

Day 1: Off-peak period

$$d_{intersection} = \frac{\sum(4\ x\ 572) + (4\ x\ 607) + (5\ x\ 742) + (4\ x\ 657)}{\sum(572 + 607 + 742 + 657)} = 4\ s/veh$$

Day 2: Peak period

$$d_{intersection} = \frac{\sum(18\ x\ 841) + (16\ x\ 806) + (26\ x1082) + (102\ x\ 1164)}{\sum(841 + 806 + 1082 + 1164)} = 45\ s/veh$$

Day 2: Off-peak Period

$$d_{intersection} = \frac{\sum(4 \text{ x } 547) + (4 \text{ x } 642) + (4 \text{ x } 668) + (4 \text{ x } 659)}{\sum(547 + 642 + 668 + 659)} = 4\ s/veh$$

Day 3: Peak period

$$d_{intersection} = \frac{\sum(10 \text{ x } 891) + (14 \text{ x } 867) + (21 \text{ x } 964) + (10 \text{ x } 806)}{\sum(891 + 867 + 964 + 806)} = 14\ s/veh$$

Day 3: Off-Peak period

$$d_{intersection} = \frac{\sum(4 \text{ x } 604) + (4 \text{ x } 630) + (4 \text{ x } 644) + (4 \text{ x } 639)}{\sum(604 + 630 + 644 + 639)} = 4\ s/veh$$

Day 4: Peak period

$$d_{intersection} = \frac{\sum(7 \text{ x } 809) + (8 \text{ x } 763) + (10 \text{ x } 840) + (10 \text{ x } 886)}{\sum(809 + 763 + 840 + 886)} = 9\ s/veh$$

Day 4: Off- Peak period

$$d_{intersection} = \frac{\sum(4 \text{ x } 581) + (4 \text{ x } 607) + (4 \text{ x } 620) + (4 \text{ x } 571)}{\sum(581 + 607 + 620 + 571)} = 4\ s/veh$$

Day 5: Peak period

$$d_{intersection} = \frac{\sum(5 \text{ x } 740) + (7 \text{ x } 769) + (7 \text{ x } 787) + (5 \text{ x } 645)}{\sum(740 + 769 + 787 + 645)} = 6\ s/veh$$

Day 5: Off-Peak period

$$d_{intersection} = \frac{\sum(3 \text{ x } 532) + (3 \text{ x } 472) + (3 \text{ x } 532) + (3 \text{ x } 530)}{\sum(532 + 472 + 532 + 530)} = 3\ s/veh$$

4.2 Discussion of Results

The key performance indicators used for evaluating the performance analysis of the Arowomole Roundabout were; entry capacity, v/c ratio (degree of saturation), average delay and LOS.

4.2.1 Effect of volume on the capacity of the roundabout

High pedestrian volume has a significant effect on capacity of a Roundabout. Although, there are no designated pedestrian crossings at Arowomole Roundabout, counts showed that there were low crossing (< 50 pedestrians/hour) during the counting exercise which had no significant effect on the capacity of the roundabout as depicted in Figure 2.12. It was observed from the traffic data collected at the Arowomole roundabout that the peak period occurred between 7:30 to 8:30 am and the off-peak period occurred between 12:00 to 1:00 pm on most of the days.

It can also be observed from Table 4.6 that the heavy vehicle proportion were < 5%, indicating that the proportion of heavy vehicles had no effect on the capacity of the roundabout during the analysis period. As a common approach, when the percentage of heavy vehicles is below 5%, it has no significant effect on roundabout performance. Hence, the heavy vehicle adjustment factor, $_V$ was taken as 1; the demand flow rate in veh/h was equal to the demand flow rate in pc/h.

Table 4.20: Summarized capacity analysis results on the approach or legs (Peak Period)

DAY	APPROACH	v_i (pc/h)	q_c (pc/h)	(v/c ratio)	C_e (pc/h)	*v/c* ratio - 0.85
1	1	795	841	0.647	1227	-0.203
	2	807	934	0.704	1147	-0.146
	3	940	874	0.785	1198	-0.065
	4	962	829	0.777	1238	-0.073
2	1	841	1075	0.812	1036	-0.038
	2	806	1082	0.783	1030	-0.067
	3	1082	868	0.899	1204	+0.049
	4	1164	946	1.024	1137	+0.174
3	1	891	778	0.693	1285	-0.157
	2	867	961	0.771	1125	-0.079
	3	964	946	0.849	1136	-0.001
	4	806	886	0.678	1188	-0.172
4	1	809	708	0.598	1352	-0.252
	2	763	851	0.626	1218	-0.224
	3	840	851	0.69	1218	-0.16
	4	886	783	0.692	1279	-0.158
5	1	740	576	0.498	1487	-0.352
	2	769	703	0.567	1356	-0.283
	3	787	812	0.628	1253	-0.222

	4	645	735	0.487	1325	-0.363

Table 4.21: Summarized capacity analysis results on the approach or legs (Off-Peak Period)

DAY	APPROACH	v_i (pc/h)	q_c (pc/h)	(v/c ratio)	C_e (pc/h)	*v/c* ratio - 0.85
1	1	572	588	0.388	1474	-0.462
	2	607	643	0.428	1417	-0.422
	3	742	631	0.519	1429	-0.331
	4	657	633	0.46	1427	-0.39
2	1	547	589	0.371	1473	-0.479
	2	642	626	0.448	1434	-0.402
	3	668	641	0.471	1419	-0.379
	4	659	602	0.452	1457	-0.398
3	1	604	602	0.414	1459	-0.436
	2	630	651	0.447	1408	-0.403
	3	644	614	0.445	1446	-0.405
	4	639	602	0.438	1459	-0.412
4	1	581	579	0.392	1483	-0.458
	2	607	596	0.414	1466	-0.436
	3	620	652	0.441	1407	-0.409
	4	571	567	0.381	1497	-0.469
5	1	532	520	0.344	1548	-0.506
	2	472	532	0.307	1535	-0.543
	3	532	530	0.346	1537	-0.504
	4	530	516	0.341	1552	-0.509

By observing the (v/c - 0.85) column from Tables 4.20 and 4.21 which is based on HCM (2010), it was easy to identify the legs in a critical condition. The legs (or Approaches) with positive values in the column, that is, with v/c > 0.85 are in critical condition. These are legs 3 and 4 on Day 2 (peak period) with v/c ratio of 0.899 and 1.042, respectively. The assumption on the theory in respect of direct relationships of capacity at legs and opposing circulatory flow is used as the basis of judgment on adequacy. The entry capacity of the legs is influenced by the average entry lane width and number of entry lanes. A capacity versus circulatory flow curve fitting technique is then developed to observe the relationships or the influences.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The following conclusions were drawn from the study:

(i) The peak and off-peak periods occurred on all days on the Arowomole Roundabout between 7:30 – 8:30 am and 12:00 – 1:00 pm respectively. Also, the pedestrian count is less than 50/hour, and therefore has no significant effect to the roundabout capacity.

(ii) The average delays experienced during peak and off-peak periods ranges between 5 – 102 seconds and 3 – 5 seconds, respectively. Approach 4 experienced the highest delay time of 102 seconds on Day 2, while Approach 4 witnessed the lowest delay of 5 seconds on Day 5 of the analysis period.

(iii) The volume/capacity ratio of all the Approaches, except Approaches 3 and 4, with v/c ratios of 0.899 and 1.024, respectively on Day 2 are higher than the threshold value of 0.85. This implies that the two Approaches witnessed delays and queues on Day 2 of the analysis period.

(iv) Approaches 3 and 4 operated on levels of service (LOS) D and F respectively, during the peak periods of Day 2 of the analysis period. Other Approaches operated on LOS A-C. This further confirms the delay and queues experienced on Approaches 3 and 4, respectively.

(v) A strong linear relationship of the form y = mx + c between capacities at the roundabout approaches and opposing circulatory flows on all legs was established with R^2 value of 0.996.

(vi) The Arowomole Roundabout is adjudged to be performing well under the prevailing conditions at its design capacity.

(vii) Approach 4 was identified as the critical leg with the highest delay time and queues at the Arowomole Roundabout.

5.2.1 Recommendations

(i) Deflection and island splitters should be introduced on Leg 2 (Sunsun Road) of Arowomole Roundabout to make drivers reduce their speeds and avoid collision between neighboring leg entering vehicles.

(ii) Marked pedestrian crossing should be introduced on all approaches of the roundabout to guide pedestrians crossing and prevent them from accessing the central island in order to increase safety.

(iii) The width of approach 3, which is the most trafficked should be increased by at least 1 m to maintain continuous and smooth flow operations.

(iv) The geometric parameters for Arowomole Roundabout and other roundabouts inclusive should be obtained and made available to provide for comparison between the analytical and empirical method of capacity estimations.

(v) A more accurate method of estimating the entry capacity should be sought as more roundabouts are built with increasing vehicular traffic.

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