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DESIGN OF TRAFFIC SIGNAL AT KPAKUNGU INTERSECTION, MINNA

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ABSTRACT

Traffic signals play a very important role in controlling traffic flow at intersections. There are numerous traffic gnals present at various intersections in Niger State. This paper is aimed at designing traffic signals at Kpakungu rotary tersection. The traffic volume for each arms of the intersection were obtained from field study for Monday to Friday tween 7:00 am – 10:30 am in the morning and 3:30 pm – 7:30 pm in the evening and an average volume of traffic at ak hour was compute per day. The volumes obtained were analyzed for each section of the arms and critical volume vehicle per hour per lane also obtained. The saturation flows obtained at the intersection and the traffic phasing of ch arm also designed and the corresponding traffic flow of one arm into another estimated. The traffic signal was sign based on the critical flow at peak hours and the corresponding cycle length computed. The traffic signal design as discovered to be insufficient as the desired cycle length yielded a negative result and a flyover bridge was commended for the western by – pass road (Arm A and B) which yielded the highest traffic volume to control the affic congestion at the intersection.

Keywords: *Arms, Intersection, Roundabout, Signal, Traffic, Volume*

1.0 INTRODUCTION

As human population grows rapidly in urban areas, vehicular traffic volume has also increased proportionally following increased mobility and the geometric increase in the rate of automobile ownership. This accounts for the intense traffic congestion that is associated with urban areas which affects their livability in terms of congestion, pollution; high travel cost and delay (Sheehan, 2010). Traffic congestions are usually caused by excessive delays at intersections in most cases (Reddy and Reddy, 2016). Because the capacity of an intersection is usually lower than that of other sections of the street, bottleneck effects are bound to be experienced at intersections.

Traffic signals are standardized devices for the regulation and control of vehicular traffic, pedestrians and pedal cyclists which are used at signalized intersections, signalized pedestrian and cyclist crossings, railway crossings and at locations where control of traffic flow is required (FMW, 2013)

Various kinds of techniques and computer tools have been developed to help traffic engineers find the optimum traffic signal timing and to predict the performance of signalized intersections in terms of delays and queue lengths. One of such techniques is the Webster's method (Paul *et al.*, 2018)

Webster's methods have been used by traffic engineers to find the optimum traffic signal timing and to predict the performance of signalized intersections in terms of delays and queue lengths. Webster proposed an equation for the calculation of optimum cycle length that seeks to minimize vehicle delay. Other researchers established that this model tends to fail whenever saturation flow ratio is approximately unity. That is when demand is approximately equal to lane capacity (Zakariya and Rabia, 2016)

The observations made at Kpakungu roundabout shows that it is characterized by serious congestion and delays resulting sometimes in accidents and break downs at peak periods of working days (Mondays - Fridays), making motorists to spend long delays and congestion. This has caused lost in productive hours and inconveniences to the road users and the environment at large. This paper therefore, seeks to check the suitability of installing Traffic Signals to control traffic flow at the intersection. This can be achieved by carrying out traffic surveys and using the data for traffic signals.

2.0 METHODOLOGY

2.1 DESCRIPTION OF STUDY AREA

Kpakungu roundabout is located South – Western part of Bosso Local Government Area Minna of Niger state, Nigeria. Kpakungu is located on latitude 9^0 35'55.00" N and longitude 6^0 32' 00"E of the state while Niger state is located between latitude 8^0 10' N and 100 30'N and between longitude 3^0 30'E and 7^0 30'E. Niger State covers an area of 96,363 square Kilometres. Minna being the state capital is located at the North- Eastern part of the land that makes up Niger State along the Lagos-Kano railway track as shown in Figure 1. It enjoys a strategic location and relatively easy accessibility from all parts of the country at kpakungu along western by–pass in Minna, Niger state. The intersection is characterized with high density of traffic as the road serve as inflow to Minna town from Bida along which there is Headquarter of National Examination Council (NECO) and Federal University of Technology Minna. This roundabout contains four legs: Western bye – pass road, Minna – Bida road, Shiroro road and Soje road as shown in Plate 1.

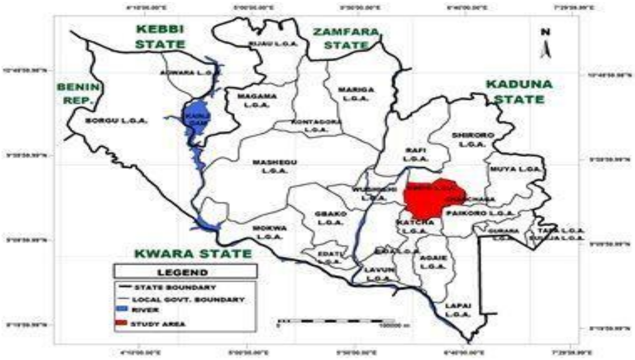

Figure 1: Map Showing Bosso Local Government, Niger State

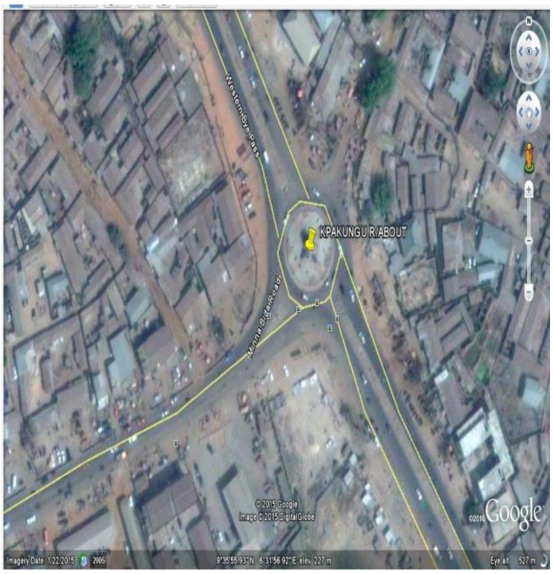

Plate 1: Google Map Showing the Imagery of Kpakungu Rotary Intersection, Minna

2.1 DATA COLLECTION

The traffic data was obtained from direct field manual method of counting and the volume of traffic was estimated from direct volume data of the intersection. Data are collected on working days from 7.00a.m to 10:30a.m and from 3:30p.m to 7.00p.m per day.

Geometric Data

Measurement of the physical geometry of the roundabout is carried out using measuring tape and calibrated steel pole. The tape was used to measure the type of terrain whether level, rolling or mountainous. The slope of the roads surrounded by the intersection is also determined. The results of the geometric data are presented in the next section.

Traffic Volume Study

Manual traffic counting method is adopted in collecting the vehicle volume data. Tally sheets with provision for vehicle categories and time interval were used to record number of vehicles. The categories of vehicles are; Taxi, Personal Car, Motorcycle, Lorry, Petrol Tankers, Trailers, and Bus. This is aimed at determining the Passenger Car Unit (PCU) through the Passenger Car Equivalent (PCE). The geometric properties of the intersection were determined, the entry, circulatory and turning movements were counted separately for each arm. The capacity, delay, ratio of flow to capacity of each arm and level of service of the roundabout were evaluated using the data collected from the manual traffic count and the geometric properties so measured. The study of traffic volume and density is also done.

Traffic Characteristics

The speed study was done manually; field personnel were hired and stationed at each section of the four legs to assist in carrying out the field operation. A fifteen-meter section is taken on each of the four legs and a manual registration number was adopted. This method involves speed analysis of vehicles at different section of the road (i.e Horizontal and Vertical alignment). The entry time as well as exit time of each of the vehicle studied is determined using stop watch and the average running speed of the vehicles is determined.

2.2 DESIGN OF TRAFFIC SIGNALS

The cycle length was estimated from the computational analysis of the data obtained from field survey and the following formulae were used to design the green timing of each arm.

The length of yellow change interval (y);

$$y_{A,B} = t + \frac{1.47 \; x \; S_{85}}{2a+(2g \; x \; 0.01G)} \quad (1)$$

Length of all red phase (ar)

$$(ar)_{AB} = \max\left[\left(\frac{w+L}{1.47 \; x \; S_{85}}\right)\left(\frac{P}{1.47 \; x \; S_{85}}\right)\right] \quad (2)$$

Where:

W = Distance from the departure STOP line to the far side of the farthest conflicting traffic lane (m) taken as 15.0m

P = Distance from the departure STOP line to the far side of the farthest conflicting cross walk (m) = 10.8 + 4(3.65) = 25.40m

L = length of standard vehicle usually taken between 5.49m – 6m
Estimating the desired cycle length,

$$C_{desired} = \frac{L}{1 - \left[\frac{V_c}{Saturation\ Flow\ x\ PHF\ x\ (v/_c)}\right]} \quad (3)$$

PHF = Peak hour factor (taken as 95%) v/c = Target v/c ratio for the critical movement in the intersection (taken as 0.9).

3.0 RESULTS AND DISCUSSION

3.1 Geometrical Properties of the Intersection

The intersection is a rotary intersection with a diameter of about 28 meters from the measurement taken. The roundabout has four legs as shown in Table 1. Arm A and Arm B of the leg is exactly along the western by-pass which is observed to be the busiest road with high traffic volume. Arm A and B is a dual carriageway with two lanes each and shoulders.

Table 1: Geometrical Properties of the Roads at the Intersection

Road /Arm	Carriage Type	Carriage Way Width (m)	Median Width (m)	Shoulder Width (m)
Kpakungu - Shiroro Road (Arm A)	Dual	7.3	5.3	2.75
Kpakungu - Kure Market Road (Arm B)	Dual	7.3	5.3	2.75
Kpakungu - Bidda Road (Arm C)	Single	7.3	-	-
Kpakungu - Soje Road (Arm D)	Single	7.3	-	-

3.2 Traffic Volume

The average traffic volume of Arm A into B and arm B into A is 1,652 and 1,487 respectively which is higher than C into B and C into A which is 684 and 276 respectively for morning while traffic volume of Arm A into B and arm B into A is 1,735 and 1,562 respectively which is higher than C into B and C into A which are 719 and 290 respectively for evening. Traffic signals are designed based on vehicle per hour (Veh/h), an average value of the PCU will be adopted in the design of the traffic signals. The bar chat of the average traffic volume is also presented in Figure 4. The volume of traffic flowing into arm A, B and C is more than that flowing into D as a result of the level of service of the road.

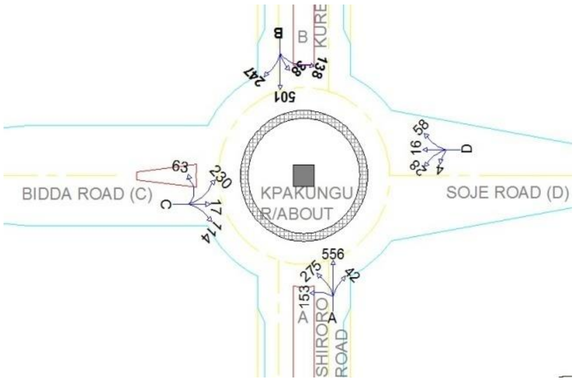

Figure 2: Phasing of Average Traffic Volume for Evening Peak Hour

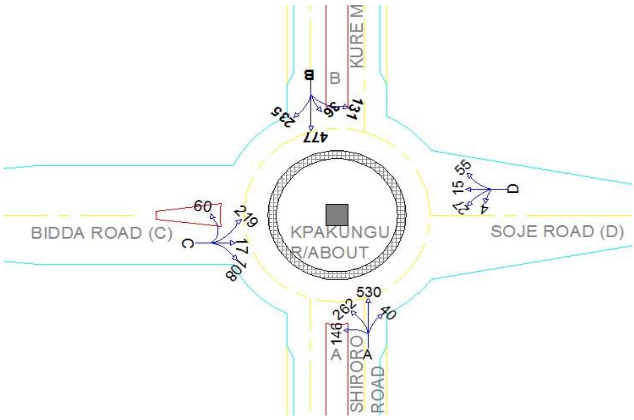

Figure 3: Phasing of Average Traffic Volume for Morning Peak Hour

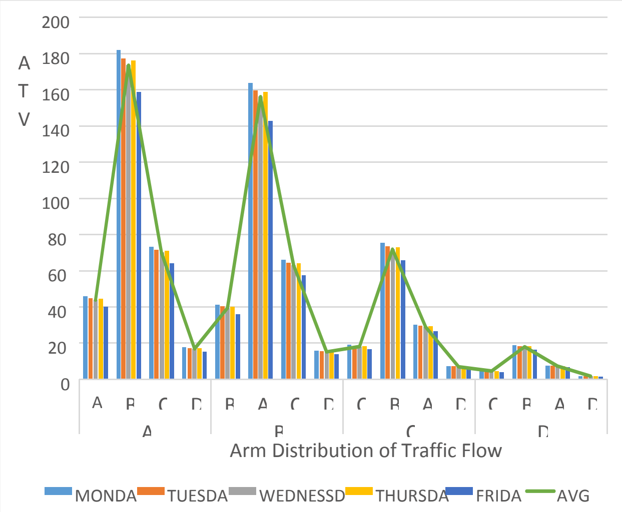

Figure 4: Average Volume with days

3.3 DESIGN OF TRAFFIC SIGNALS

The average traffic volume of all the four arms of the intersection for peak hours has been estimated and presented in Figure 2 and 3 for evening and morning respectively. The volume of traffic flowing into other arms for a different phase is estimated.

Table 2: Design Parameters

Element	Values
Average Speed Study	40km/hr
Deceleration rate of Vehicle	3.0m/s^2
Grade of Approach	-2.50%
Drivers Reaction Time	1.0s
Acceleration Due to Gravity	9.81m/s^2
Cross Walk Distance	10.80m

There exists a variation in the vehicular speed at the intersection and hence the direct speed cannot be used in the design, however recommendation from statistical analysis shows that 85th percentiles and 15th percentile is used in the design.

The length of yellow change interval (y);

$$y_{A,B} = t + \frac{1.47\ x\ S_{85}}{2a + (2g\ x\ 0.01G)} = 11.2\ secs$$

Length of all red phase (ar)

$$(ar)_{AB} = \max\left[\left(\frac{w+L}{1.47\ x\ S_{85}}\right)\left(\frac{P}{1.47\ x\ S_{85}}\right)\right] = \max[0.41, 0.49] = 0.49 secs$$

Where:

W = Distance from the departure STOP line to the far side of the farthest conflicting traffic lane (m) taken as 15.0m

P = Distance from the departure STOP line to the far side of the farthest conflicting cross walk (m) = 10.8 + 4(3.65) = 25.40m

L = length of standard vehicle usually taken between 5.49m – 6m

$$(ar)_{AC} = \max[0.35, 0.25] = 0.35 secs$$

Estimating the loss time

Start – up loss time (l_1) = 2.0 secs / phase

Clearance loss time (l_2) = Y – e

$Y_{AB} = y_{ab} + ar_{ab} = 11.2 + 0.49 = 11.63$ secs

$Y_{AC} = y_{ac} + ar_{ac} = 11.2 + 0.35 = 11.55$ secs.

Total loss time (t_L) = e + l_2

Y = Total length of change and clearance time (s)

Estimating the desired cycle length,

$$C_{desired} = \frac{L}{1 - \left[\frac{V_c}{Saturation\ Flow\ x\ PHF\ x\ (^v/_c)}\right]} = -92.48\ secs$$

PHF = Peak hour factor (taken as 95%) v/c = Target v/c ratio for the critical movement in the intersection (taken as 0.9)

The saturation flow = $\frac{3600}{2.12} = 1700.$

The green time of each of the phase is estimated by multiplying the total green phase with a fraction of the phase volume to the total critical flow volume of traffic.

For morning peak hour;

V_c=963+471+624=2031 tvu/h

The negative sign indicates that there is no cycle length that can accommodate a Vc of 2031tvu/hr at this location

Total green phase = 92.48 – 34.85 = 57.55secs

Effective Green Time to each phase.

$g_A = 57.55\ x\ \frac{963}{2031} = 27.29\ secs$

$g_B = 57.55\ x\ \frac{471}{2031} = 13.35\ secs$

$g_C = 57.55\ x\ \frac{624}{2031} = 17.68\ secs$

For evening peak hour;

V_c = 915 + 505 + 580 = 2000 tvu/h

$$C_{desired} = \frac{34.85}{1 - \left[\frac{2000}{1700\ x\ 0.95\ x\ 0.9}\right]} = -61.15\ secs$$

The negative sign indicates that there is no cycle length that can accommodate a Vc of 2031tvu/hr at this location

Total green phase = 61.15 – 34.85 = 26.30 secs

Effective Green Time to each phase.

$g_A = 26.3\ x\ \frac{915}{2000} = 12.66\ secs$

$g_B = 26.3\ x\ \frac{505}{2000} = 6.19\ secs$

$g_C = 26.3\ x\ \frac{580}{2000} = 8.21\ secs$

4.0 CONCLUSION

The traffic signals for the intersection have been designed from the estimated traffic volume for each of the arm. The saturation flow is obtained from calculation, loss time and cycle length for each phases are also obtained. The traffic volume of the road along the western by – pass which is coded as Arm A and B in this paper is regarded the busiest, as the traffic coordination shows that western by – pass serve the adjacent Minna – Zungeru Axis, which is the main arteries of transportation in the city of Minna. Moreover, the volume of traffic coming from arm C is also relatively high as the inflow is received from adjoining communities as well as some other important economic asset that is present along the artery. A close relationship exists between the volume of traffic obtained in the morning and evening which shows a cyclic movement of vehicles at the intersection. The value of the cycle length obtained for the intersection is negative which indicates that there is no cycle length that can accommodate a critical volume of the traffic flow. The capacity of the intersection is more than what a signal can control. The designed traffic timing of arm A (Shiroro road) flowing into A is 27 seconds, flowing into B is 15 seconds, and flowing into C is 17 Seconds.

5.0 RECOMMENDATION

This paper work has investigated the traffic capacity of Kpakungu intersection. The following recommendations are given from the analysis of the result obtained;

1. The traffic light is not sufficient for the intersection as the cycle time yielded a negative result.

2. A flyover bridge is recommended at the intersection that is parallel along the arm A and B of the intersection to accommodate traffic along the busiest road.

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