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An Assessment of the Performance of Traffic Control Signals Installed at a Main Junction in Ado Ekiti, Nigeria

O.A. Oni[1] O.O. Fagbohun[2]
1.Department of Civil Engineering, Ekiti State University, Ado Ekiti, Nigeria
2.Department of Electrical Engineering, Ekiti State University, Ado Ekiti

Abstract
The traffic at one of the major isolated signalised junctions in Ado Ekiti, Nigeria was evaluated. Traffic counts were undertaken from 7am to 7pm on the approaches to the junction over a period of one week. Peak periods of traffic appeared to be 7am-10am and 3pm-6pm respectively. The maximum flow rate for the traffic streams was calculated from the geometric characteristics of the junction and the direction of the streams. Owing to non-marking of the lanes, the degree of saturation on each approach to the junction was calculated from the aggregation of such for the traffic streams. The results show that one of the approaches to the junction was mainly congested throughout the day, and therefore the existing traffic control signals were ineffective for the traffic at the approach.
Keywords: traffic control signals, saturation, congestion, traffic stream, demand, capacity

1. Introduction

Traffic control signals are used to control the flows of traffic mainly at road junctions, but also at pedestrian crossing and other locations where they deemed necessary, such as temporary road construction sites. Initially, traffic control signals were used when there was inadequate land available for enlarging a junction, however, increased sophistication in the control systems that enables handling of multiple tasks, using modern signal controllers has resulted in their widespread use in junctions with heavy traffic (Slinn et al, 1998; Sutandi, 2007; Oni, 2009). They separate and regulate the conflicting traffic in a safe, efficient and equitable manner within the road space at junctions, using allocation of time to various traffic streams. A traffic stream can comprise vehicles or pedestrians / cyclists. Among the popular signal timing programs used in the UK are OSCADY (PRO AND CLASSIC), LINSIG, SIGSIGN and TRANSYT. In the US, programs such as EVIPAS, HCM/CINEMA, HCS, SIDRAL, SIGNAL 97 and SOAP are commonly used (Oni, 2007).

It is well documented that majority of accidents that have injury in Europe occur often at road junctions within the urban areas (Archer and Vogel, 2000). This is not surprising as road junctions in urban areas are "meeting" points for pedestrians, cyclists and vehicles, and therefore conflicting spots susceptible to human and vehicle errors leading to road accidents. For instance, 6,758 people were killed in motor vehicle traffic crashes at road junctions in the United States in 2010 despite a reduction of 7.1% on previous year fatalities (NHTSA, 2012). Similarly, there were 587 fatal accidents out of the 89,912 accidents reported for all road junctions in Great Britain in 2014. In contrast, there were 1071 fatal accidents out of the 56, 410 accidents that occurred not at or within 20m of junctions in Great Britain in 2014. Approximately 66% of the reported accidents in the Great Britain in 2014 were attributed to driver/rider error or reaction while 4% were caused by vehicle defects (DOT, 2015). There is no data on accidents at road junctions in Nigeria but the percentage of causative factors is likely to be greater than the reported values for Great Britain owing to less developed traffic control devices, driver indiscipline and much less enforcement of traffic laws. Nigeria has an estimated road traffic death of 20.5 per 100,000 of population in 2013, which is high compared to the UK of 2.9 per 100,000 of population (WHO, 2015).

There is no doubt that inadequate management of traffic at junctions will lead to slower vehicular speed, queuing, delay and thus congestion, which is a major issue in transport planning. A study undertaken by INRIX, a leading international provider of real-time traffic information, transportation analytics and connected driver services and the Centre for Economics and Business Research estimates the annual cost of congestion in the UK to rise by 63% - from £13.1 billion in 2013 to £21 billion in 2030. This equates to a total cumulative congestion cost of *£307 billion* to the UK economy (INRIX, 2014). In Nigeria, US $1million is estimated to be lost to traffic congestion in Lagos annually (Olorunpomi, 2010). This is substantial considering a gross national income per capita of US$2710 (WHO, 2015).

Quality researches on the adequacy of the traffic control signals installed at junctions in Nigeria are rare. Majority of authors have reported on the basic flow characteristics and have not quantified the congestion at the junctions. Furthermore, many studies have been on traffic controlled manually by traffic wardens. Asenime and Mobereola (2015) reported that the server utilisation, defined as the ratio of arrival rate to service, of the signalised junction at Maryland Interchange, Lagos was less than 1, indicating the effectiveness of the traffic signals. They stated that land-use activities often interact with traffic streams often causing significant delay to the traffic along Obanikoro-Maryland corridor. Udoh and Ekpenyong (2012) reported that the mean delay at any signalized junction in Uyo metropolis, Nigeria was 63s. Similarly, Aderamo and Atomode (2011) reported that an average of 46.7% of the total delay at seven junctions manually controlled at Ilorin, Nigeria was caused by traffic controller/wardens while an average of 23.3% of the total delay was caused by parking problems. Vehicle turning and manoeuvring, vehicle breakdown, accident, road side hawking and retailing and pedestrian crossing caused 8.9%, 6.7%, 5.6%, 4.4%, and 2.2% respectively of the total delay. However, Ndoke (2006) stated that manual traffic control at three junctions in Minna, Niger State, Nigeria appeared satisfactory, although the volume of traffic at these junctions was not critical.

The volume of traffic in Ado Ekiti between 2004 and 2014 has increased fourfold without any significant improvement in the carriage way (Ogunleye, 2015). In a study to find out the physical factors responsible for increased vehicular delay at junctions in Ado Ekiti, Abe and Adam (2014) measured the effective width of the roads that intersect at the junctions. They found out that street trading and illegal parking occupy 29.4% of the available road space and the majority of the roads have no shoulder, road markings and signs (regulatory, warning, and guide), pedestrian crossing, and pedestrian bridges. The non-standard condition of the roads was also reported by Oyinloye (2014) through the interpretation of satellite image of the road network of Ado Ekiti. The health effects of the traffic congestion on road users in Ado Ekiti were studied using questionnaires, and it was found out that physical breakdown, mental and psychological effects were experienced by the users (Awosusi and Akindutire, 2010).

2. Study Area

The study area is Ado Ekiti, Nigeria, which is located between latitude 7º25' and 7º47'north of the equator, and between longitude 5º5' and 5º30' east of the Greenwich Meridian (Figure 1). Over the years, Ado Ekiti city has expanded to the surrounding villages. The population from 1991 census was 127,579. This increased to 308,621, from the 2006 census (NPC, 2006). Using a 6.5% growth rate, the population projection for 2013 from the 2006 census is 479,593. Ado Ekiti is the capital of Ekiti State and also the headquarters of Ado Local Government. Since the creation of Ekiti State in 1996, there has been a rise in rural-urban migration and also influx of people from various places in Nigeria and abroad, owing to the establishment of Afe Babalola University in the town and a federal university located at Oye Ekiti, which is at a commuting distance from Greenwich Meridian (Figure 1). Over the years, Ado Ekiti town has expanded to the surrounding villages. The population from 1991 census was 127,579. This increased to 308,621, from the 2006 census (NPC, 2006). Using a 6.5% growth rate, the population projection for 2013 from the 2006 census is 479,593. Ado Ekiti is the capital of Ekiti State and also the headquarters of Ado Local Government. Since the creation of Ekiti State in 1996, there has been a rise in rural-urban migration and also influx of people from various places in Nigeria and abroad, owing to the establishment of Afe Babalola University in the town and a federal university located at Oye Ekiti, which is at a commuting distance from Ado Ekiti.

Enforcement of traffic rules and control of traffic in Ado Ekiti is mainly undertaken by the officers of the Federal Road Safety Corps (FRSC), Nigerian Police (NPF), and Ekiti State Traffic Control (ESTC) respectively. Statistics reported by FRSC (2013) for the year 2013, show that 227 vehicles were involved in road traffic accidents in Ekiti State, of which 102 involved cars, 59 involved motorcycles and 21 involved minibuses while the rest were other modes of transport. Of these, 131 were classified as private vehicles, 94 as commercial vehicles, and 2 as government vehicles. There were 42 fatalities and 350 injured persons in all the accidents. This shows a slight yearly fall in fatalities, which was recorded as 57 for 2012. The injured persons in 2012 were 349. The probable causative factors of road traffic accidents in 2013 were mainly speed violation, loss of control and dangerous driving (FRSC, 2013). This will also be representative of Ado Ekiti as the majority of the vehicles in Ekiti State ply the roads in Ado Ekiti.

The signalised junction studied is located at the intersection of Matthew Street, Ijigbo Street, Irona Street, and Ajilosun Street (Figure 1). The junction is a roundabout, popularly known as the Matthew Junction (or Roundabout) or Ijigbo Junction (or Roundabout). It is one of the major signalised roundabouts in Ado Ekiti. It was chosen as it is located in the city centre, and links Ado Ekiti with all the main towns in Ekiti State. It is also links Ado Ekiti with the capital of neighbouring states, especially Akure, the metropolis of Ondo State. The land-use comprises location of commercial institutions, shops, markets, motor parks, kiosks and makeshift stalls. The diagrams of the location of the traffic control signals (lights) and details of the geometric characteristics at the junction are shown in Figures 2 and 3 respectively

3. Materials and Methods

The data used in this study were obtained from desktop studies, reconnaissance and field studies. The reconnaissance, which is the preliminary survey, was used to ascertain the desk study and observe the changes in the land use. The data obtained includes geometric parameters of the lanes and traffic information at the junction. The geometric parameters, which include the width and gradient of lanes and turning radius, were obtained from the geometric design of the road network in Ado Ekiti during the desk studies.

The traffic information, which includes traffic volumes and composition, and signal timings were obtained from field studies on site, using survey assistants.

Matthew Junction was signalised when the roundabout previously used to control the traffic at the junction could not cope with traffic volume, therefore leading to congestion. The best method of assessing the adequacy of installed traffic control signals is to determine the congestion at the pertinent junction. Generally, congestion is measured by the degree of saturation, which is the ratio of demand to capacity on each approach (consisting of lane (s)) to the junction.

The basic expressions for saturation flow as used in OSCADY (Kimber et al, 1986; Burtenshaw and Xiaoyan, 2003) are:

$$S_a = 2080 - 140\delta n - 42\delta GG + 100(w - 3.25) \quad (1)$$

$$S_t = \frac{S_a}{\left(1+\left(\frac{1.5}{r}\right)\right)} \quad (2)$$

where:
Sa and St = are the saturation flows (pcu/hr) foe straight-ahead and turning traffic respectively.'
δn = takes the value 1 for nearside lane (including single lane); 0 otherwise.
δG = take the value 1 for an uphill entry; 0 otherwise.
G = is the gradient (percent)
w = is the lane width (metres)
r = is the radius of turn (metres)
pcu=passenger car unit

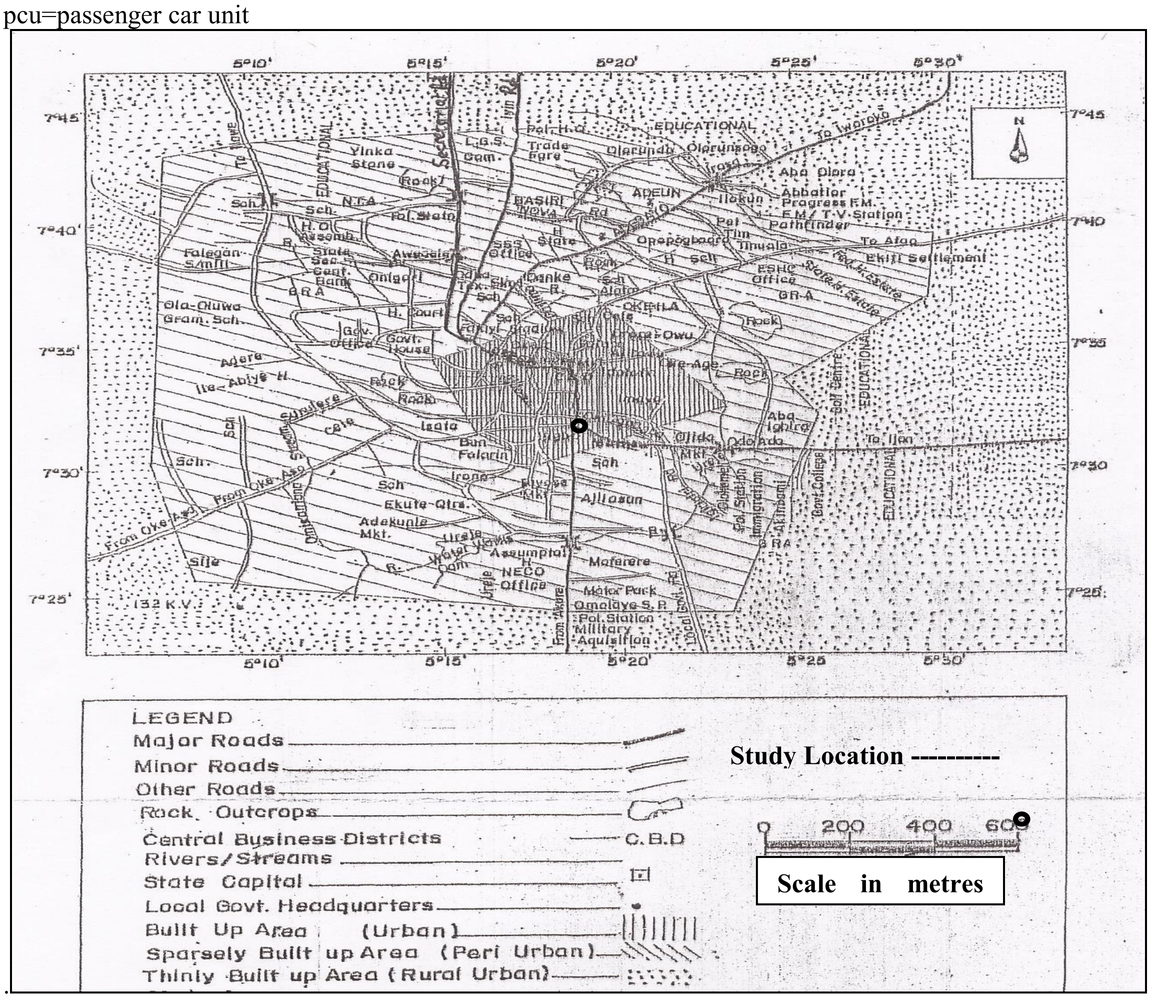

Figure 1: Map of Road Network of Ado Ekiti (Ado Ekiti Local Government, nd); EKSU, 2010)

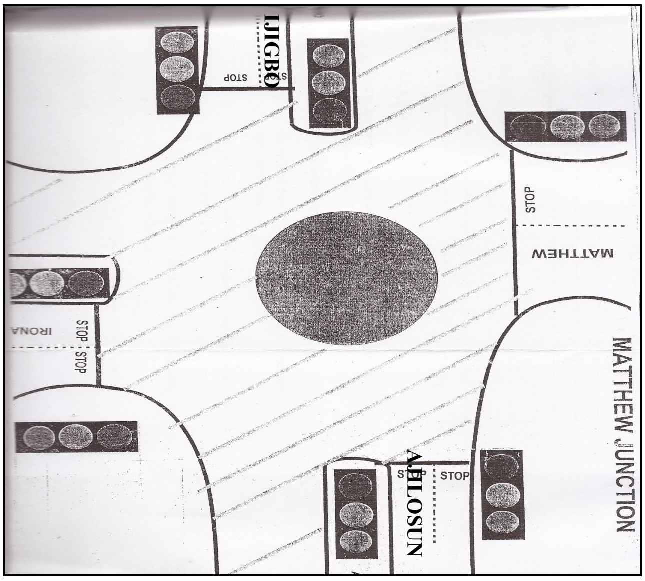

Figure 2: The location of traffic control signals (lights) at Matthew Junction.

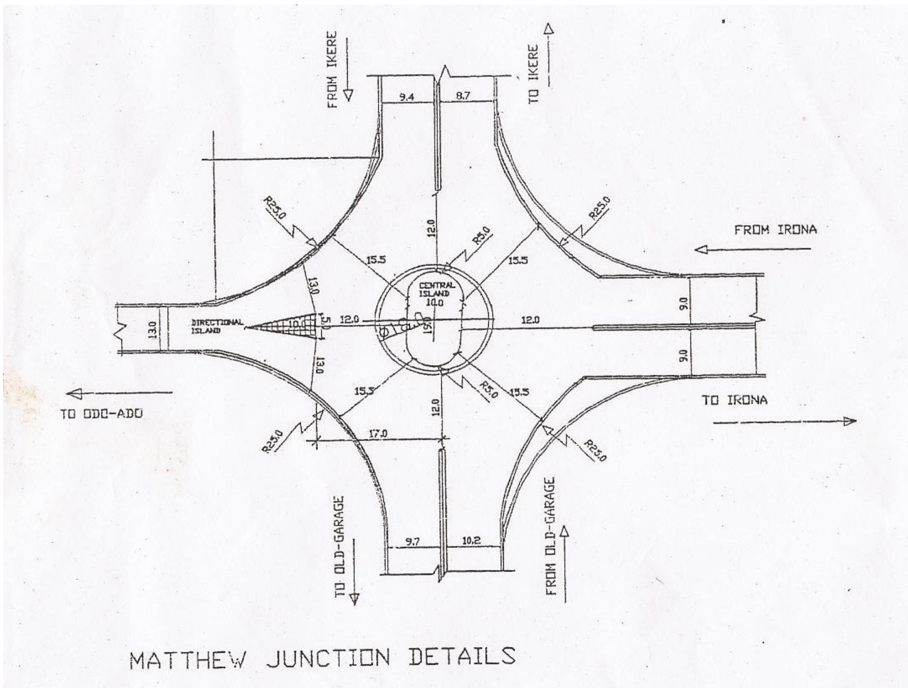

Figure 3: The geometric details of Matthew Junction.

The maximum saturation flow (capacity) is calculated as:

$$Maximum\ saturation\ flow = \frac{saturation\ flow \times green\ time}{cyle\ time} \quad (3)$$

The degree of saturation is calculated as:

$$Degree\ of\ saturation = \frac{Demand}{Capacity} \quad (4)$$

The demand is estimated through the actual flow at the junction while the capacity is the estimated maximum flow rate. An approach to a junction is said to be congested if the degree of saturation is greater than 85%.

4. Results and Discussion

The timings of the traffic control signals located at the approaches to Matthew Junction are shown in Table 1. The traffic control signals for the junction are isolated from the traffic control signals at other junctions in Ado Ekiti. All the signalised junctions in Ado Ekiti are isolated. As can be seen in Figure 2, there are traffic control signals for right turners at the approaches at Ijigbo Street, Irona Street, Ajilosun Street respectively. However, these control signals are not effective because there are no markings for right turners on the lanes therefore all vehicles use the lanes indiscriminately and are thus effectively controlled by the control signals for straight and turning vehicles whose timings are shown in Table 1.

Table 1: Signal Timings at Matthew Junction.

Approach	Green Time (s)	Red Time (s)	Clearance Time (s)
Ajilosun Street	75	42	1
Irona Street	16	93	1
Matthew Street	19	34	1
Ijigbo Street	45	72	1

Traffic counts were undertaken at Matthew Junction from for a week (Monday to Sunday) in 2013. The hourly counts were taken to be representative of the traffic volume at the junction. Traffic volumes showed Monday as the most congested day and thus its data are presented in this paper. Moreover, as the objective of the study is to assess the adequacy of the installed traffic signal control, especially during the busiest period. The traffic data for all the approaches to Matthew Junction are shown in Tables 2A, 3A, 4A and 5A respectively. The capacity data for the approaches are shown in Figures 2B, 3B, 4B and 5B respectively. Since the lanes for turning and straight vehicles were not separated, the saturation flow for each traffic stream was calculated using the characteristics (geometrics and turns) of each approach to the junction. The maximum flow rate was also calculated using the signal timing for the pertinent approach to the junction. The degree of saturation for each approach to the junction was then calculated from the summation of the degree of saturation for the traffic streams. The demand used for the calculation of the degree of saturation was obtained from the observed passenger car units.

Table 2A: Traffic data for Irona-Street approach to the junction for Monday

Time	From Irona Street to				Degree of Saturation (%)	State of Congestion
	Matthew Street (pcu)	Ajilosun Street (pcu)	Ijigbo Street (pcu)	Return (pcu)		
7-8am	242	88	165	10	146	Congested
8-9am	181	78	141	13	120	Congested
9-10am	176	34	132	11	102	Congested
10-11am	151	45	100	8	88	Congested
11-12pm	141	61	121	7	96	Congested
12-1 pm	139	51	117	8	91	Congested
1-2pm	121	57	115	4	87	Congested
2-3pm	127	68	121	3	93	Congested
3-4pm	131	71	156	6	107	Congested
4-5pm	128	110	216	12	138	Congested
5-6pm	200	119	210	10	158	Congested
6-7pm	168	112	181	5	137	Congested

Table 2B: Capacity data for Irona-Street approach to the junction for Monday

Lane Status	δn	δG	G (%)	w (m)	r (m)	Sa (pcu)	St (pcu)	Maximum Flow Rate (pcu/h)
Straight-Matthew St.	0	1	2	9		2571	-	374
Nearside-Ajilosun St.	1	1	2	9	25	2431	2293	334
Turn-Ijigbo St.	0	1	2	9	9	2571	2204	321
Return.	0	1	2	9	9	2571	2204	321

Table 3A: Traffic data for Ajilosun-Street approach to the junction for Monday

Time	From Ajilosun Street to				Degree of Saturation (%)	State of Congestion
	Ijigbo Street (pcu)	Matthew Street (pcu)	Irona Street (pcu)	Return (pcu)		
7-8am	151	220	204	13	39	Uncongested
8-9am	139	210	201	14	38	Uncongested
9-10am	129	298	171	6	40	Uncongested
10-11am	121	101	168	3	26	Uncongested
11-12pm	119	124	120	5	24	Uncongested
12-1 pm	141	138	108	4	26	Uncongested
1-2pm	131	102	98	1	22	Uncongested
2-3pm	109	171	91	3	25	Uncongested
3-4pm	107	201	181	8	33	Uncongested
4-5pm	144	120	104	11	25	Uncongested
5-6pm	121	100	203	12	29	Uncongested
6-7pm	101	188	113	5	27	Uncongested

Table 3B: Capacity data for Ajilosun-Street approach to the junction for Monday

Lane Status	δn	δG	G (%)	w (m)	r (m)	Sa (pcu)	St (pcu)	Max Flow Rate (pcu/h)
Straight-Ijigbo St	0	1	2	9.4	0	2611	-	380
Nearside-Matthew St	1	1	2	9.4	25	2471	2331	339
Turn-Irona St	0	1	2	9.4	9	2611	2238	326
Return	0	1	2	9.4	9	2611	2238	326

As it is shown in Tables 2A, 3A, 4A and 5A, all the approaches generally had peak periods of 7am-10am and 3pm-6pm. The morning peak period occurred as a result of the vehicular movement of all types of workers including civil servants, bankers, teachers and artisans go to work. This was also the period for "school runs", start of business among the traders, and all other human activities, especially those that needed to be done before the scorching heat of the sun set in. The evening peak period occurred when all those that have gone to work or school in the morning returned back home. Out of all the approaches to Matthew Junction, only Irona Street Approach had a degree of saturation greater than 85% (0.85) during the peak hours and off-peak periods. This shows that all the approaches to Matthew Junction except Irona Street Approach were not congested from 7pm to 6pm. This indicates that the traffic control signals used at the junction were fairly adequate. There are many factors that might contribute to the congestion being experienced at the Irona Street junction.

Table 4A: Traffic data for Matthew-Street approach to the junction for Monday

Time	From Matthew Street to				Degree of Saturation (%)	State of Congestion
	Irona Street (pcu)	Ijigbo Street (pcu)	Ajilosun Street (pcu)	Return (pcu)		
7-8am	261	204	100	11	73	Uncongested
8-9am	210	211	92	12	67	Uncongested
9-10am	274	105	50	8	54	Uncongested
10-11am	251	211	44	6	65	Uncongested
11-12pm	231	219	38	5	62	Uncongested
12-1 pm	211	200	37	4	57	Uncongested
1-2pm	181	170	31	3	49	Uncongested
2-3pm	171	168	29	2	47	Uncongested
3-4pm	206	150	51	1	51	Uncongested
4-5pm	172	178	44	6	51	Uncongested
5-6pm	254	141	40	4	55	Uncongested
6-7pm	100	132	33	0	34	Uncongested

Table 4B: Capacity data for Matthew-Street approach to the junction for Monday

Lane Status	δn	δG	G (%)	w (m)	r (m)	Sa (pcu/h)	St (pcu/hr)	Max Flow Rate (pcu/h
Straight-Irona St	0	0	-1	6.5	0	2405		846
Nearside-Ijigbo St.	1	0	-1	6.5	25	2265	2137	752
Turn-Ajilosun St.	0	0	-1	6.5	9	2405	2061	725
Return	0	0	-1	6.5	9	2405	2061	725

Table 5A: Traffic data for Ijigbo-Street approach to the junction for Monday

Time	From Ijigbo Street				Degree of Saturation (%)	State of Congestion
	Ajilosun Street (pcu)	Irona Street (pcu)	Matthew Street (pcu)	Return (pcu)		
7-8am	246	210	240	15	74	Uncongested
8-9am	231	208	172	6	63	Uncongested
9-10am	150	171	100	1	43	Uncongested
10-11am	161	151	123	3	45	Uncongested
11-12pm	144	142	108	4	41	Uncongested
12-1 pm	161	139	112	6	43	Uncongested
1-2pm	120	121	116	7	38	Uncongested
2-3pm	140	120	94	8	37	Uncongested
3-4pm	170	191	93	2	47	Uncongested
4-5pm	112	156	156	5	45	Uncongested
5-6pm	188	146	110	3	46	Uncongested
6-7pm	101	131	121	1	37	Uncongested

Table 5B: Capacity data for Ijigbo-Street approach to the junction for Monday

Lane Status	δn	δG	G (%)	w (m)	r (m)	Sa (pcu)	St (pcu)	Max Flow Rate (pcu/h
Straight-Ajilosun St.	0	0	-1	10.2	0	2775	-	1058
Nearside-Irona St.	1	0	-1	10.2	25	2635	2486	948
Turn-Matthew St.	0	0	-1	10.2	9	2775	2379	907
Return	0	0	-1	10.2	9	2775	2379	907

One of such factors is non-optimal setting of the traffic control lights as the green time is relatively small compared to the red time at the junction and relative to the green times of other approaches to the junction. Also non-marking of the lanes, which prevented right turners from prioritised passage through the junction, would enhance congestion. The poor road network and unplanned land use from the adjoining traditional areas are factors likely to increase the volume of traffic at this approach. In addition, the shoppers from the market along Irona Street would increase pedestrian and vehicle traffic on the approach. Moreover, the pedestrians would narrow the road space owing to inadequate pedestrian path on the carriage way.

5.0 Conclusion

The performance of the installed traffic control signal at Matthew Junction was assessed through the analysis of the traffic data and geometric details of the approaches to the junction. Owing to non-marking of the lanes on the approach, the maximum flow rate of the traffic streams were calculated separately to reflect the direction of the streams at the roundabout. The degree of saturation of each approach to the junction was determined from the aggregation of such for the traffic streams.

In general, the degree of saturation showed peak periods of 7am-10am and 3pm-6pm respectively, although there was not much difference from the low periods. Since the values of degree of saturation of the Irona Street approach to the junction are greater than 85%, there was congestion, indicating inefficiency of the installed traffic control signals at the approach.

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