LEVEL OF SERVICE (LOS) OF FREEWAY SEGMENTS WITHIN MAKURDI METROPOLIS

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ABSTRACT

Traffic characteristics of selected freeway segments within Makurdi metropolis were studied to determine the level of service (LOS) for the selected routes. The roads studied were Makurdi-Jos road (Route 1), Iyorchia Ayu road (Route 2) and Makurdi-Otukpo road (Route 3). Traffic count to determine the traffic volume/flow was undertaken for a period of seven days with spot speed along the routes obtained with the help of speed gun. Results obtained shows the highest volume of traffic along the routes experience during the morning peak of 7:00 AM TO 9:00 AM and evening peak between 5:00 PM to 6:00 PM on week days. The density speed linear models for the routes was found to linear for each lane route which were $u = 91.14 - 1.86k$, $u = 88.08 - 1.69k$, $u = 68.70 - 0.61k$, $u = 58.87 - 0.42k$, $u = 74.69 - 0.91k$, *,and* $u = 71.57 - 0.87k$ *for Route 1A, 1B, 2A, 2B, 3A and 3B respectively. It was also found that Route 1A and 1B has an average arterial speeds of 57.4 km/hr and 57.9 km/hr with free flow speeds of 91.2 km/hr and 88.1 km/hr respectively and this implies that the routes have average arterial speeds which are a little more than 50% but less than 70% of their free flow speeds thereby describing it as LOS C. In the same vain, routes 2A and 2B have arterial speeds of 44.8 km/hr and 41.5 km/hr with free flow speeds of 113 km/hr and 140 km/hr respectively which amount to about 70% of their free flow speeds hence, LOS on the routes is LOS B. Also routes 3A and 3B have speeds of 49.9 km/hr and 47 km/hr with free flow speeds of 82 km/hr and 82 km/hr respectively which are greater than 50% of their free flow speeds but not up 70% hence their LOS is described as LOS C. The road links LOS should be maintained and care should be taken not to worsen the level of service within Makurdi metropolis.*

Keyword: - *Level of Service (LOS), Traffic Characteristics*

1. INTRODUCTION

The economic and social development of a nation includes the highway network and how it is able to efficiently serve it purpose of reducing journey time and cost of travel within the country. Transportation engineers seek to plan for safe, efficient and convenient movement of persons and goods from one location to another. It is therefore paramount to frequently assess the effectiveness of road networks within the city as the population of a city increases in order to enable for future planning and management of traffic for the good of the people which if not taken care will lead into congestion of the roads [1]. It is important to have a good knowledge of traffic flow parameters and how the relate to each other for a safe, smooth and economic traffic operations [2].

The travel time for a given road is affected by the density and flow which determines the speed on such road. At low traffic volumes, the prevailing speed limit governs the flow but this has been shown that it is influenced by the geometric conditions on the road facility, including lane widths and shoulder clearances. This geometric attributes and the level of comfort allows the drivers to move at desired speed (free-flow speed) at this low flow [3].

As traffic flow increases, the operation on road facility is governed by the interactions of vehicles. Eventually, the density on the road increases to a point where speeds begin to drop, as drivers are no longer comfortable maintaining high speeds with limited manoeuvre space. The traffic demand continues to increase which can exceed the available capacity and flows becomes unstable and congested.

In order to measure the level of effectiveness, the density, speed, flow must be measured and analyzed so as to determine the level of service (LOS) on road link. This road links are freeway segments. Freeway segment is

defined as a divided highway with full control of access and two or more lanes for the exclusive use of traffic in each direction that is outside of the influence of an access-controlled facilty with no signalized or stop-controlled at-grade intersection intersecting the mainline [4]. Freeway capacity is expressed in passenger cars per hour per lane, which can be accommodated by a uniform freeway segment under prevailing traffic and roadway conditions in on direction of flow. The service measure for freeway LOS is the average segment density in passenger cars per kilometre per lane [5].

LOS is group in A, B, C, D, E, and F, where LOS A is completely free-flowing conditions with average travel speed usually 90% of the free flow speed for arterial class. LOS B is stable flow for a freeway with an average travel speed of about 70% of the free flow speed for arterial class. LOS C is reasonable and uniform flow but with lower operating speed having an average travel speed of 50% of the free flow speed. LOS D is approaching unstable flow with low operating speeds, LOS E described unstable flow while LOS F described forced flow or the stop-and-go movement [1,3].

Many research on traffic delays and capacity assessment has been carried out on intersections and roundabout (both signal and unsignalized intersections and roundabouts) [6,7,8,9]. Traffic flows on road links comes from or moves to intersections and roundabout which contributes to traffic at the intersections and roundabouts. Therefore this research assessed freeway segments and determined level of services (LOS) of some selected roads in Makurdi metropolis for proper management and future designs. This was achieved by determining the spot speed of vehicles, traffic volume/flow, traffic density and establishment of relationship between flow, speed and density of selected road links at 1km road length. Three road links on Iyorchia Ayu road, Makurdi-Jos road, and Makurdi-Otukpo road) were considered and their city description names and research notations given in Table 1 with each lane considered individually.

Table 1: Road links descriptions with notation

Route Starting Point	**Route End Point**	**Main Notation**	**Lane Notation**
SRS Junction	New Bridge	Route 1 (Iyorchia Ayu Road)	Route 1A
New Bridge	SRS Junction		Route 1B
Wurukum Roundabout	Savannah Bus stop	Route 2 (Makurdi-Jos Road)	Route 2A
Savannah Bus stop	Wurukum Roundabout		Route 2B
Wurukum Roundabout	OG Winners Plaza	Route 3 (Makurdi-Otukpo Road)	Route 3A
OG Winners Plaza	Wurukum Roundabout		Route 3B

2. MATERIALS AND METHODS

2.1 Description of Study Area

Makurdi is the capital city of Benue State in middle belt of Nigeria. It is a state mostly populated by civil servants, farmers and traders. I have River Benue running through the state.

Three major routes links where considered namely Route 1 (SRS Junction – New Bridge) named Makurdi – Jos Road which is on the North side of River Benue. It is a double lane single carriage way. Route 2 (Wurukum Roundabout – Savannah bus stop) named Iyorchia Ayu Road which is dual carriage way with each carriage way carrying traffic in opposite direction to each other. Route 3 (Wurukum Roundabout to OG Winners Plaza) named Old Otukpo Road which is a dual lane single carriage way. Each lane in on these three routes were studied separately with routes notation given in Table 1. Plate 1 screen shot from Google map on the study locations.

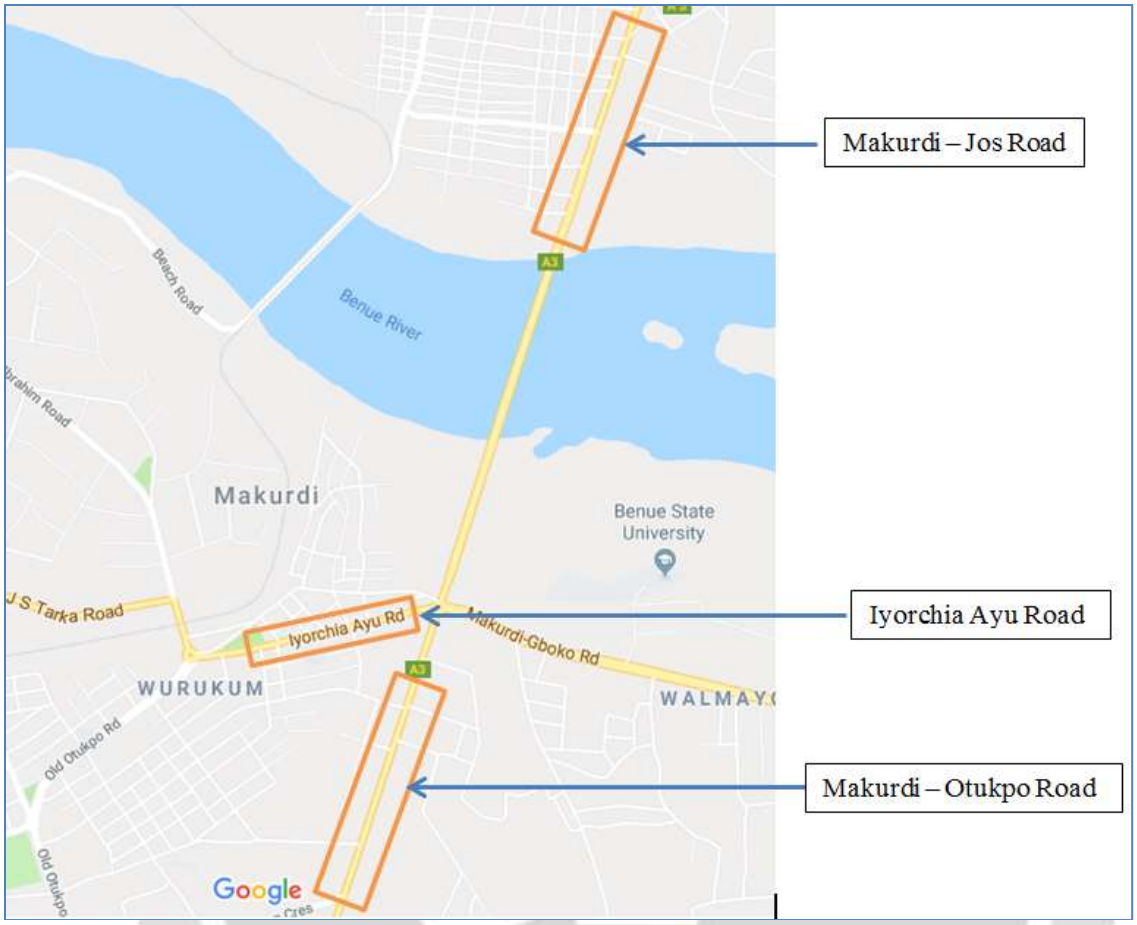

Plate 1: Screenshot of Google map show the study sites [10]

2.3 Methodology

2.3.1 Methodology for traffic volume/flow and spot speed determination

The procedure followed in determining traffic volume/flow are:

- Well trained observers were positioned at various sections of the roadway of interest.
- The number of vehicles passing each observer was noted and recorded by means of tallies using prepared data sheets and pencils.
- The counting was within hourly intervals.
- This was repeated for a week (7 days) of 12hrs daily.
- The results were tabulated for calculations and analysis

For spot speed, a hand-held speed gun was used for the measurement of spot speed of vehicles along the road links. Two observers, one equipped with the speed gun and the other with a pencil and paper for recording were stationed at convenient sections of the various links. The bearer of the speed gun points the instrument at random samples of approaching vehicles at an angle to eliminate errors with the button depressed until the vehicle just passes the observer. The button is then released and the average speed of the vehicle is displayed. The speed is then read by the first observer to the second for recording. This was repeated for the desired number of vehicle samples for the given days of survey.

The data was presented in tables with road links denoted by notations given in Table 1 used for purpose of convenience and ease of data presentation. This makes the result reading in Route 1A, 1B, 2A, 2B, 3A and 3B.

2.3.2 Methodology of Data Analysis

After the determination of average daily flow and the respective daily mean speeds, daily density (*k*) is determined by calculations using

$$k = \frac{q}{u} \quad (1)$$

To obtain the desired relationships among the various traffic flow parameters, a linear regression model of the form:

$$y = a+bx \quad (2)$$

was assumed and fitted between speed and density such that *y* denotes the speed (*u*), and *x* denotes the density (*k*).

The coefficients *a* and *b* are computed using:

$$b = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sum_{i=1}^{n}(x_i-\bar{x})^2} \quad (3.1)$$

$$a = \bar{y} - b\bar{x} \quad (3.2)$$

Where x_i and y_i are the samples, *n* is the number of samples and $\bar{x}$ and $\bar{y}$ are the mean of x_i and y_i respectively.

The boundary parameters are then found as follow:

$a = u_f$ (Free flow speed) (4)

$b = \frac{u_f}{k_j} \rightarrow k_j = \frac{a}{b}$ (Jam density) (5)

The maximum flow, q_{max} is given by as:

$$q_{max} = \frac{u_f k_j}{4} = \frac{a^2}{4b} \quad (6)$$

Having found the boundary parameters given in equations (4), (5) and (6), the relationship between speed, density and flow at any point within the traffic stream was established which is related to equation (3.2) and is given as:

$$u = u_f - \frac{u_f}{k_j}k \quad (7)$$

The equivalent PCU are calculated based on Federal Ministry of Works' Federal Highway design manual part 1 [11] in which vehicle classification and equivalent PCU are given in Table 2.

Table 2: Equivalent Passenger Car Units

Vehicle Type	Passenger Car Units			
	Rural Roads	Urban Roads	Roundabouts	Traffic Signals
Cars & light vans	1.0	1.0	1.0	1.0
Heavy Vehicles	3.0	1.75	2.8	1.75
Buses & Coaches	3.0	3.0	2.8	2.25
Motorcycles	1.0	0.75	0.75	0.33
Pedal cycles	0.5	0.33	0.5	0.2

In the research, the column for Urban Roads was used for the pcu value computation for the various vehicle types. Pedal cycles were not considered due to very minimal value recorded for them.

3. DATA/RESULTS PRESENTATION AND ANALYSIS

The summary of the survey data is systematically presented in tables. The traffic count is presented in Table 3 with the average speed presented in Table 4. Using the pcu values in Table 2, the hourly traffic flow for the week is given in Table 5. Equation (1) was used to calculate traffic density given in Table 6. The summary of the speed, flow and density is presented in Table 7 while the Table 8 present the various linear regression models for the routes and their maximum flow (q_{max}), jam density (k_j) and free flow speed (u_f).

Table 3: Summary of traffic count results for one week

		MON	TUE	WED	THUR	FRI	SAT	SUN	TOTAL
Route 1A	Motorcycles	5040	3541	3323	4236	3954	4382	4735	29211
	PC/mini Buses	2563	2231	2076	2373	2486	2186	2104	16019
	Trc/Cst Buses	218	192	126	166	194	235	105	1236
	Trl/Mc Buses	97	98	71	78	101	107	77	629
Route 1B	Motorcycles	4816	3725	3213	4397	3749	4561	4406	28867
	PC/mini Buses	2983	2700	2056	2227	2059	2363	2119	14388
	Trc/Cst Buses	177	96	155	104	143	264	105	1044
	Trl/Mc Buses	56	52	123	62	60	115	68	536
Route 2A	Motorcycles	9363	8899	6883	4543	4414	4234	5260	43596
	PC/mini Buses	3591	3052	2498	1902	2657	2079	2355	18134
	Trc/Cst Buses	633	554	194	158	230	142	97	2008
	Trl/Mc Buses	77	56	82	105	99	95	65	579
Route 2B	Motorcycles	10135	9266	6305	4363	4850	4286	5307	44512
	PC/mini Buses	3484	3056	2402	2347	2753	2262	2240	18544
	Trc/Cst Buses	506	461	313	188	262	125	102	1957
	Trl/Mc Buses	94	90	97	75	79	86	62	583
Route 3A	Motorcycles	7760	7141	4714	5070	4885	3896	3996	37462
	PC/mini Buses	3387	2871	2297	2077	2361	1888	2237	17118
	Trc/Cst Buses	161	109	175	129	243	167	72	1056
	Trl/Mc Buses	91	56	82	81	111	115	42	578
Route 3B	Motorcycles	7971	7107	5123	4834	5347	4164	4038	38584
	PC/mini Buses	3261	3427	2756	2137	2540	1977	2202	18300
	Trc/Cst Buses	123	117	125	210	161	148	90	974
	Trl/Mc Buses	62	57	68	92	77	89	60	505

Table 4: Summary of average daily speed

DAY	AVERAGE SPEED (Km/hr.)					
	Route 1A	**Route 1B**	**Route 2A**	**Route 2B**	**Route 3A**	**Route 3B**
MON.	45.5	42.3	25.6	20.3	30.7	31.0
TUE.	66.7	63.4	31.7	29.1	31.5	33.8
WED.	70.3	68.8	35.8	38.2	49.3	43.1
THUR.	56.6	58.5	65.0	52.6	53.8	48.9
FRI.	54.4	57.1	57.8	41.0	50.2	42.0
SAT.	51.3	46.7	60.9	63.3	68.1	64.2
SUN.	57.0	68.5	55.3	46.2	65.4	65.7
MEAN	57.4	57.9	47.4	41.5	49.9	47.0

Table 5: Average hourly distribution of Equivalent PCU for one week

DAY	AVERAGE TRAFFIC FLOW PER HOUR (Veh/hr)					
	Route 1A	**Route 1B**	**Route 2A**	**Route 2B**	**Route 3A**	**Route 3B**
MON.	1169	1179	1992	2042	1627	1607
TUE.	920	945	1811	1847	1431	1522
WED.	834	851	1374	1320	1064	1170
THUR.	1013	954	984	1029	1153	1O68
FRI.	1016	884	1111	1181	1131	1177
SAT.	1034	1099	965	992	908	938
SUN.	1012	969	1111	1098	914	928
MEAN	1000	983	1335	1358	1175	1201

Table 6: Summary of calculated traffic density

DAY	CALCULATED TRAFFIC DENSITY (Veh/km)					
	Route 1A	**Route 1B**	**Route 2A**	**Route 2B**	**Route 3A**	**Route 3B**
MON.	26	28	79	101	53	52
TUE.	14	15	57	64	45	45
WED.	12	12	38	35	22	27
THUR.	18	16	15	20	21	22
FRI.	19	16	19	29	23	28
SAT.	20	24	16	16	13	15
SUN	10	14	20	24	14	14

Table 7: Summary of traffic stream characteristics

		DAY						
Route	**Parameter**	**MON.**	**TUE.**	**WED.**	**THUR**	**FRI.**	**SAT.**	**SUN.**
1A	Speed (km/hr)	45.5	66.7	70.3	56.6	54.4	51.3	57.0
	Flow(Veh/hr)	1169	920	834	1013	1016	1034	1012
	Density(Veh/km)	26	14	12	18	19	20	18
1B	Speed (km/hr)	42.3	63.4	68.8	58.5	57.1	46.7	68.5
	Flow(Veh/hr)	1179	945	851	954	884	1099	969
	Density(Veh/km)	28	15	12	16	16	24	14
2A	Speed (km/hr)	25.6	31.7	35.8	65.0	57.8	60.9	55.3
	Flow(Veh/hr)	1992	1811	1374	984	1111	965	1111
	Density(Veh/km)	79	57	38	15	19	16	20
2B	Speed (km/hr)	20.3	29.1	38.2	52.6	41.0	63.3	46.2
	Flow(Veh/hr)	2042	1847	1320	1029	1181	992	1098
	Density(Veh/km)	101	64	35	20	29	16	24
3A	Speed (km/hr)	30.7	31.5	49.3	53.8	50.2	68.1	65.4
	Flow(Veh/hr)	1627	1431	1064	1153	1131	908	914
	Density(Veh/km)	53	45	22	21	23	13	14
3B	Speed (km/hr)	31.0	33.8	43.1	48.9	42.0	64.2	65.7
	Flow(Veh/hr)	1607	1522	1170	1068	1177	938	928
	Density(Veh/km)	52	45	27	22	28	15	14

Table 8: Summary of results from models and outcome for each lane

Route	**Model**	q_{max} **(Veh/hr)**	k_j **(veh/km)**	u_f **(km/hr)**
1A	$u = 91.14 - 1.86k$	1117	49	91.14
1B	$u = 88.08 - 1.69k$	1145	52	88.08
2A	$u = 68.70 - 0.61k$	1941	113	68.70
2B	$u = 58.87 - 0.42k$	2061	140	58.87
3A	$u = 74.69 - 0.91k$	1531	82	74.69
3B	$u = 71.57 - 0.87k$	1467	82	71.57

4. DISCUSSION OF RESULTS

From Table 3, the traffic count results shows that motorcycles constitute about 50% of the total traffic on the metropolitan streets of Makurdi followed by passenger cars and mini buses which contribute about 40% of the traffic while heavy vehicles like coaster/Marco polo buses, trucks and trailers constitute only about 10% of the total traffic stream.

According to total equivalent PCU flow of Table 5, there is an indication that route 2A and 2B are the busiest among the six routes of interest followed by routes 3A and 3B with routes 1A and 1B having the lowest traffic flow, a consequence of which routes 2A and 2B have the lowest speed, followed by routes 3A and 3B with routes 1A and 1B having the highest spot speed value.

From analysis conducted to establish a relationship between speed, flow and density of the traffic stream on each route coupled with results of speed data given in Table 4 and 8, level of service, LOS for the links is thus: routes 1A and 1B have average arterial speeds of 57.4 and 57.9 with free flow speeds of 91.2 and 88.1 respectively and this implies that the routes have average arterial speeds which are a little more than 50% but less 70% of their free flow speeds thereby describing it as LOS C.

In the same vain, routes 2A and 2B have arterial speeds of 44.8 km/hr and 41.5 km/hr with free flow speeds of 113 km/hr and 140 km/hr respectively which amount to about 70% of their free flow speeds hence, LOS on the routes is LOS B.

Also routes 3A and 3B have speeds of 49.9 km/hr and 47 km/hr with free flow speeds of 82 km/hr and 82 km/hr respectively which are greater than 50% of their free flow speeds but not up 70% hence their LOS is described as LOS C

5. CONCLUSION

In this research, the highest peak hours of traffic flow occur between the hours of 7:00 am and 9:00 am for morning peak and 5:00 pm and 6:00 pm for evening peak on week days while peak flow during weekends occurred between 4:00 pm to 6:00 pm.

Speed studies showed that route 1A and 1B had the highest average spot speed values of 57.4 km/hr and 57.9 km/hr respectively followed by routes 3A and 3B which recorded 49.9 km/hr. and 47.0 km/hr. respectively while routes 2A and 2B recorded 47.4 km/hr and 41.5 km/hr.

Route 1 was found to possess a Level of Service C. Route 2 had a Level of Service B while route 3 also had Level of service C.

6. RECOMMENDATION

Care should be taken to maintain and improve the level of service for the routes so as not to get worst with increasing population. The road pavement should be maintained and the shoulders work upon.

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