CHARACTERIZATION OF MAJOR INTERSECTIONS IN AKURE, NIGERIA

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ABSTRACT

The performance of intersections and drivers' behaviour are crucial to road network opperational efficiency and safety; while Gap acceptance is an important parameter associated with its assessment. Five intersections comprising of three Tees (RN_1, RN_2, RN_3) and two Cross (RN_4, RN_5) critical to traffic flow were selected for detailed study. Data on Goemtric features were collected using odometer while video recording technique was used to collect data on gap acceptance parameters, vehicle waiting and arrival time. The data were analyzed using logit and Raff methods. Average carriageway widths of 7.12 m was obtained which is less than 7.30 m specified, leading to the reduction of the Level of Service (LOS). The operating LOS for the Tee and Cross intersections, were "E" and "F" respectively indicating that travel speeds were substantially restricted and roadway operations were with extreme delays as indicated in the Highway Capacity Manual. The analysis of the critical gap resulted in average values of 7.46 sec, 8.02 sec, and 8.07 sec respectively for RN_2, RN_3 and RN_4 which are higher than the recommended value for left turning in the HCM 2000; indicating that the subject vehicle drivers were conservatives and appeared to choose a gap that were sufficiently long to avoid a collision or major conflict. However, the values of 6.33 sec and 6.87 sec were obtained for RN1 and RN5 respectively signifying that the drivers were aggressive at the intersections. Intelligent transport systems is recommended for traffic management in the study area.

KEYWORDS: *Drivers; intersection; level of service; traffic management*

1.0 INTRODUCTION

Intersections are the most critical points for the operation of an urban road network. They usually constitute major bottlenecks, due to conflicting interactions between traffic streams in different directions as illustrated in Figure 1.

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Studies on traffic characteristics at intersections have been focused more on signalized than unsignalized ones globally; the perception has been that research on unsignalized intersections is unnecessary, since most intersections are signalized and so very limited studies has been reported especially in developing countries like Nigeria (Owolabi et al., 2016). To effectively characterize intersections, knowledge of geometric features, gap acceptance parameters and magnitude of delay is essential. While the critical gap and follow-up time are the two main gap acceptance parameters, delay is one of the principal parameters used as measure of effectiveness to determine the level of service (LOS).

According to Nagalla et al., (2017), driver's gap acceptance behaviour highly influences the performance and safety of unsignalized intersections. At unsignalized intersections, crossing drivers have to accept or reject the available gap; thus, it gives gap acceptance a unique condition for analysis.

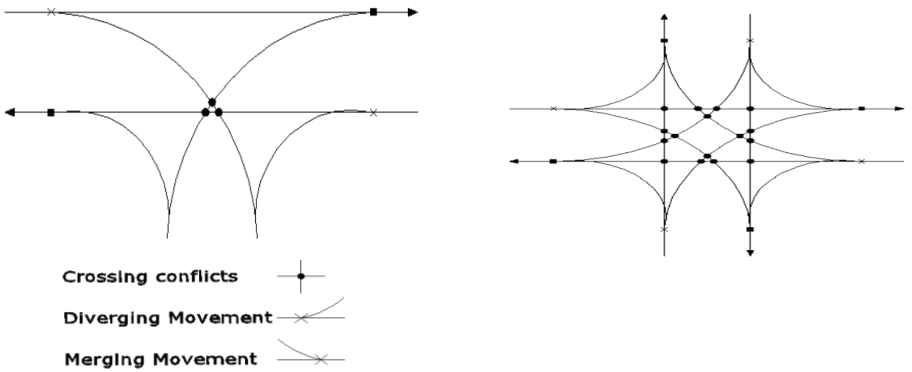

Figure 1 Types of movement at intersections

Several studies have been carried out to determine drivers characteristics and examine various aspects of gap acceptance behavior at intersections, using either deterministic or stochastic methods. Examples of deterministic methods include the Raff's method (Fitpatrick, 1991; Gattis and Low, 1999); the stochastic methods include Logit model (Pollatschek et. al., 2002; Rossi et. al., 2013; Cassidy et al., 1995; Gattis and Low, 1998; Yan and Radwan, 2008; Harwood et. al., 2000; Zohdy et al., 2010), Probit model (Hamed and Easa, 1997; Lassarre et al., 1991). Dangazo 1981 used the "probit model" to reflect the heterogeneity of drivers behaviors and estimate the parameters of normal distribution of the intersection critical gap. He found that there were diversities not only between different drivers, but also with the same driver. That is different drivers as well as the same driver behave differently to the same gap size. Cassidy et al. (1995) used binary logit model to estimate the mean of the single-value critical gap function to evaluate capacity and delay experimentally; with this model, he concluded that delay affect gap acceptance at intersections.

Furthermore, Kita (1993) formulated a gap acceptance model at the merging sections of freeways; he use binary logit model as the explanatory variable such as distance of the acceleration lane, agp and relative velocity. In the research conducted by Yang and Koutsopoolis (1996), they presented a rule based lane changing model applied to freeways. They provided changeable lanes, lane changing scenarios, and modeled cases where drivers faced conflicting objectives. In addition, the critical gap at an unsignalized intersection was also determined through the gap acceptance concept using fixed critical gap for each vehicle, which varied over a population size as described in Equation 1.

$$P(t) = \frac{1}{\beta\Gamma(k)} X \left(\frac{t-a}{\beta}\right)^{k-1} X e^{\left(\frac{t-a}{\beta}\right)} \quad (1)$$

Where:
$P(t)$ is the probability density function of headway (t);
a and β are location and scale parameter;
K is parameter that determines the shape of the distribution.
Reseacher also have used the utility maximization principle, originated from the choice theory, to obtain the probability of a gap occurring as described in Equation 2.

$$C_{pi} = \frac{3600}{t_m} X e^{\frac{t_o x \Sigma_j V_{cj}}{3600}} \quad (2)$$

$$t_o = t_g - \frac{t_m}{2}$$

where:
$C_{p\lambda}$ is the potential capacity of minor movement i in P.C.U./hr,
V_{cj} is the volume of traffic in conflicting stream j in vph;
t_g is the critical acceptance gap in seconds;
t_m is the follow –up time in seconds

Consequently, McGowen and Stanley (2012) in a recent study proposed an alternative model for estimating the critical gap, which could yield accurate estimates of the mean critical gap as long as accurate estimates of the major street traffic were given. Also, Fuzzy Logic was used by Rossi et. al., (2012) to properly treat the uncertainty, which affects gap-acceptance decision process. Vasconcelos et al. (2013) compared different methods to estimate critical headway at roundabouts and suggested that locally calibrated parameters should be used for capacity calculations. In another research conducted by Rossi et. al., (2012), Fuzzy Logic was used by to properly treat the uncertainty, which affects gap-acceptance decision process. However, Zhou et al., (2014) identify factors that may influence the gap acceptance behavior of drivers who turn left from the major road at unsignalized intersections. A correlated logit models were used to estimate the probability of accepting a gap. They found that the gap duration, the number of rejected gaps, the mean and total time interval of the rejected gaps and the gender of the driver were all significant in explaining the variation of the gap acceptance probability. Also, Nagalla et al., (2017), analyzed gap acceptance behavior at unsignalized intersections using support vector machines, decision tree and random forests, they opined that decision tree generated by CART algorithm provides critical insights into decision making process employed by the driver. Random forests and decision tree implicitly establish the relative importance of different factors affecting the driver's decision.

The study is design to characterize the major intersections in Akure, Nigeria using geometric features, average delay and gap acceptance.

2.0 THE STUDY AREA

Akure the capital city of Ondo State is one of the fastest growing urban settlements in the South Western region of Nigeria with a population of 387,087 according to 2006 census. It is located on latitude 7° 15′ 00″ N and longitude 5° 12′ 00′′E and has an area of 30.02 square kilometres. The city of Akure was not planned *ab-initio* and as a result of this, there is minimal functional relationship between the various land uses. According to Fasakin (2000), Akure is composed mainly of residential areas forming over 90% of the developed area with additional activities such as warehousing; manufacturing, workshops and other commercial activities are that are located within the residential neighborhoods.

Over the years, the number of vehicles on its roads has increased greatly due to increasing socioeconomic activities. Increase in infra-structural facilities such as housing, electricity, water supply and transportation caused rural – urban migration has imposed serious strains on existing transportation infrastructure resulting in traffic congestion (Owolabi 2004). Owolabi (2004) further affirmed that the poorly developed road network and inefficient traffic management techniques in the metropolis often create chaotic traffic pattern, since then the situation has not changed much. The natural pattern of development in Akure township is linear along main roads; Oyemekun-Oba Adesida road and Arakale-Oda road. These roads connect other streets like Aiyedun, Isolo, Araromi, Oke-Ijebu, Elerinla, Fanibi, Isikan and Adegbola residential areas.

In Akure metropolis, unsignalized intersections are the most common where they are controlled by Stop and Yield signs as well as control by the pre-timed traffic signal. The traffic composition is mixed and dominated by taxis, motorcycles and minibuses (Owolabi, 2009). In the study by Oyedepo (2014), 49.82% of the vehicle sample passenger's car, 39.87% were motorcycles, and 9.37% were buses, while 2axle- load and 3axle-load were 0.73% and 0.21% respectively. Figure 2 is the map of Ondo State showing the study area.

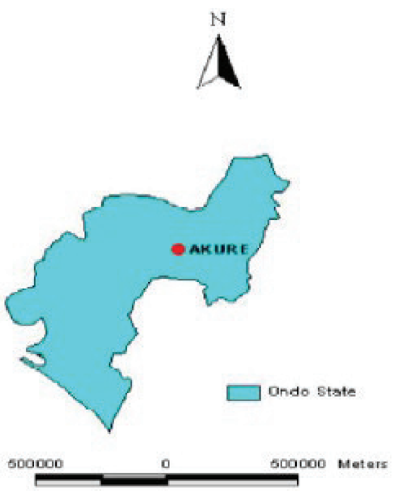

Figure 2 Map of Ondo State Showing the Study Area
(Rectas Archive Ile-Ife, 2006)

3.0 METHODOLOGY

Five intersections shown in Figure 3 consisting of three Tee intersections namely Road block (RN_1), Cathedral (RN_2), Akure Town hall-Araromi junction (RN_3), and two Cross intersections which are NEPA (NR_4) and Odole (RN_5) critical to traffic flow in the study area were selected. Data on geometric features were collected using odometer. Video recording technique was used to collect data on gap acceptance parameter and vehicle waiting/ arrival time. The camera was stationed at an elevated vantage point from the roadside of the selected intersections to observe the movements of vehicles. Two cine cameras were used at each intersection to provide complementary views, and hidden from drivers so that they would not be distracted from exhibiting their normal behavioral patterns.

Digital video recordings were made of drivers turning left from the major road and their gap acceptance behavior at each intersection. The video was processed later in the lab to extract data needed such as the time when the left turning vehicle arrived, the gap length in the oncoming traffic, and whether or not the gap was accepted by the driver.

The delay was measured by taking note of how long a vehicle waited at a particular approach before having right-of-way. Both Logit and Raff methods were used to evaluate tc. The geometric features, gap acceptance parameters and delay were used for intersections characterization. The delay and tc at each intersection were compared with the recommended standard in the HCM 2000 to facilitate intersection's characterization.

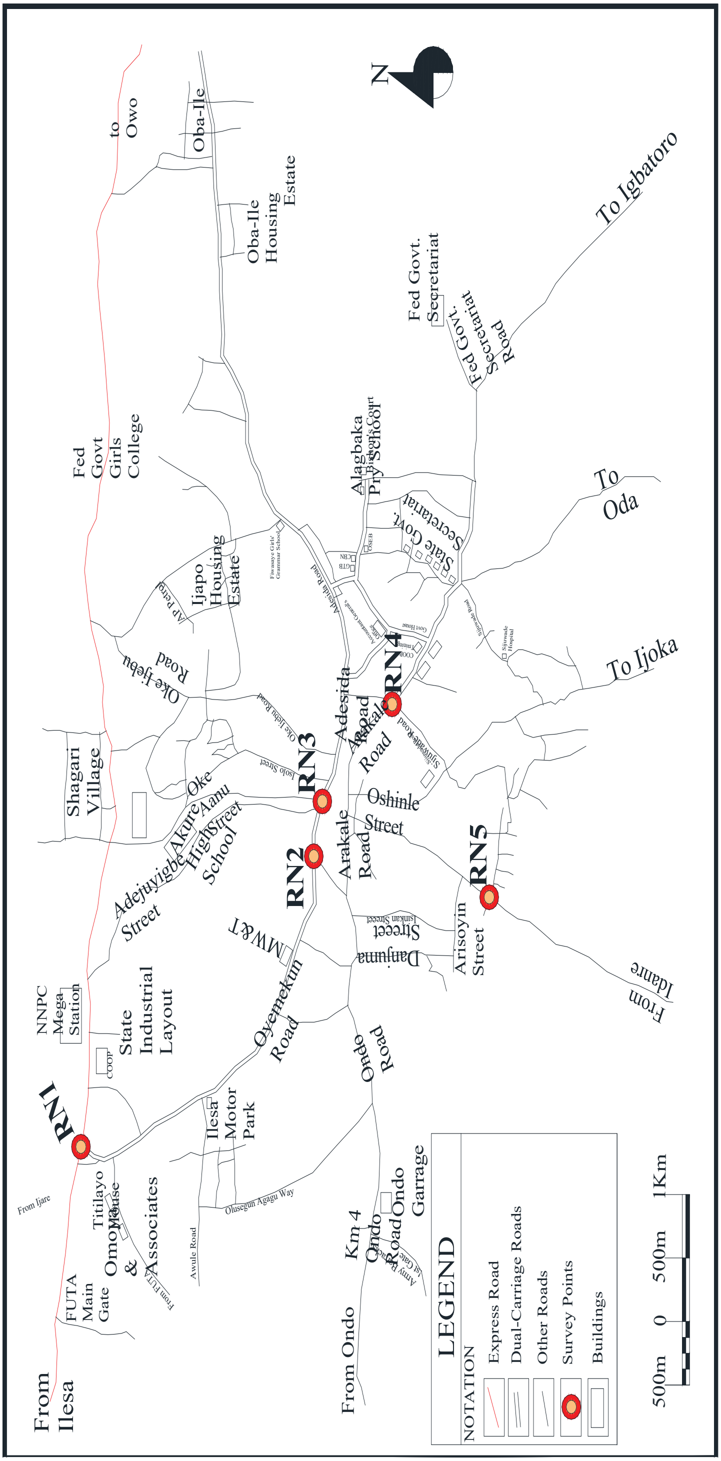

Figure 3 Street guide map of akure showing the survey points (Ministry of Lands and Housing, 2010)

4.0 RESULTS AND DISCUSSION

The geometric features of the selected intersections in Table 1 shows that the Tee and Cross intersections have average carriageway width of 7.20 m, 7.0 m,and 7.15 m at RN_1, RN_3 and RN_5 respectively which is less than 7.30 metres specified by the Nigerian Highway Capacity Manual. The implication is that those intersections were not operating at their full capacity as such were operating at reduced LOS. Tables 2 to 6 show the analysis of gap acceptance for the selected intersections using Logit (Stochastic) method while Figure 4 to 8 presents the analysis using Raff method.

Table 1 Geometric features of the selected intersection

S/N	Intersection	Types of Intersection	m_{sw} (m)	m_n	m_w (m)
1.	Road Block (RN_1)	Tee TWSC	7.10	2	7.30
2.	Cathedral(RN_2)	Tee TWSC	7.30	2	7.30
3.	Araromi-Town Hall (RN_3)	Tee TWSC	7.20	2	6.80
4.	NEPA –Federal Secretarial Junction (RN_4)	Cross	7.30	2	7.3
5.	Odole (RN_5)	Cross	7.30	2	7.0

Note: m_{sw} is the major street width in metres;
m_n is the number of lane of minor movement;
m_w is the minor approach width in metres

Table 2 Accepted and rejected gaps of left turn from minor road for roadblock (RN_1)

Gap Class X(secs	Number of observed acceptance	Number of observed rejection	Cumulative of observed acceptance	Cumulative of observed rejection	N	P	P/(1-P)	Y	W	WY	WX	WXY	WX^2
0.95	1	20	0	223	21	0.048	0.050	-2.996	0.952	-2.853	0.905	-2.710	0.860
1.95	2	28	2	203	30	0.067	0.071	-2.639	1.867	-4.926	3.640	-9.606	7.098
2.95	2	33	4	175	35	0.057	0.061	-2.803	1.886	-5.286	5.563	-15.595	16.410
3.95	5	35	9	142	40	0.125	0.143	-1.946	4.375	-8.513	17.281	-33.628	68.261
4.95	9	22	18	107	31	0.290	0.409	-0.894	6.387	-5.709	31.616	-28.259	156.500
5.95	30	33	48	85	63	0.476	0.909	-0.095	15.714	-1.498	93.500	-8.912	556.325
6.95	52	25	100	52	77	0.675	2.080	0.732	16.883	12.365	117.338	85.934	815.497
7.95	25	20	125	27	45	0.556	1.250	0.223	11.111	2.479	88.333	19.711	702.250
8.95	32	7	157	7	39	0.821	4.571	1.520	5.744	8.729	51.405	78.127	460.076
9.95	25	0	182	0	25	1.00							
	183	223			406				64.919	-5.212	409.581	85.063	2783.276
			Factor	-6.31									
			EQ1		WY	W	WX						
			EQ2		WXY	WX	WX^2						
			EQ1*Factor		32.8854	-409.581	-2584.09						
			EQ1+EQ2		117.948	0.000	199.182						
			Slope		0.59216								
			WXY=Y-Intercept*sum(WX)+ Slope*Sum(WX^2)										
			Y-intercept	-3.8163			t_c=6.31 sec						

Where: N= number of observations P = probability of observed acceptance, Y=LN $\left(\frac{P}{1-P}\right)$ LN= natural logarithms, $W = N *$ P(1-P) Factor=$\frac{\sum WX}{\sum W}$ EQ_1=Factor* $\sum$ WY

Table 3 Accepted and rejected gaps of left turn from minor road for cathedral (RN_2)

Gap Class X(secs	Number of observed acceptance	Number of observed rejection	Cumulative of observed acceptance	Cumulative of observed rejection	N	P	P/(1-P)	Y	W	WY	WX	WXY	WX²
0.95	1	33	0	246	34	0.029	0.030	-3.497	0.971	-3.394	0.922	-3.224	0.876
1.95	1	31	1	213	32	0.031	0.032	-3.434	0.969	-3.327	1.889	-6.487	3.684
2.95	1	22	2	182	23	0.043	0.045	-3.091	0.957	-2.957	2.822	-8.722	8.324
3.95	2	15	4	160	17	0.118	0.133	-2.015	1.765	-3.556	6.971	-14.045	27.534
4.95	10	23	14	145	33	0.303	0.435	-0.833	6.970	-5.805	34.500	-28.735	170.775
5.95	9	31	23	122	40	0.225	0.290	-1.237	6.975	-8.626	41.501	-51.327	246.932
6.95	19	35	42	91	54	0.352	0.543	-0.611	12.315	-7.523	85.588	-52.286	594.836
7.95	46	41	88	56	87	0.529	1.122	0.115	21.678	2.494	172.341	19.831	1370.114
8.95	45	15	133	15	60	0.750	3.000	1.099	11.250	12.359	100.688	110.617	901.153
9.95	22	3	155	0	25	0.88	7.333	1.992	2.640	5.260	26.268	52.337	261.367
10.95	12	0	167	0	12	1.00							
11.95	1	0	168	0	1	1.00							
	169	249			418				66.488	-15.074	473.490	17.958	3585.595
			Factor	-7.12									
			EQ1		WY	W	WX						
			EQ2		WXY	WX	WX²						
			EQ1*Factor		107.3451	-473.49	-3371.91						
			EQ1+EQ2		125.303	0.000	213.685						
			Slope		0.586389								
			WXY=Y-Intercept*sum(WX)+ Slope*Sum(WX²)										
			Y-intercept	-4.40263		t_c=7.12sec							

Table 4 Accepted and rejected gaps of left turn from minor road for town hall (RN_3)

Gap Class X(secs	Number of observed acceptance	Number of observed rejection	Cumulative of observed acceptance	Cumulative of observed rejection	N	P	P/(1-P)	Y	W	WY	WX	WXY	WX^2
0.95	0	32	0	246	32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.95	0	28	0	214	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.95	1	31	1	186	32	0.031	0.032	-3.434	0.969	-3.327	2.858	-9.814	8.431
3.95	2	33	3	155	35	0.057	0.061	-2.803	1.886	-5.286	7.449	-20.881	29.422
4.95	5	27	8	122	32	0.156	0.185	-1.686	4.219	-7.114	20.883	-35.217	103.370
5.95	2	18	10	95	20	0.100	0.111	-2.197	1.800	-3.955	10.710	-23.532	63.725
6.95	11	19	21	77	30	0.367	0.579	-0.547	6.967	-3.808	48.418	-26.463	336.507
7.95	18	33	39	58	51	0.353	0.545	-0.606	11.647	-7.060	92.594	-56.125	736.123
8.95	45	25	84	25	70	0.643	1.800	0.588	16.071	9.447	143.839	84.547	1287.362
9.95	52	8	136	0	60	0.87	6.500	1.872	6.933	12.978	68.987	129.129	686.417
					0								
					0								
	136	254			390				50.492	-8.125	395.738	41.645	3251.356
			Factor	-7.84									
			EQ1		WY	W	WX						
			EQ2		WXY	WX	WX^2						
			EQ1*Factor		63.68424	-395.738	-3101.66						
			EQ1+EQ2		105.329	0.000	149.693						
			Slope		0.703634								
			WXY=Y-Intercept*sum(WX) + Slope*Sum(WX^2)										
			Y-intercept	-5.67578		t_c=7.83sec							

Table 5 Accepted and rejected gaps of left turn from minor road for NEPA (RN_4)

Gap Class X(secs	Number of observed acceptance	Number of observed rejection	Cumulative of observed acceptance	Cumulative of observed rejection	N	P	P/(1-P)	Y	W	WY	WX	WXY	WX^2
0.95	0	40	0	264	40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.95	0	37	0	224	37	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.95	0	25	0	187	25	0.000	0.000			0.000	0.000	0.000	0.000
3.95	1	27	1	162	28	0.036	0.037	-3.296	0.964	-3.178	3.809	-12.554	15.045
4.95	1	32	2	135	33	0.030	0.031	-3.466	0.970	-3.361	4.800	-16.636	23.760
5.95	8	18	10	103	26	0.308	0.444	-0.811	5.538	-4.491	32.954	-26.723	196.075
6.95	15	21	25	85	36	0.417	0.714	-0.336	8.750	-2.944	60.813	-20.462	422.647
7.95	18	36	43	64	54	0.333	0.500	-0.693	12.000	-8.318	95.400	-66.126	758.430
8.95	45	28	88	28	73	0.616	1.607	0.474	17.260	8.189	154.479	73.294	1382.591
9.95	52	8	140	0	60	0.87	6.500	1.872	6.933	12.978	68.987	129.129	686.417
					0								
					0								
	140	272			412				52.416	-1.125	421.241	59.923	3484.966
			Factor	-8.04									
			EQ1		WY	W	WX						
			EQ2		WXY	WX	WX^2						
			EQ1*Factor		9.040599	-421.241	-3385.3						
			EQ1+EQ2		68.964	0.000	99.661						
			Slope		0.691981								
			WXY=Y-Intercept*sum(WX)+ Slope*Sum(WX^2)										
			Y-intercept	-5.58257		t_c=8.04sec							

Table 6 Accepted and rejected gaps of left turn from minor road for odole (RN_5)

Gap Class X(secs	Number of observed acceptance	Number of observed rejection	Cumulative of observed acceptance	Cumulative of observed rejection	N	P	P/(1-P)	Y	W	WY	WX	WXY	WX²
0.95	0	25	0	155	25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.95	0	22	0	130	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.95	0	15	0	108	15	0.000	0.000			0.000	0.000	0.000	0.000
3.95	2	21	2	93	23	0.087	0.095	-2.351	1.826	-4.294	7.213	-16.961	28.492
4.95	5	21	7	72	26	0.192	0.238	-1.435	4.038	-5.796	19.990	-28.688	98.952
5.95	24	18	31	51	42	0.571	1.333	0.288	10.286	2.959	61.200	17.606	364.140
6.95	23	21	54	33	44	0.523	1.095	0.091	10.977	0.999	76.292	6.940	530.230
7.95	42	7	96	12	49	0.857	6.000	1.792	6.000	10.751	47.700	85.467	379.215
8.95	51	5	147	5	56	0.911	10.200	2.322	4.554	10.575	40.754	94.648	364.752
9.95	52	9	199	0	61	0.85	5.778	1.754	7.672	13.457	76.338	133.898	759.560
					0								
					0								
	199	164			363				45.353	28.651	329.488	292.910	2525.341
			Factor	-7.26									
			EQ1		WY	W	WX						
			EQ2		WXY	WX	WX²						
			EQ1*Factor		-208.148	-329.488	-2393.7						
			EQ1+EQ2		84.763	0.000	131.640						
			Slope		0.643899								
			WXY=Y-Intercept*sum(WX) + Slope*Sum(WX²)										
			Y-intercept	-4.04614		t_c=7.26sec							

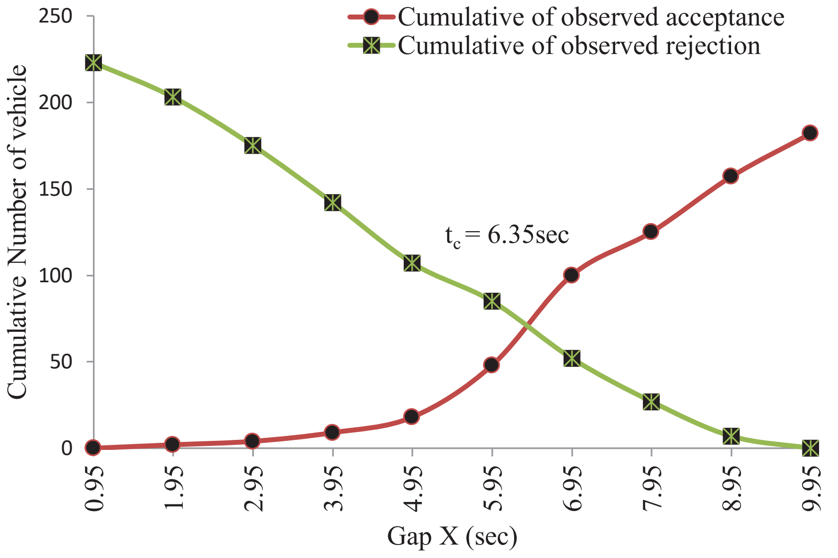

Figure 4 Cumulative plot of observed acceptance and observe rejection for left turning vehicle from the minor road for RN_1

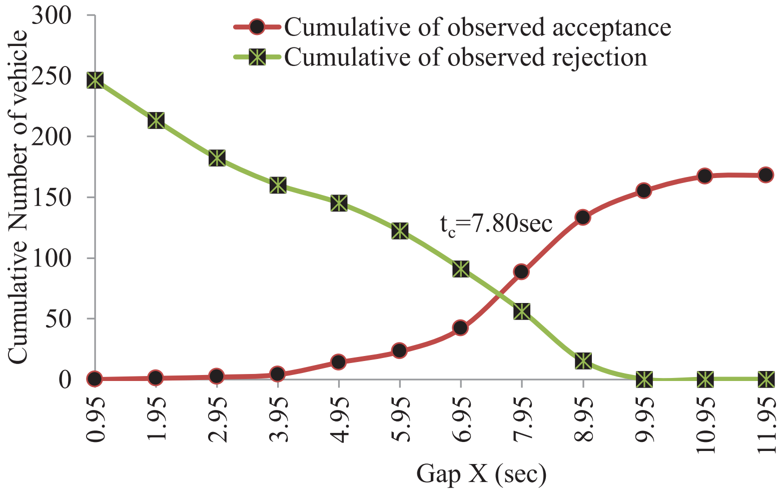

Figure 5 Cumulative plot of observed acceptance and observed rejection for left turning vehicle from the minor road for RN_2

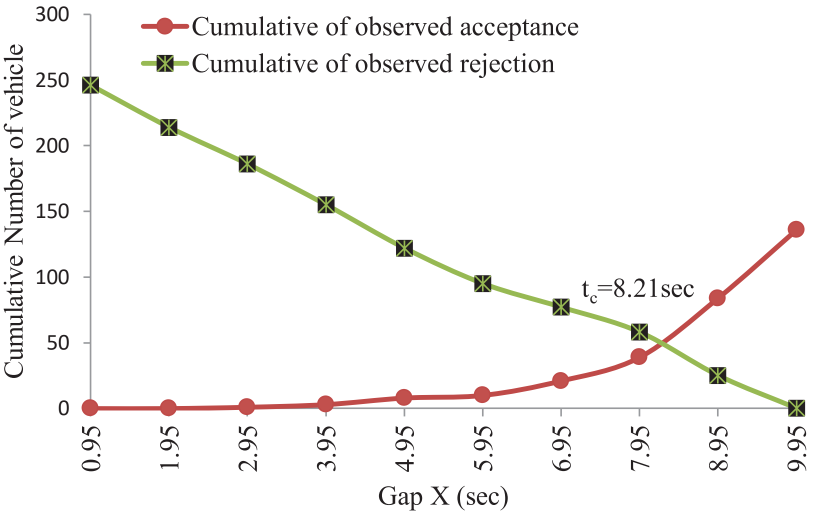

Figure 6 Cumulative plot of observed acceptance and observe rejection for left turning vehicle from the minor road for RN_3

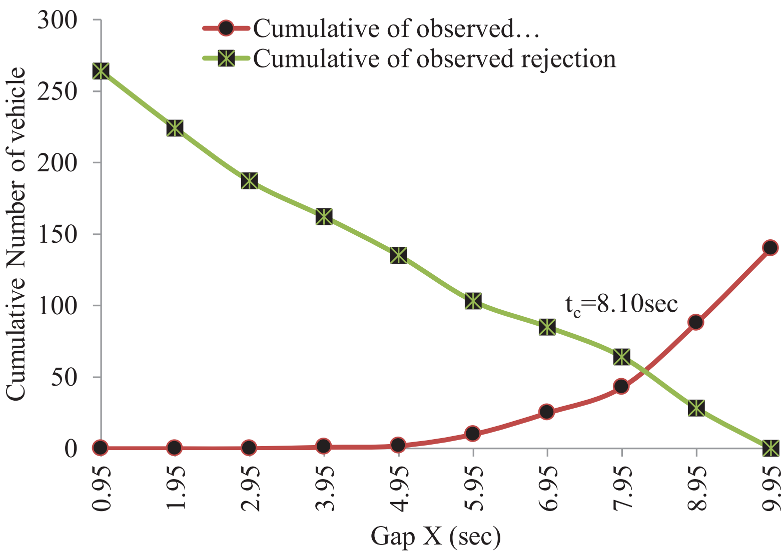

Figure 7 Cumulative plot of observed acceptance and observe rejection for left turning vehicle from the minor road for RN_4

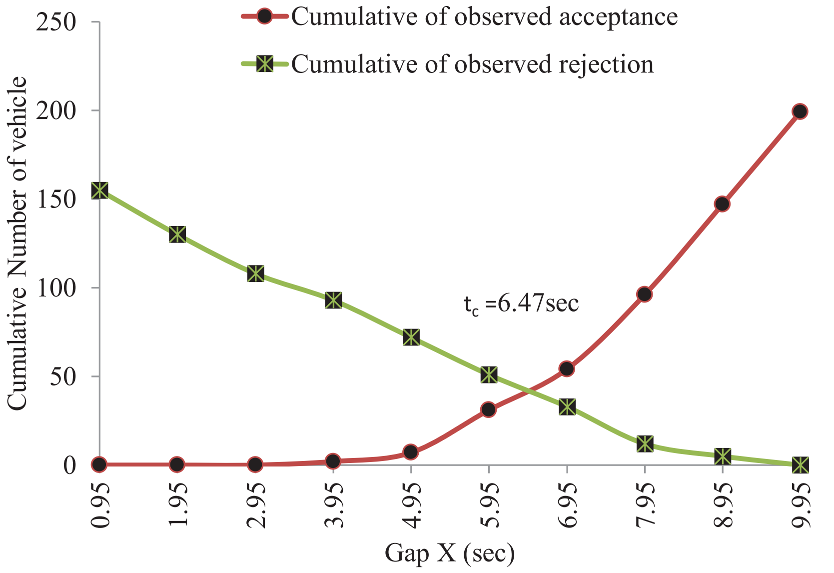

Figure 8 Cumulative Plot of Observed Acceptance and Observe Rejection for Left Turning Vehicle from the Minor Road for RN_5

The critical gap values were estimated to the nearest 0.5 second interval from Figures 4 to 8. Table 7 gives the recommended critical gap and follow-up time, while Table 8 is the LOS criteria for intersections in accordance with HCM 2000. Table 9 gives a comparison of the critical gap at the selected intersections using both Logit and Raff methods.

Table 7 Recommended critical gap and lag

Vehicle Movement	Critical Gap (t_c) in sec for two lane Major Street	Lag t_f in sec
Left turn from major road	4.1	2.2
Right turn form minor road	6.2	3.3
Through traffic on minor	6.5	4.0
Left turn from minor	7.1	3.5

Source: HCM 2000

Table 8 Level of service criteria for intersections

LOS	Signalized Delay per Vehicle (sec/veh)	Unsignalized Delay per Vehicle(sec/veh)	Description
A	0-10	0-10	Free flow traffic conditions with very low delay at intersections.
B	>10-20	>10-15	Reasonably unimpeded traffic operations with only short traffic delays at intersections.
C	>20-35	>15-25	Stable operating conditions with average traffic delays at intersections
D	>35-55	>25-35	Operating conditions result in lower travel speeds and higher delays intersections
E	>55-80	>35-50	Travel speeds are substantially restricted with problems likely to occur at intersections
F	>80	>50	Roadway operations are over capacity with extreme delays likely at intersections

Source: HCM 2000

Table 9 Summary of Critical Gap Analysis using Logit and Raff Method

Intersection	Method of Analysis for tc in sec			Average Delay (sec)	Remarks
	Logit	Raff	Average Value		
RN1	6.31	6.35	6.33	62.68	F
RN2	7.12	7.80	7.46	43.36	E
RN3	7.83	8.21	8.02	45.89	E
RN4	8.04	8.10	8.07	49.07	E
RN5	7.26	6.47	6.87	40.88	E

Results of the critical gap using both Logit and Raff methods show that there are differences in critical gap among the selected intersection; the values obtained using Raff method were generally more than those obtained using Logit method for all the intersections except at RN_5. Comparing the values obtained with the recommended values for left turning in Table 7, average values of 7.46 sec, 8.02 sec and 8.07 sec respectively were obtained for RN_2, RN_3 and RN_4 which indicate that the subject vehicle (SV) drivers were conservatives and appear to choose a gap that is sufficiently long to avoid a collision or major conflict.

However, values of 6.33 sec and 6.87 sec were obtained for RN_1 and RN_5 respectively indicating that the drivers were somewhat impatient at those intersections. Also, observations show that SV drivers may vary considerably in their preference to what constitutes an acceptable gap, this might be due to the fact that the study locations have different land use, geometric and traffic patterns. Comparing the result of average delay obtained in Table 9 with the LOS criteria for intersection in Table 8; RN_1 falls within the LOS E where travel speeds are substantially restricted, thus, traffic congestion is inevitable at the intersections.

5.0 CONCLUSION

The appraisal of geometric features of RN_1, RN_3, and RN_5 indicates that average carriageway width were less than 7.30 metres specifies by the Nigerian Highway Capacity Manual. The implications is that the intersections were not operating at their full capacity which reduces their LOS. The LOS "E" and "F" obtained for Tee and Cross intersections respectively indicates that the operating conditions were not favourable. Also, the values of the critical gap obtained for RN2, RN3, and RN4 were more than the recommended value of 7.1 sec which indicate that the SV drivers are conservative, while the value obatined for RN1 and RN5 that is more than the recommended value of 7.1 sec show that the drivers at these intersections were somewhat impatient. In order to improve the flow of traffic in the study area, the following measures are recommended:

i. Provisions of effective and efficient traffic signal to control traffic at the cross intersections and traffic warden at the tee intersections; this will minimize delay and provide safety to traffic and pedestrians by reducing the conflicting movements;
ii. Increasing effectiveness of regulatory and enforcement mechanisms through traffic education, this will enlighten road users on traffic safety consciousness and traffic rules concept to create a good traffic circumstance in order to realize the modern and efficient transportation management; and
iii. Introducing intelligent transport systems for traffic management.

The above recommendations will improve the LOS and ensure smooth flow of traffic at the study locations.

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