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Modelling and Simulation of Uyo Metropolis Vehicular Traffic Control

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ABSTRACT

The aim of this paper is to develop a traffic model to study vehicle flow on Uyo metropolis roads. For the study traffic data is obtained from a network of eight selected traffic congestion prone intersections in the case study area. Miller's Approximate Expressions model is used to analyse for the average waiting time of vehicles in the network. MATLAB/SIMULINK software is used to simulate the traffic model for the network and a total of eight different simulations of one hour duration each were carried out. The comparison of the simulation results and the measured data for each hourly interval considered for average waiting time, total queue length and total number of served vehicles in the entire network show that the model is stable and reliable.

Keywords: Modelling, Average Waiting Time, Vehicle Traffic Control, Network, MATLAB & Model

1. INTRODUCTION

As population within cities around the world increases geometrically by the day, the number of vehicles on the roadways has also increased resulting in slow movement and traffic congestion [1]. This has hampered the socio-economic development of the affected places, resulting in reduced man-hour and hence productivity. One effective way of tackling this problem will be to model the traffic flow so as to enhance traffic flow prediction, incident detection and traffic control. Traffic modelling actually provides fundamental understanding of traffic dynamics and behaviour [2]. Traffic flows at intersections are generally seen to be complex, fuzzy and random processes [3] as such the development of traffic models is always a hard nut to crack for researchers. Several works have been made in the modelling of traffic flow in intersections [4 - 9]. The most common model adopted by researchers is the queuing theory model, generally because the theory provides various characteristics of the waiting line, like waiting time or length of the queue. The three main concepts in queuing theory are customers, queues, and servers (service mechanisms). In general, in a queuing system, customers for the queuing system are generated by an input source. The customers are generated according to a statistical distribution and the distribution describes their inter-arrival times, in other words, the times between arrivals of customers. The customers join a queue. At various times, customers are selected for service by the server (service mechanism). The basis on which the customers are selected is called the queue discipline [10].

In this paper a traffic model is developed for Uyo metropolis consisting of a network of eight selected traffic congestion prone intersections. MATLAB/SIMULINK is used to simulate the traffic model and the performance of the simulated model is obtained by comparing the simulated results with the field data.

2. METHODOLOGY

2.1 Data Collection

For this work traffic data was obtained from a network of eight selected traffic congestion prone intersections in Uyo metropolis in Nigeria. The intersections considered are Abak Road by Ukana Offot Street - 1, Abak Road by Udobio Street - 2, Abak Road by Ibom Plaza Bypass - 3, Aka Road by Ibom ByPass - 4, Ikot Ekpene Road by Ibom Bypass - 5, Ibom Plaza roundabout - 6, Oron Road by Ibom ByPass - 7, and Oron Road by Gibbs Street - 8. A schematic diagram of the studied environment and the road networks is shown in figure 1. Intersections 1, 2 and 8 are four-way, intersections 3 and 4 are three-way, intersection 6 is a roundabout, while intersections 5 and 7 are two-way.

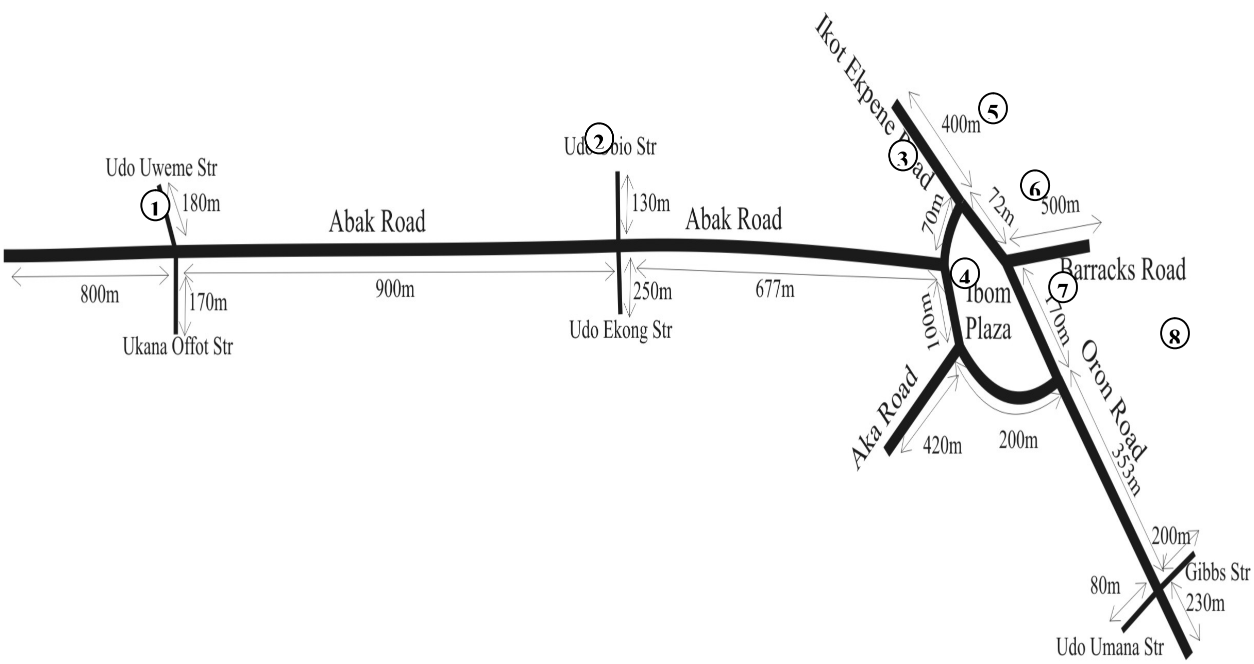

Figure 1: Schematic Diagram of the Area Considered for the Study

Manual counting method was adopted in the collection of the traffic data. Observers were position at strategic locations at the intersections to record data for a specific time interval. The data considered for this study were number of vehicles arriving and leaving each intersection for an hour interval, vehicles in queue on the hour, average number of vehicles leaving each route for a given pass time during heavy traffic, the effective green and cycle times for each intersection.

The data were collected simultaneously from the various intersections from 7.00 am to 11.00 am on Monday and Tuesday (April 1st and 2nd, 2013). The data collected are presented in Appendix A.

2.2 Data Analysis

For the traffic data analysis, the "Approximate Expressions" by Miller [5] for the identified $\{(M/D/1):(\infty/FCFS)\}$ queuing model. The following assumptions are used in the modelling:

1. The arrival of vehicles follows a Poisson distribution with arrival flow rate (q), since vehicular arrival is random.
2. The intersection has a fixed-cycle regulation.
3. The interval between departures of vehicles is constant.
4. There is only one server per route which occasionally takes a vacation to serve clients in another route.
5. There is no limit in the service capacity.
6. The service policy is non-gated constant time with clients served in a First-come-First-served regime.

Definition of Basic Notations

c: Cycle length (sec)
g: Effective green time (sec)
A_t: Number of arrivals
t_m: Number of arrivals measured time (sec)
D_t: Maximum number of departure during green time, g
q: Arrival flow rate of vehicle per second during
S: Saturation flow rate of vehicle per second during green light
μ: Service rate of vehicle per time length of green time, g
Q_0: Vehicle queue length at the beginning of a cycle
Y: Flow ratio
X: Degree of saturation
Q_c: Vehicle queue length at the end of a cycle
ΔD_t: Reserved capacity (non-delayed arrivals)
AWT: Average waiting time of vehicle per cycle

Let

$$Q_c = Q_0 + A_t - D_t \dots\dots\dots (1)$$

If the system is in equilibrium, then,

$$Q_c = Q_0 \dots\dots\dots (2)$$

Also,

$$q = \frac{A_t}{t_m} \dots\dots\dots (3)$$

$$S = \frac{D_t}{g} \dots\dots\dots (4)$$

$$\mu = \frac{1}{S} \dots\dots\dots (5)$$

$$Y = \frac{q}{S} \dots\dots\dots (6)$$

$$\lambda = \frac{g}{c} \dots\dots\dots (7)$$

$$X = \frac{Y}{\lambda} \dots\dots\dots (8)$$

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The queue is in equilibrium if

$$X < 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The average waiting time (AWT) of vehicles per cycle is given as [4]:

$$AWT = \frac{c(1-\lambda)^2}{2(1-Y)} + \frac{Q_0}{q} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Using (1) – (10) on Tables 1 – 5 in Appendix A, the average waiting time for each route in each intersection is computed from where the average waiting time at each intersection of the network is gotten. Table 6 in Appendix B shows the average waiting at each intersection as well as for the entire network on Monday and Tuesday. The analysis result shows that the average waiting time of vehicles in the studied traffic network for the considered time periods range from 120.21 sec to 158.50 sec.

3. DEVELOPMENT OF TRAFFIC MODEL

The traffic model for the case study area in Uyo metropolis was developed using MATLAB/SIMULINK. The model network layout showing the various intersections, routes, traffic lights and movements is shown in figure 2.

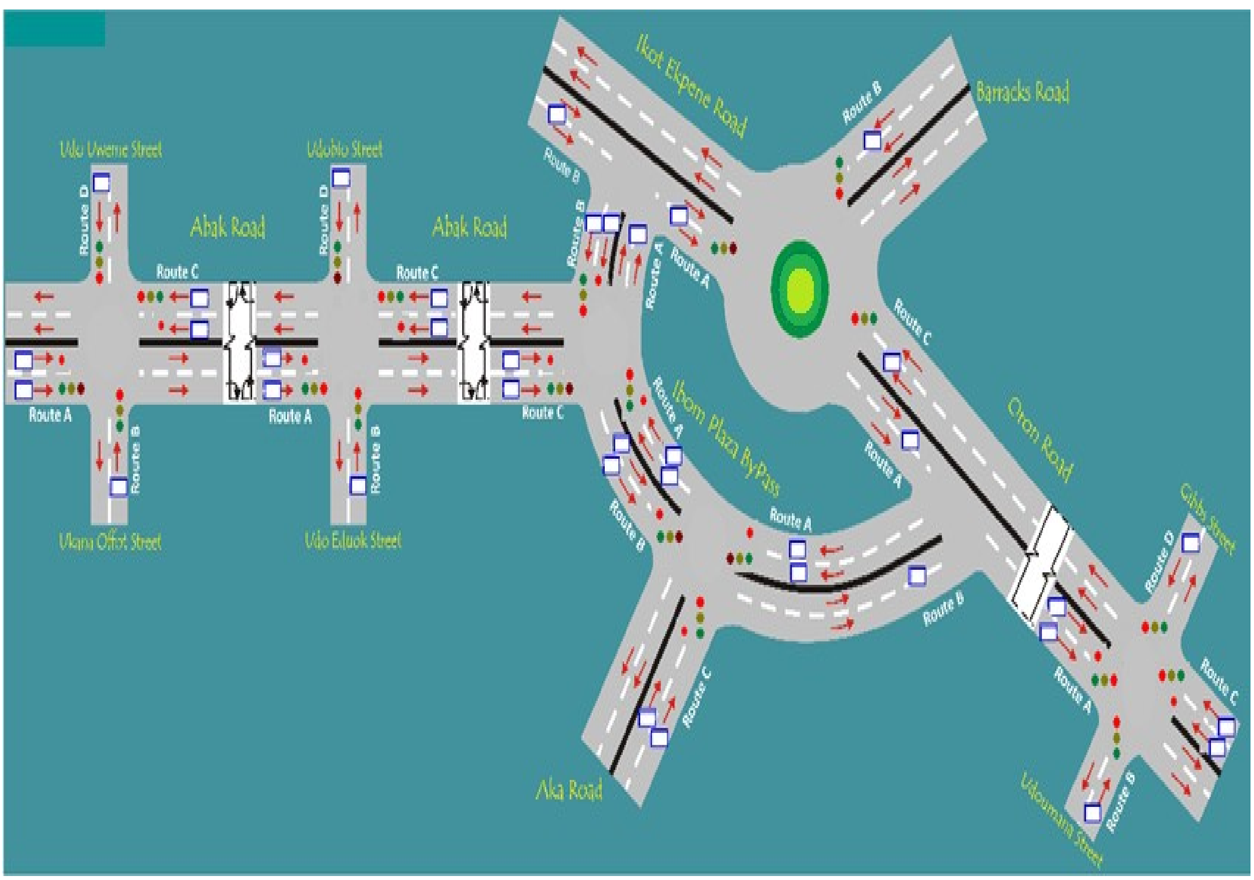

Figure 2: The model network layout in SIMULINK

The interconnection of all the intersections with the splitting of various routes into movements is shown in figure 3. It actually consists of three main units, namely: Routes subsystem, Intersection subsystem and Destination. For the purpose of explanation, Abak road by Ukana Offot street intersection of the sub-model shown in figure 4 is explained.

Vehicles from routes A of intersection on arriving splits into two movements which are the through with right-turn movement (A1_TR) and the U- with left-turn movement (A1_UL). Same is applicable to all other routes with more than one lane. On receiving green signal, vehicles in a movement proceed to cross the intersection to their destination routes. The internal structure of route A subsystem of Abak road by Ukana Offot street intersection is presented in Figure 5.

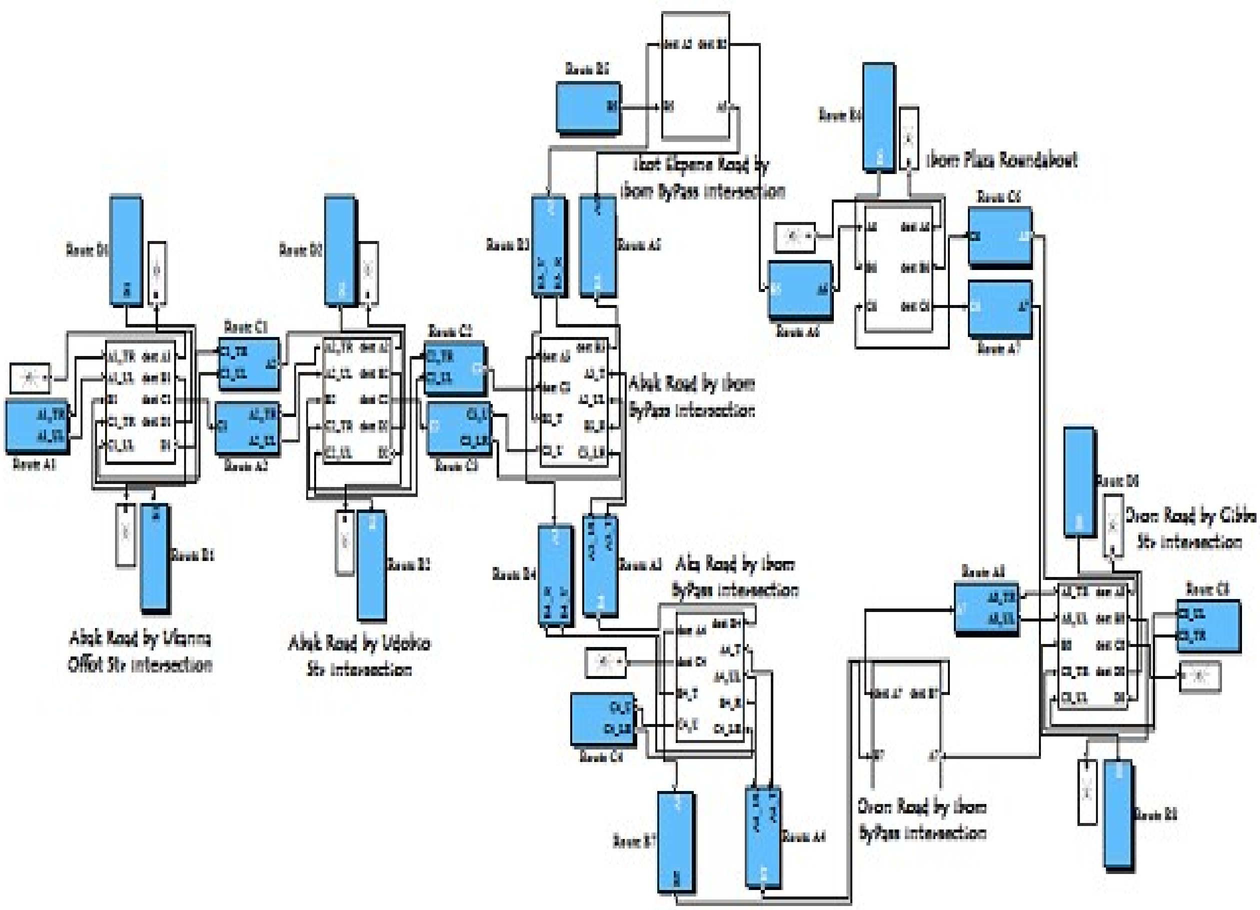

Figure 3: Interconnection of the intersections in Uyo Metropolis in SIMULINK

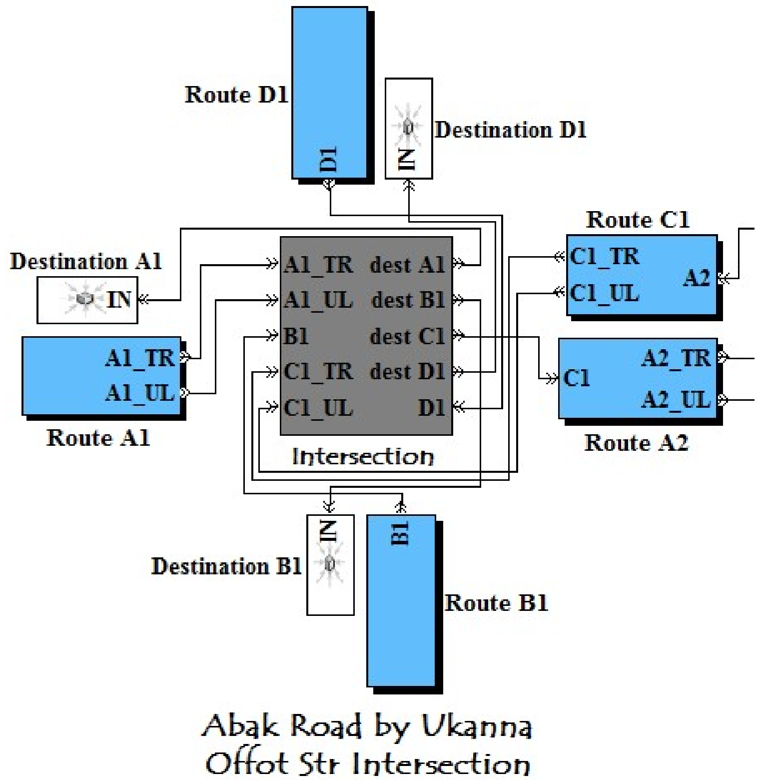

Figure 4: Abak road by Ukana offot street intersection with its various routes

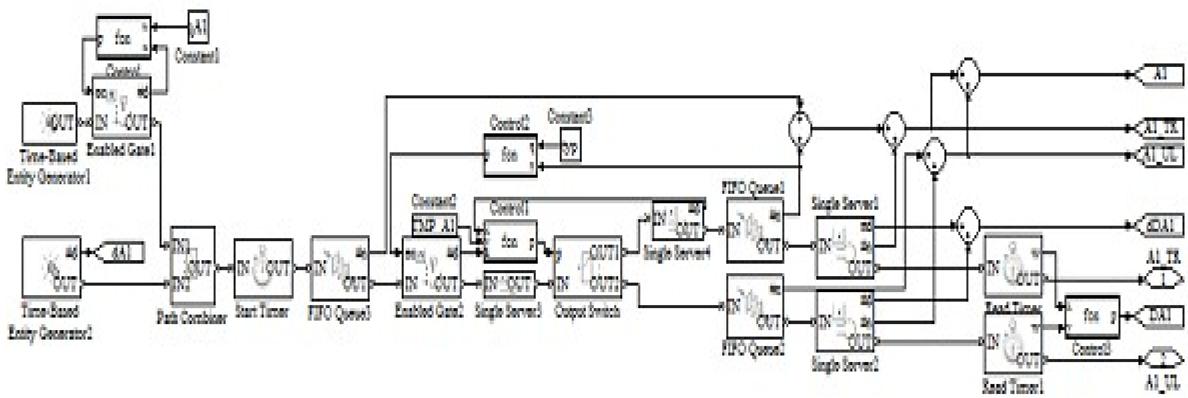

Figure 5: Internal structure of the route A subsystem of Abak road by Ukana Offot intersection

The *Routes* subsystem is responsible for the generation of vehicles into each route, and splitting them into various movements. Vehicles are generated as entities using time-based entity generator blocks. At the start of the simulation, the time-based entity generator1 block in conjunction with Enable gate1, Constant block and Embedded MATLAB block (Control), generates entities to serve as initial queue length. Time-based entity generator2 block is used to generate vehicles in form of entities during simulation as the route's arrival rate.

While the number of departed entities is sent to the Goto block (dA1) for onward passage to its corresponding "From" blocks, the departed entities themselves go through the path combiner to the First-In-First-Out (FIFO) Queue3 block via the Start Timer block which set a timer with a tag on each entity that pass through it. The Output switch block is responsible for the splitting of entities (vehicles) in the route into two movements (Through-Right-turn movement, TR, and U-Left-Turn movement, UL) based on the input signal from Embedded MATLAB block (Control1). Control1 uses the turning movement proportion of route A array (TMP_A1) from Constant2 block to select the output port of the Output switch in which the arriving entity departs. FIFO Queue1 and FIFO Queue2 blocks contain entities waiting for the next green signal in TR and UL movements respectively, while Single server1 and Single server2 determine the rate at which entities depart each movement by specifying the service time.
Read timer blocks read and use the value of timer that the Start timer block previously associated with the arriving entities to determine the duration of time each entity had spent in the queue. Control3 then computes the average delay of entities in the entire routes and output the result to the "Goto" block (DA1) for onward passage to its "From" blocks. The entities from each movement leave the route to the intersection subsystem via ports 1 (A1_TR) and 2 (A1_UL).

The intersection subsystem (Figure 6) consists of the following main units: Agent sub-model, phase switch module, downstream flow limiter, enable gate module, output switch module, single server module and control module and path combiner module. The subsystem is responsible for enabling the flow of entities of movements of the selected green phase from the intersection's Agent. Each of the enable gate1 blocks allows the passage of entities from its movement only when it receives enable signal from the downstream flow limiter embedded MATLAB block which disallow flow into already congested downstream intersection link. For instance whenever route A of the downstream intersection exceeds its capacity, the enable gate of through and right-turn movement of route A of intersection 1, A1_TR, is temporary disable, meaning the movement is not permitted to allow entities out.

The "enable gate2" blocks are enable for the passage of entities based on the signal from the phase switch embedded MATLAB block. The phase switch module uses the value of the phase from the Agent, and the type of the control scheme, to decide the movements to be enabled. The entities leaving "enable gate2" blocks enter the output switches where they are splits into individual movements such as U-turn, left-turn, through and right-turn movements, based on the signal from control1 embedded MATLAB blocks. Control1 block uses turning movement proportion array from Constant1 block to select the output port of the Output switch in which the arriving entity departs. The path combiner blocks combine entities from all movements going into the same destination routes.

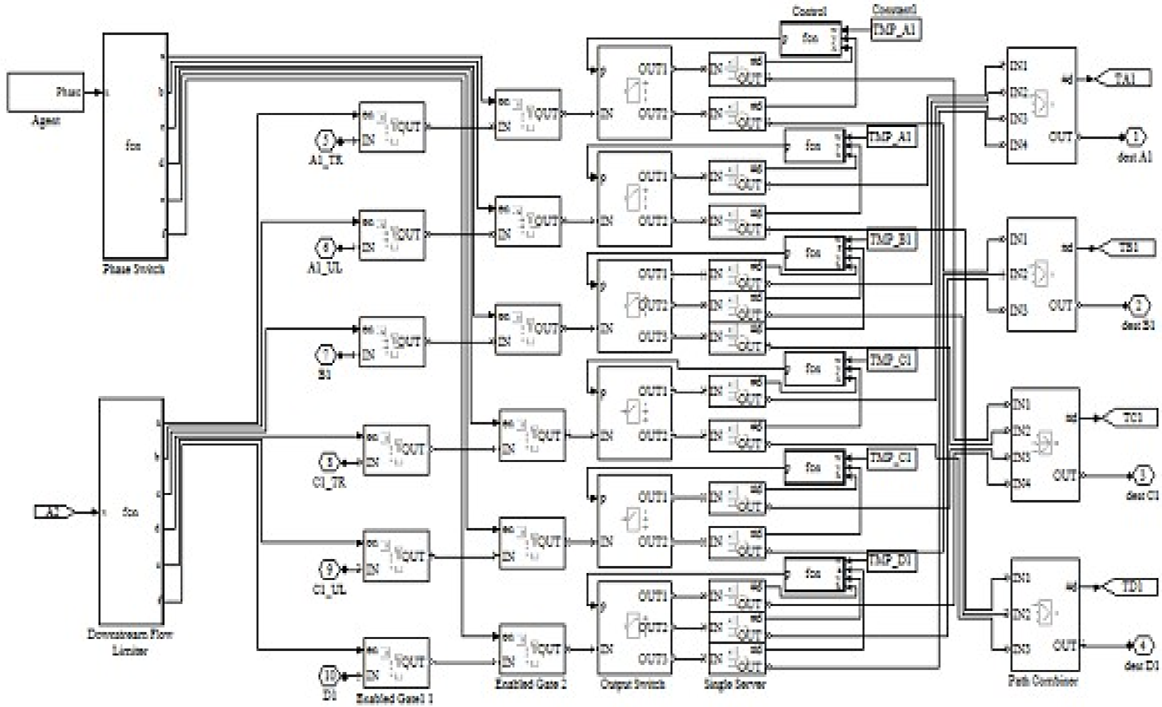

Figure 6: Internal structure of Abak road by Ukana Offot intersection subsystem

The agent sub-model as shown in Figure 7 consists of Fixed-time signal controller and Traffic light display module. The traffic controller outputs the value of a chosen phase with its green signal duration while the traffic display module (embedded MATLAB) activates the appropriate traffic lights for the selected phase.

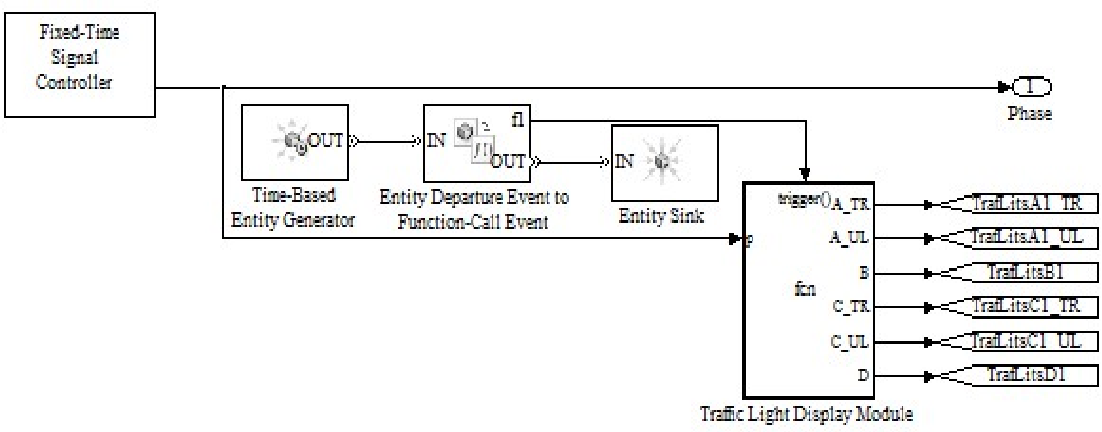

Figure 7: Internal structure of an agent sub-model

The fixed-time traffic controller sub-model (Figure 8) controls the phase sequencing for the fixed-time traffic controllers, and also sets appropriate signal duration for each phase selected. The signal duration is predetermined by the event-based sequence block. For each entity generated by the time-based generator, the "set attribute" block assigns the signal duration as the attribute. The FIFO queue block holds entities sequentially until the single server block is empty. Every time an entity is served by the server, the "entity departure event to function-call event" block generates a function call that is used to select the next phase in the function-call subsystem.

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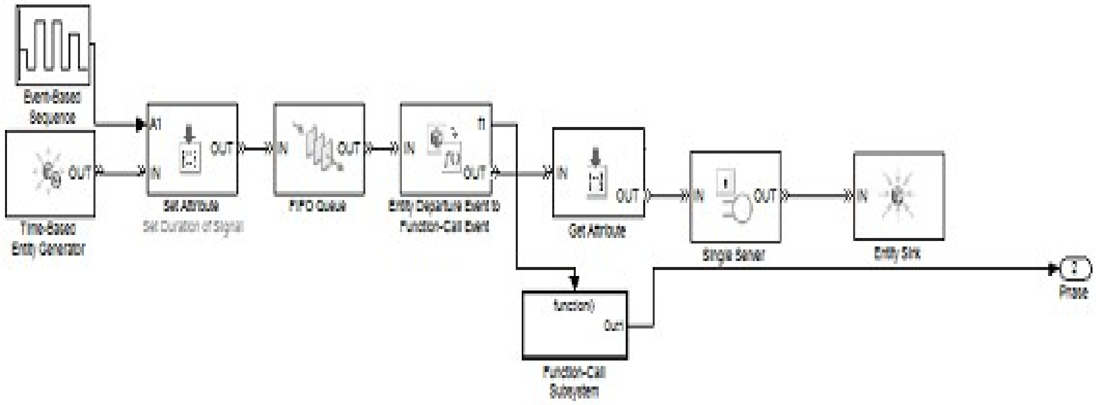

Figure 8: Internal structure of a fixed-time traffic controller sub-model

4. SIMULATION

A total of eight different simulations of one hour duration were done using arrival flow rate, service rate, green time and cycle time for each route and intersection in the developed SIMULINK traffic model. The simulations results shown in Appendix C were compared with the case study data in terms of total volume of served (departed) vehicles, total vehicles in queue and average waiting time in the entire network for each hour interval for Monday and Tuesday. The comparison is shown in Table 10 – 12 in Appendix D.

5. DISCUSSION

The comparisons between the field data and the simulation result show a minimum of 1.49% and a maximum of 13.67% for average waiting time, a minimum of 1.28% and a maximum of 13.58% for vehicles in queue, and a minimum of 0.40% and a maximum of 2.06% for average waiting time. The noticeable differences between the measured and simulated data with respect to average waiting time and queue are attributed mainly to the average service rate used in the simulation as against the varied service rate for each served vehicle. Even at that the differences is very reasonable. Also considering the difference in the total number of served vehicles, which is very low, it shows that the developed model is able to serve almost equal number of vehicles when compared with the measured data in each hourly interval.

6. CONCLUSION

In this paper, the "Approximate Expressions" developed by Miller was used to analysed for the average waiting time of vehicles based on the traffic flow data obtained from a network of eight intersections in a section of Uyo Metropolis. The analysis result shows that the average waiting time of vehicles in the studied traffic network for the considered time periods range from 114.54 sec to 158.50 sec. MATLAB/SIMULINK software was used to develop a traffic model for the network and a total of eight different simulations of one hour duration each were carried out. The comparison of the simulation results and the measured data for each hourly interval considered for average waiting time, total queue length and total number of served vehicles in the entire network show that the performance of the developed model can be said to reflect the real traffic scenario in Uyo Metropolis.

REFERENCES

[1] Sugiyama, Y., Fukui, M., Kikuchi, M., Hasebe, K., Nakayama, A., Nishinari, K., Tadaki, S. and Yukawa, S. (2008): *Traffic Jams without Bottlenecks: Experimental Evidence for the Physical Mechanism of the Formation of a Jam*. New Journal of Physics, 10, 1-7.

[2] Lopez, J. F. (2013): A Queuing Model for New York and Woodland, A Research Paper, Stetson University.

[3] Wannige, C. T. and Sonnadara, D.U.J. (2009): *Adaptive Neuro-Fuzzy Traffic Signal Control for Multiple Junctions*. IEEE International Conference on Industrial and Information Systems (ICIIS), Sri Lanka, 262-267.

[4] Udoh, N. S., & Ekpenyong, E. J. (2012): *Analysis of Traffic Flow at Signalized Junctions in Uyo Metropolis*. Studies in Mathematical Sciences, 5 (2), 72-89.

[5] Miller, A. J. (1963): *Analysis of bunching in rural two-lane traffic*. Operations Res. Quarterly, 14.

[6] Aradhye, A. and Kallurkar, S. (2014): *Application of Queuing Theory to Reduce Waiting Period of Pilgrim*. International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), 3 (10), 16775-16781

[7] Lartey, J.D. (2014) Predicting Traffic Congestion: *A Queuing Perspective*. Open Journal of Modelling and Simulation, 2, 57-66. http://dx.doi.org/10.4236/ojmsi.2014.22008

[8] Kurihara, T., Raunheitte, L. T., Camargo, R., Filho, A. R. and Petroni, J. (2014): *A Computational Model to Study Urban Traffic Control*. International Journal of Computer Theory and Engineering, 6 (5), 382-385

[9] Wang, F., Ye, C., Zhang, Y. and Li, Y. (2014): *Simulation Analysis and Improvement of the Vehicle Queuing System on Intersections Based on MATLAB*. The Open Cybernetics & Systemics Journal, 2014, 8, 217-223.

[10] Soh, A. C., Khalid, M., Yusuf, R. and Marhaban, M. H. (2007): *Modelling and Optimisation of a Traffic Intersection Based on Queue Theory and Markov Decision Control Methods*. Proc. First Asia International Conference on Modelling & Simulation, Asia Modelling Symposium 2007, 27-30

APPENDIX A

Table 1: Number of vehicles arriving each intersection for an hour interval

TIME	INTERSECTION	MONDAY				TUESDAY			
		ROUTES				ROUTES			
		A	B	C	D	A	B	C	D
7 - 8 AM	1	1343	350	1386	202	1335	344	1346	199
	2	1288	344	1345	323	1334	319	1357	325
	3	770	501	1141		833	606	1231	
	4	464	490	1246		529	498	1201	
	5	651	1805			758	1803		
	6	1950	551	1061		1943	580	1107	
	7	1601	407			1722	361		
	8	1539	231	1101	169	1554	219	1084	182
8 - 9 AM	1	1498	416	1454	215	1524	420	1462	226
	2	1420	392	1486	339	1482	376	1453	353
	3	919	600	1314		943	577	1374	
	4	473	568	1325		554	588	1327	
	5	824	1912			819	1889		
	6	2063	637	1220		2084	604	1302	
	7	1676	372			1742	428		
	8	1578	296	1275	231	1612	364	1289	219
9 - 10 AM	1	1407	428	1433	212	1467	395	1450	218
	2	1370	396	1441	355	1434	386	1417	372
	3	892	605	1311		769	555	1341	
	4	470	598	1302		510	522	1324	
	5	758	1876			666	1834		
	6	2087	591	1148		1972	629	1220	
	7	1528	362			1677	372		
	8	1390	283	1258	203	1532	298	1245	211
10 - 11 AM	1	1305	422	1329	220	1299	414	1286	201
	2	1353	374	1357	331	1350	355	1384	347
	3	823	597	1242		733	541	1257	
	4	391	545	1237		426	528	1305	
	5	780	1749			642	1754		
	6	1958	607	1148		1898	650	1259	
	7	1483	344			1460	366		
	8	1470	279	1221	201	1477	269	1214	175

Table 2: Number of vehicles departing each intersection for an hour interval

INTER.	MONDAY				TUESDAY			
	7-8AM	8-9AM	9-10AM	10-11AM	7-8AM	8-9AM	9-10AM	10-11AM
1	3164	3462	3430	3485	3126	3429	3413	3441
2	3159	3543	3594	3536	3236	3560	3566	3514
3	2376	2846	2795	2682	2634	2872	2673	2550
4	2160	2393	2371	2167	2201	2461	2367	2274
5	2450	2663	2692	2555	2549	2661	2527	2439
6	3505	3923	3806	3761	3594	3970	3833	3785
7	2009	2054	1886	1826	2091	2171	2044	1828
8	2897	3299	3235	3138	2904	3372	3289	3183
Total	21720	24183	23809	23150	22335	24496	23712	23014

Table 3: Number of vehicles in queue at each intersection on hour

TIME	INTERSECTION	MONDAY					TUESDAY				
		ROUTES					ROUTES				
		A	B	C	D	Total	A	B	C	D	Total
7:00 AM	1	7	2	24	0	33	9	1	6	0	16
	2	7	3	8	1	19	6	0	3	0	9
	3	2	4	10		16	1	2	8		11
	4	0	1	5		6	0	2	9		11
	5	0	13			13	3	15			18
	6	12	2	24		38	10	1	27		38
	7	11	1			12	13	2			15
	8	15	2	3	2	22	9	1	4	0	14
8:00 AM	1	46	1	101	2	150	27	10	77	0	114
	2	70	8	69	13	160	38	7	62	1	108
	3	4	14	34		52	18	12	17		47
	4	7	7	32		46	5	18	15		38
	5	4	15			19	12	18			30
	6	25	9	61		95	33	6	35		74
	7	7	4			11	5	2			7
	8	129	7	24	5	165	91	4	48	6	149
9:00 AM	1	133	10	120	8	271	129	9	173	6	317
	2	103	13	130	8	254	111	13	88	0	212
	3	14	15	10		39	12	4	53		69
	4	8	5	6		19	3	17	26		46
	5	5	87			92	6	71			77
	6	31	9	52		92	39	5	50		94
	7	5	0			5	4	2			6
	8	210	1	32	3	246	190	5	64	2	261
10:00 AM	1	128	22	171	1	322	188	2	242	2	434
	2	81	15	124	2	222	150	7	98	0	255
	3	6	11	35		52	9	1	6	0	61
	4	7	7	4		18	2	10	23		35
	5	2	32			34	2	48			50
	6	38	7	67		112	39	2	41		82
	7	6	3			9	10	1			11
	8	103	4	38	0	145	181	0	70	7	258
11:00 AM	1	17	9	82	5	113	77	10	104	2	193
	2	13	12	68	8	101	85	8	81	3	177
	3	8	3	21		32	12	14	16		42
	4	8	13	3		24	2	8	10		20
	5	3	5			8	0	7			7
	6	30	11	23		64	33	5	66		104
	7	7	3			10	7	2			9
	8	142	8	26	2	178	174	4	25	7	210

Table 4: Average number of served vehicles for a green time during heavy traffic

INTERSECTION	ROUTES			
	A	B	C	D
1	67	22	68	10
2	68	21	71	17
3	40	28	62	
4	17	23	54	
5	16	32		
6	110	31	64	
7	32	17		
8	67	15	56	11

Table 5: Effective Green time (g) and Cycle time (c)

INTER.	ROUTES				c (s)
	A	B	C	D	
	g (s)	g (s)	g (s)	g (s)	
1	45	35	45	20	169
2	45	30	45	30	174
3	55	30	65		168
4	31	48	63		160
5	60	60			60
6	83	39	50		189
7	60	60			60
8	45	30	40	20	159

APPENDIX B

Table 6: Average waiting time (sec) for each route in each intersection

INTER.	MONDAY				TUESDAY			
	7-8AM	8-9AM	9-10AM	10-11AM	7-8AM	8-9AM	9-10AM	10-11AM
1	172.54	275.53	305.63	172.01	160.23	292.39	344.30	221.47
2	218.51	262.97	237.53	171.27	155.59	221.04	240.68	204.39
3	130.41	111.41	117.61	96.38	123.04	128.67	127.28	126.30
4	125.06	98.31	98.66	112.69	129.34	126.69	103.37	89.22
5	26.02	92.83	35.45	12.07	46.47	80.84	52.52	7.18
6	168.03	152.23	174.99	125.53	132.82	146.26	135.60	157.26
7	25.56	5.37	21.99	24.19	15.20	12.54	15.57	18.47
8	209.28	219.50	167.83	202.18	198.99	234.60	248.73	234.90
Average	134.43	152.27	144.96	114.54	120.21	155.38	158.50	132.40

APPENDIX C

Table 7: Simulation Result - Average waiting time (sec) for each route in each intersection

INTER.	MONDAY				TUESDAY			
	7-8AM	8-9AM	9-10AM	10-11AM	7-8AM	8-9AM	9-10AM	10-11AM
1	166.73	255.96	297.32	179.35	138.25	286.04	346.43	188.16
2	142.51	249.55	201.07	136.25	137.55	232.12	285.29	197.72
3	107.33	118.58	132.12	107.39	112.62	148.25	158.74	122.63
4	136.33	121.25	114.01	96.51	102.20	129.73	117.05	99.09
5	53.99	93.91	40.70	14.12	33.00	80.50	63.93	2.80
6	131.41	141.24	141.88	122.44	126.11	201.70	144.17	157.42
7	11.17	60.69	4.71	11.30	7.08	12.47	30.07	11.08
8	188.71	228.55	210.60	123.71	176.52	246.73	218.17	173.45
Average	**117.27**	**158.72**	**142.80**	**98.88**	**104.17**	**167.19**	**170.48**	**119.05**

Table 8: Simulation Result - Number of vehicles in queue at each intersection on hour

INTER.	MONDAY				TUESDAY			
	7-8AM	8-9AM	9-10AM	10-11AM	7-8AM	8-9AM	9-10AM	10-11AM
1	127	282	338	145	90	342	432	157
2	218	251	155	164	139	228	305	261
3	31	41	55	31	36	73	65	35
4	18	30	27	18	21	47	31	21
5	4	44	32	4	3	53	4	1
6	70	130	85	67	68	158	85	102
7	7	13	4	6	3	9	21	6
8	152	214	169	36	130	246	205	107
Total	**627**	**1005**	**865**	**471**	**490**	**1156**	**1148**	**690**

Table 9: Simulation Result - Number of vehicles departing each intersection for an hour interval

INTER.	MONDAY				TUESDAY			
	7-8AM	8-9AM	9-10AM	10-11AM	7-8AM	8-9AM	9-10AM	10-11AM
1	3187	3455	3424	3479	3139	3410	3427	3449
2	3237	3547	3633	3570	3270	3543	3579	3498
3	2440	2855	2806	2718	2653	2861	2678	2544
4	2220	2384	2397	2187	2235	2454	2379	2283
5	2489	2713	2697	2580	2581	2681	2569	2446
6	3577	3973	3847	3792	3635	3925	3884	3795
7	2063	2033	1929	1858	2126	2147	2059	1855
8	2954	3319	3246	3265	2950	3369	3353	3241
Total	**22167**	**24279**	**23979**	**23449**	**22589**	**24390**	**23928**	**23111**

APPENDIX D

Table 10: Comparison of Field data and Simulation Result for Average Waiting Time

		7 - 8AM	8 - 9AM	9 - 10AM	10 - 11AM
FIELD	MONDAY	134.43	152.27	144.96	114.54
	TUESDAY	120.21	155.38	158.50	132.40
SIMULATION	MONDAY	117.27	158.72	142.80	98.88
	TUESDAY	104.17	167.19	170.48	119.05
COMPARISON	MONDAY	12.76%	4.23%	1.49%	13.67%
	TUESDAY	13.35%	7.60%	7.56%	10.09%

Table 11: Comparison of Field data and Simulation Result for Vehicles in Queue

		8AM	9AM	10AM	11AM
FIELD	MONDAY	698	1018	914	530
	TUESDAY	567	1082	1186	762
SIMULATION	MONDAY	627	1005	865	471
	TUESDAY	490	1156	1148	690
COMPARISON	MONDAY	10.17%	1.28%	5.36%	11.13%
	TUESDAY	13.58%	6.84%	3.20%	9.45%

Table 12: Comparison of Field data and Simulation Result for Total serviced vehicles

		7 - 8AM	8 - 9AM	9 - 10AM	10 - 11AM
FIELD	MONDAY	21720	24183	23809	23150
	TUESDAY	22335	24496	23712	23014
SIMULATION	MONDAY	22167	24279	23979	23449
	TUESDAY	22589	24390	23928	23111
COMPARISON	MONDAY	2.06%	0.40%	0.71%	1.29%
	TUESDAY	1.14%	0.43%	0.91%	0.42%