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Original Article

Empirical Assessment of Mixed Traffic Congestion on Selected Arterials in an Urban Metropolis, Nigeria

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ABSTRACT

The study was aimed at investigating the appropriateness and development of congestion indices and predictive model with operational parameters for congestion on the roads of a developing city. A manual 12-hour (6.00 am- 6.00 pm) traffic count was conducted for seven consecutive days of the week and converted to passenger car units (pcu) on Gboko, Iorchia Ayu, Otukpo, Joe Akaahan, Atom Kpera and Lafia roads of Markurdi to determine congestion spots. Five parameters of volume, headway, speed, density and delay were derived from the generated database in accordance with Highway Capacity Manual of 2010. Traffic congestion indices, with corresponding predictive models, were quantified, and a 15-year congestion forecast made to obtain the future operating scenarios on Makurdi roads. Makurdi roads were dominated by cars of 38.09-61.87%, motorcycles of 15.58-22.85%, minibuses of 10.63-31.33%, and tricycles, luxurious buses, lorries/trucks, trailers/tankers of 0.03-7.75%; with operating significant parameters at peak period of 2322-3134 pcu/h., 305-990 pcu/km., 1.7-2.2 s and 17-40 km/h for the volume, density, headway and speed, respectively; the degree of congestion on the selected routes were moderate to severe (volume capacity ratio of 0.51-1.32) and substantially dependent on the operating parameters, predictive model for the roadway traffic congestion index, $CI = 107.071+0.028v+10.054Sl +0.013c$ with $R^2 = 0.97$, was generated with volume (v), segment length (Sl) and capacity (c); and a 15-year projection indicated that Joe Akaahan Road would be heavily congested. All other segments would be severely congested. The present and 15-year projected CI values were 1.83 and 3.77 respectively, indicating extra vehicle kilometer travel due to congestion of 377%. It is recommended that congestion indices and predictive model are useful tools for management of congestion on urban roads of a developing city.

1. Introduction

Road network and transportation management is an important task for the socio-political and economic growth of a place. Surface transportation system, that is, the network of roads, streets, bus routes, rail lines, cycle lanes, bike and pedestrian ways connects communities and facilitate commerce; connects residents to work, homes, schools, services and each other [1]. But each year, the condition of traffic gets worsened around the world due to increase in population growth, dense concentrations in urban areas, and deteriorating condition of roads which contributes to negative outcomes on every sector of the economy, global greenhouse gas emissions and atmospheric pollution, high financial lost is recorded annually due to commute times and vehicle maintenance, and even stress-related health problems on the individuals affected [2].

There is need to identify solutions for urban traffic congestion problems in developing countries aimed at not

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only increasing traffic flow but also higher economic productivity, a cleaner and safe environment. While new road construction reduces traffic congestion on short term bases, in the longer term it simply motivates further growth in car ownership, increased travel demand and a shift away from public transportation [2]. Lack of traffic database and reliable predictive models for developing economies has been compelling issues for urban transportation planning, management design for both current and future scenerios. Therefore; development of predictive operational models and appropriate database for the current and future urban traffic scenarios are required to proactively and sustainably manage the traffic congestion problems and aid intelligent movement along the corridors of the road network in a developing city without addition to existing fixed facilities, where traffic and land use management are not fully synchronised.

Urban traffic congestion poses challenges to the attainment of mobility and economic sustainable development. Policies, traffic congestion index models and database abound with which the ensuring challenges could be proactively and sustainably managed for developed economies and cities. These are absent for developing cities and economies like Nigeria. A successful evaluation of appropriateness and development of the congestion index database and models with operating parameters for current and future urban traffic scenarios on urban road network of developing cities shall increase mobility, save economy and minimize road accident, while addressing whatever deficiency in application of the existing models and database for urban traffic in developing economy where desired efforts are yet robust enough. The study is aimed at investigating the appropriateness and development of congestion indices and predictive model with operational parameters for efficient management of congestion on the road networks of a developing city.

2. Materials and Methods

2.1 Data Collection and Analysis

Table 1, shows the road segments considered for the study and their detailed information.

Table 1: Detailed Information on the Routes Considered

Roads	Route Segments	Segment Length (m)
Gboko Road	Wurukum - BSUTH	4400
Iorchia Ayu Road	Wurukum -Savannah Roundabout	1300
Otukpo Road	Wurukum-NNPC Station	5400
Joe Akaahan Road	High level Roundabout-Police HQTRS	2200
Atom Kpera Road	Rain Oil–Modern Market	2500
Lafia Road	Wurukum – North Bank	4100

A reconnaissance survey was conducted on Gboko, Iorchia Ayu, Otukpo, Joe Akaahan, Atom Kpera and Lafia traffic movement corridors of the Markurdi road networks to determine congestion spots. A manual 12-hour (6.00 am-6.00 pm) traffic count was conducted for seven consecutive days of the week and converted to passenger car units (pcu). A 15-minute traffic delay study was consequently conducted during the peak hours of the 7 days. Five significant parameters of volume, headway, speed, density and delay were derived from the generated database in accordance with Highway Capacity Manual of 2010 [3], and analyzed with Microsoft Excel software 2018 version. Traffic congestion indices, with corresponding predictive models, were quantified, and a 15-year congestion forecast made to obtain the future operating scenarios on Makurdi road networks. The international standards used to determine the degree of congestion are shown in Table 2.

Table 2: Standardized Measures of Traffic Congestion

V/C range	**PAG Standard [4]**	**FHWA Standard[5]**
V/C < 0.50	No or low congestion	Below capacity
0.50 < V/C < 0.74	Moderate congestion	Below capacity
0.75 < V/C < 1.00	Heavy congestion	Approaching capacity
V/C > 1.00	Severe congestion	Exceeding capacity

Source: [4 and 5]

The projected peak volume and future V/C were calculated using the following equation

$$P_n = P_o(1+r)^n \; and \; future \; V/C = P_n/C \qquad (1)$$

where;

$P_n = Projected\ Peak\ Volume$ (pcu/hr),
$P_o = Present\ Peak\ Volume$ (pcu/hr),
$r = Population\ growth\ rate$ (5 %),
$n = Number\ of\ projected\ years$ (15 in this case), and $C = Capacity$ (pcu/hr)

3. Results and Discussion

3.1 Mixed Traffic Composition on Makurdi Roads

The summary of traffic composition on the six (6) studied roads for 7 days is presented in Table 3. It shows that the traffic stream traversing the makurdi roads could be described as heterogeneous with seven (7) classes of vehicles. Oturkpo road is the most trafficked, while Lafia road is the least.

Table 3: Summary of Traffic Composition by Type in percentage on Makurdi Urban Roads

Traffic Composition by Type (%)								
Road segment/ Vehicle Type	Motor cycle	Tricycle	Pickup/ Car	Minibus	Lux Bus	Lorry/ Truck	Trailer/ Tanker	Total number of vehicles
Gboko Road	25.97	2.14	58.29	10.63	0.21	1.39	1.37	8773
Iorchia Ayu	19.63	2.94	61.87	14.88	0.08	0.22	0.38	12360
Atom Kpera road	22.85	1.17	58.47	12.25	0.03	4.60	0.64	13183
Oturkpo road	18.22	5.64	61.02	12.85	0.05	1.09	1.14	13397
Joe Akaahan	15.58	2.96	55.86	17.80	0.05	6.37	1.37	8524
Lafia Road	21.43	7.75	38.09	31.33	0.28	0.63	0.49	5726
Range	15.58-25.97	1.17-7.75	38.09-61.87	10.63 – 31.33	0.03 – 0.28	0.22 – 6.37	0.38 – 1.37	5726 - 13397
Mean	20.61	3.77	55.60	16.62	0.12	2.38	0.90	10327.17

From Table 3, the respective proportions and distributions are displayed. This implies that the Makurdi road network traffic is mixed and dominated by cars (32.61 to 61.87%), followed by motorcycle (15.58 to 22.85%), the composition of minibuses is low (12.25 to 31.33%), while the proportion range of tricycle, luxurious bus, lorry/truck, trailer/tanker are the lowest (0.03 to 7.75%).

On a general basis, passenger cars constitutes the largest of the traffic stream traversing the Makurdi roads. It may therefore be concluded that although the traffic on the urban segments are mixed traffic, the heavier trucks, trailer/tankers (5 and 6 Axles) are negligible.

3.2 Traffic Parameters and Congestion Indices

The Design Manual for Roads and Bridges, [6] provides the standardized values for the capacity in pcu/hr for all types of roads (as shown in Table 4).

Table 4: Capacities (pcu/hr) of Urban Roads, One-way Hourly Flows

		Two-way Single Carriageway – Busiest direction flow (Assumes a 60/40 directional split)									**Dual carriageway**			
		Total number of lanes									Number of Lanes in each direction			
		2				2-3	3	3-4	4	4+	2		3	4
Carriageway width		6.1m	6.75m	7.3m	9.0m	10.0m	12.3m	13.5m	14.6m	18.0m	6.75m	7.3m	11.0m	14.6m
Road Type	UM	Not applicable										4000	5600	7200
	UAP1	1020	1320	1590	1860	2010	2550	2800	3050	3300	3350	3600	5200	*
	UAP2	1020	1260	1470	1550	1650	1700	1900	2100	2700	2950	3200	4800	*
	UAP3	900	1110	1300	1530	1620	*	*	*	*	2300	**2600**	3300	*
	UAP4	750	900	1140	1320	1410	*	*	*	*	*	*	*	*

Source: [6]

The summary of the peak volume and volume-capacity ratios on each route for seven (7) days from Sunday to Saturday for all selected roads are shown in Table 5. The traffic volume of the six studied segments ranges from 1100-3134 veh/hr, while, The v/c ranges from 0.51 to 1.32. High level – Police headquarters segment (Joe Akaahan Road) (with v/c of 0.51) was the least congested while Wurukum – NNPC segment (Oturkpo road) (with v/c of 1.32) was the most congested along direction 1 while in direction 2, the v/c ratio ranges from 0.58 to 1.14, indicating that the degree of congestion on the Makurdi

urban roads on each of selected routes were moderate to severe in accordance with [4].

Table 5: Summary of the Volume-Capacity Ratio (V/C) during the Peak Periods

Segments	Location 1	To (Direction 1)			From (Direction 2)			Location 2
		V_{peak} (pcu/hr)	C (pcu/hr)	V/C	V_{peak} (pcu/hr)	C (pcu/hr)	V/C	
RA1	Duku Park	1831	2600	0.70	1514	2600	0.58	Wurukum Market
RA2	Wurukum Market	1318	2600	0.51	1686	2600	0.65	Nobis Super Market
RA3	Yaman Park	1716	1300	1.32	1477	1300	1.14	FCMB
RA4	Modern market Juction	1341	2600	0.52	1377	2600	0.53	Modern market Juction
RB	Court five	1656	1300	1.28	1412	1300	1.09	SRS Juction
RC	Zenith Bank	1222	1300	0.94	1100	1300	0.84	NYSC Secretariat

Note: V_{peak} is the peak volume, C is the capacity and V/C is the volume-capacity ratio of the routes.

3.3 Spot Speed Analysis

Figures 1 and 2 show typical speed distribution curves as obtained from the speed data. The 15th percentile speed (Minimum allowable speed), 50th percentile speed (Median speed) and the 85th percentile speed (Maximum safe speed) of the segments obtained from speed distribution curve are summarised in Table 6.

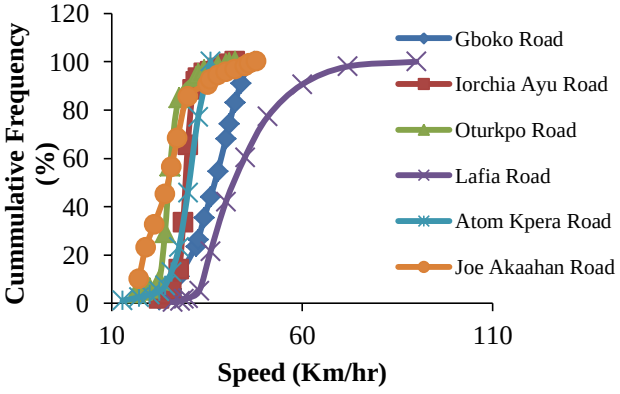

Fig 1. Speed Distribution Curve in Direction 1 (To) for all Road Segments Considered.

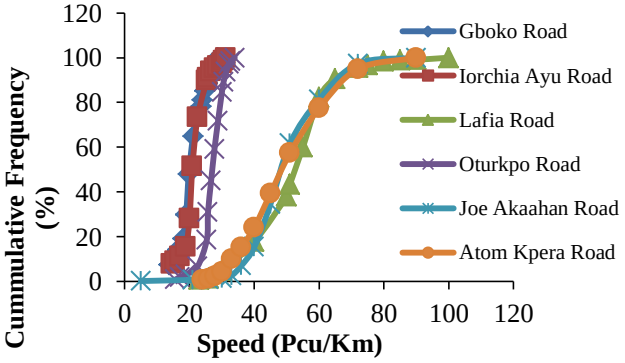

Fig 2. Speed Distribution Curve in Direction 2 (From) for all Road Segments Considered.

The Minimum allowable speed on the studied road segments ranges from 18 km/hr to 36 km/hr along direction 1. Highlevel – Police Headquarter segment (Joe Akaahan Road) (with P_{15} of 18 km/hr) was the most congested while Wurukum – Northbank (Lafia Road) (with P_{15} of 36 km/hr) was the least congested since the lower the Minimum allowable speed, the higher the intensity of traffic congestion. Along direction 2, the Minimum allowable speed ranges from 17 km/h to 40 km/h. This means the Wurukum BSUTH segment (with P_{15} of 17 km/h) was the most congested while the High level Police headquarters segment (with P_{15} of 40 km/h) was the least congested since the lower the Minimum allowable speed, the higher the intensity of traffic congestion. It was hence, established from the result that at higher traffic volume, there was lower value of value of minimum allowable speed, hence speed is affected by traffic volume.

Table 6: Summary of the Percentile Speeds during the Peak Periods

Location 1	To (Direction 1)			From (Direction 2)			Location 2
	P_{15} (km/hr)	P_{50} (km/hr)	P_{85} (km/hr)	P_{15} (km/hr)	P_{50} (km/hr)	P_{85} (km/hr)	
Duku Park	28	37	43	17	20	24	Wurukum Market
Wurukum Market	27	29	32	19	21	25	Nobis Super Market
Yaman Park	23	25	28	25	27	30	FCMB
Modern market Juction	26	32	34	36	47	68	Modern market Juction
Court five	36	42	57	37	53	62	SRS Juction
Zenith Bank	18	25	30	40	47	62	NYSC Secretariat

Note: P_{15} is the Minimum allowable speed (15^{th} percentile speed), P_{50} is the Median speed (50^{th} percentile speed) and P_{85} is the Maximum safe speed (85^{th} percentile speed) of the routes

3.4 Time Headway Analysis

The headway studies were carried out to describe the traffic situation of the routes with regards to time difference in vehicles arrivals at the observed points as measured from the front bumper of a vehicle to the front bumper of the next successive vehicle. The summary of peak volume(V_{peak}) and average headway ($\bar{h}_{avg}$) is presented in Table 7, while the relationship between peak volume and average headway is illustrated in Figure 3. The average headway $\bar{h}_{avg}$ ranges from 1.7 s to 3.1 s in order of decreasing degree of congestion, that is, the shorter the headway, the higher the degree of congestion. This signifies that Wurukum – NNPC segment of Otukpo road (with $\bar{h}_{avg}$of 1.7 s) was the most congested while Gboko road (with $\bar{h}_{avg}$of 3.1 s) was the least congested. Along direction 2, the average headway, $\bar{h}_{avg}$ ranges from 1.6 s to 2.5 s in order of decreasing degree of congestion. This implies that Gboko road (with $\bar{h}_{avg}$of 1.6 s) was the most congested while Atom Kpera road (with $\bar{h}_{avg}$of 2.5 s) was the least congested.

Table 7: Summary of the Average Headway during the Peak Periods

Location 1	To (Direction 1)		From (Direction 2)		Location 2
	$\bar{h}_{ava}$ (s)	V_{peak} (pcu/hr)	$\bar{h}_{ava}$ (s)	V_{peak} (pcu/hr)	
Duku Park	3.1	1161	1.6	2250	Wurukum Market
Wurukum Market	2.2	1636	1.7	2188	Nobis Super Market
Yaman Park	1.7	2118	1.8	2000	FCMB
Modern market Juction	1.7	2118	2.5	1440	Modern market Juction
Court five	2.4	1500	2.0	1800	SRS Juction
Zenith Bank	2.1	1714	2.2	1636	NYSC Secretariat

Note: $\bar{h}_{avg}$ is the average headway and V_{peak} is the peak volume of the routes

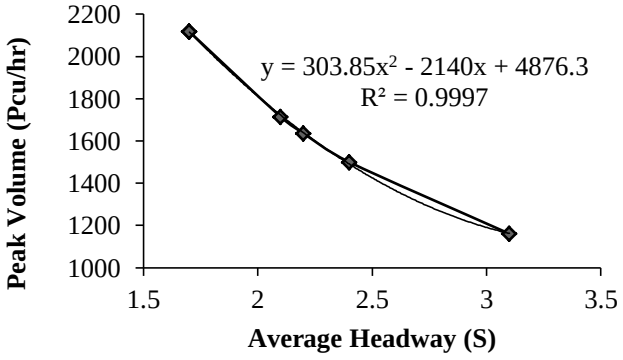

Fig 3. Peak Volume –Average Headway Relationship

3.5 Parametric Congestion Index Model - Multiple Regression Analysis

Microsoft excel software was used to run a regression analysis from which a model for congestion index (CI) was formulated with three significant parameters, volume (v), segment length (Sl) and capacity (c). Models developed from the regression analysis for congestion index (CI) using three significant parameters; volume (v), segment length (Sl) and capacity (c) are shown in Table 8. The R^2 values ranges from 0.50 to 0.97 which shows a high level of statistical significance.

Table 8: Developed congestion Index Models – Multiple regression analysis

Road Segment	Equation	R^2
Gboko Road	$CI = 224.37 + 0.078v - 8.562Sl - 0.046c$	0.52
Iorchia Ayu Road	$CI = 586.41 - 0.038v - 23.615Sl - 0.052c$	0.85
Oturkpo Road	$CI = 1046.276 - 0.064v - 50.262Sl - 0.112c$	0.50
Joe Akaahan Road	$CI = 238.087 + 0.033v - 4.014Sl - 0.021c$	0.69
Atom Kpera Road	$CI = 179.984 + 0.032v - 1.957Sl - 0.006c$	0.54
Lafia Road	$CI = 107.071 + 0.028v + 10.054Sl + 0.013c$	0.97

where;

CI = congestion index

V = traffic volume (pcu/hr)

Sl = segment length (m)

C = capacity (veh/km)

All the studied roads as shown in Table 8 have coefficient of determination not less than 0.5. These values of coefficient of determination are considered good which makes the derived models acceptable for traffic operations, planning and management.

3.7 Application of roadway congestion index

Table 9 and 10, indicate that at present study year, the value of RCI is 1.83. It means that the road network of study area carries peak period vehicle-kilometer demand, which is 1.83 times more than its capacity. In other words, a Roadway Congestion Index (RCI) of 1.83 indicates that the extra vehicle kilometer travel due to congestion in peak hours is about 183%. The data for the projected year shows that if the present condition persists without any improvement of network capacity then in the next 15-years the RCI value will increase to 3.77.

Table 9: Study Year RCI Estimation

1	2	3	4	5	6	7	8
SEGMENT NAME	*Observed Vol. (Veh/Hr)*	*Capacity (Pcu/Hr)*	*Segment Length(KM)*	*Col2*Col4*	*Col2/Col3*	*Col5*Col6*	*RCI =∑Col7/∑Col5*
Wurukum - BSUTH	3514	2600	4.4	15461.6	1.35153846	20896.94708	
Wurukum-Savannah Roundabout	3003	2600	1.3	3903.9	1.155	4509.0045	
Wurukum-NNPC,Filling Station	3193	1300	5.4	17242.2	1.22807692	21174.74792	
High level Roundabout-Police HQTRS	2618	2600	2.2	5759.6	1.00692308	5799.474154	**1.824466497**
Rain Oil Filling Station-Modern Market	3068	1300	2.5	7670	1.18	9050.6	
Wurukum – North Bank	2322	1300	4.1	9520.2	0.89307692	8502.270923	
				59557.5		**108660.6634**	

Table 10: Fifteen Year Projected RCI

1	2	3	4	5	6	7	8
SEGMENT NAME	*Observed Vol. (Veh/Hr)*	*Capacity (Pcu/Hr)*	*Segment Length(KM)*	*Col2*Col4*	*Col2/Col3*	*Col5*Col6*	*RCI =∑Col7/∑Col5*
Wurukum - BSUTH	6954	2600	4.4	30597.6	2.674615	81836.81	
Wurukum-Savannah Roundabout	6245	2600	1.3	8118.5	2.401923	19500.01	
Wurukum-NNPC Filling Station	6638	1300	5.4	35845.2	2.553077	91515.55	
High level Roundabout-Police HQTRS	5443	2600	2.2	11974.6	2.093462	25068.36	**3.771516**
Rain Oil Filling Station-Modern Market	6378	1300	2.5	15945	2.453077	39114.31	
Wurukum – North Bank	4827	1300	4.1	19790.7	1.856538	36742.2	
				122271.6		**461149.3**	

3.8 Present and projected degree of congestion

The study year degree of congestion on all the selected road segments are summarised as shown in Table 11. The projected peak volume and future V/C were estimated and the result shown in Table 12. The analysis was carried out to determine the predicted degree of congestion or future traffic condition on all the selected road segments in the next 15 years in order to carter for improved urbanization and motorization for effective management of the traffic operation on the urban roads in a developing economy.

Table 11: Present Degree of Congestion of the Selected Routes during the Peak Periods

Road Segment	Location 1	To (Direction 1)			From (Direction 2)			Location 2
		V_{peak} (pcu/hr)	Present v/c	Remarks (PAG, 2005/FHWA, 2014)	V_{peak} (pcu/hr)	Present v/c	Remarks (PAG, 2005/FHWA, 2014)	
Gboko Road	Duku Park	2000	0.77	Heavy Congestion	1514	0.58	Moderate Congestion	Wurukum Market
Iorchia Ayu Road	Wurukum Market	1318	0.51	Moderate Congestion	1686	0.65	Moderate Congestion	Nobis Super Market
Otukpo Road	Yaman Park	1716	1.32	Severe Congestion/ Exceeding Capacity	1477	1.14	Severe Congestion/ Exceeding Capacity	FCMB
Atom Kpera Road	Modern market Juction	1341	0.52	Moderate Congestion	1377	0.53	Moderate Congestion	Modern market Juction
Lafia Road	Court five	1656	1.28	Severe Congestion/ Exceeding Capacity	1412	1.09	Severe Congestion/ Exceeding Capacity	SRS Juction
Joe Akaahan Road	Zenith Bank	1222	0.94	Heavy Congestion/ Approaching Capacity	1100	0.84	Heavy Congestion/ Approaching Capacity	NYSC Secretariat

Table 12: Projected Degree of Congestion of the Selected Routes during the Peak Periods

Road Segment	Location 1	To (Direction 1)			From (Direction 2)			Location 2
		V_{peak} (pcu/hr)	Future v/c	Remarks (PAG, 2005/FHWA, 2014)	V_{Peak} (pcu/hr)	Future v/c	Remarks (PAG, 2005/FHWA, 2014)	
Gboko Road	Duku Park	3807	1.46	Severe Congestion/ Exceeding Capacity	3147	1.21	Severe Congestion/ Exceeding Capacity	Wurukum Market
Iorchia Ayu Road	Wurukum Market	2740	1.05	Severe Congestion/ Exceeding Capacity	3505	1.35	Severe Congestion/ Exceeding Capacity	Nobis Super Market
Otukpo Road	Yaman Park	3567	2.74	Severe Congestion/ Exceeding Capacity	3071	2.60	Severe Congestion/ Exceeding Capacity	FCMB
Atom Kpera Road	Modern Market Juction	2580	1.95	Severe Congestion/ Exceeding Capacity	2863	2.20	Severe Congestion/ Exceeding Capacity	Severe Congestion/ Exceeding Capacity
Joe Akaahan Road	Zenith Bank	2540	0.98	Heavy Congestion	2287	0.88	Heavy Congestion	NYSC Secretariat
Lafia Road	Court five	3443	2.65	Severe Congestion/ Exceeding Capacity	2935	2.26	Severe Congestion/ Exceeding Capacity	SRS Juction

The v/c ratio (degree of congestion) in direction 1 and 2 are shown in Figure 4 and 5 respectively. At present, Gboko and Iorchia Ayu roads were moderately congested in direction 2, Joe Akaahan road was heavily congested in

both directions while other segments were severely congested in both directions. Table 12 shows the degree of congestion on all the selected road segments in the next 15 years in order to carter for improved urbanisation and motorization for effective management of traffic operation on the urban roads in a developing economy. Only Joe Akaahan road would be heavily congested while other segments would be severely congested in both directions under the prevailing roadway and traffic conditions.

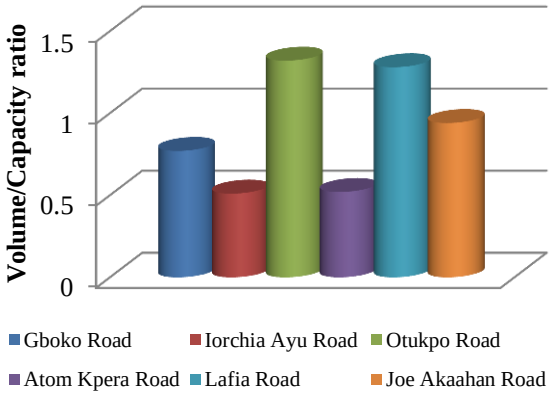

Fig 4. Pictorial comparison of v/c ratio on the studied roads in Direction 1.

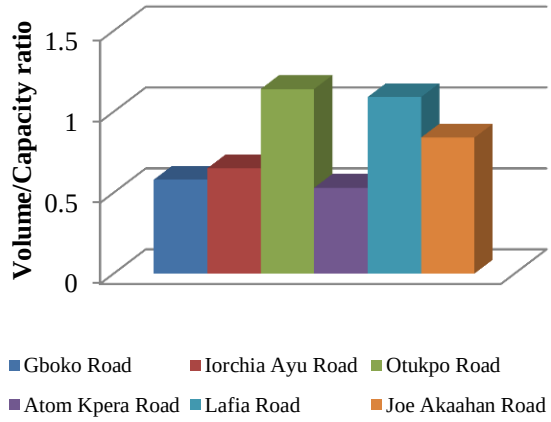

Fig 5. Pictorial comparison of v/c ratio on the studied roads in Direction 2.

3.9 Urban road traffic management at desired level of service (LOS).

The developed database for indices and degree of congestion obtained from the analysis can be adopted to determine the combination of volume/capacity ratio in line with segment length, speed and density that would give a desired level of service (LOS) at present and future conditions. This can be useful for effective planning and management of traffic on urban road network of a developing city. Figure 6 – 7 show the pictorial view of the future v/c ratios on the studied roads in direction 1 and 2 respectively.

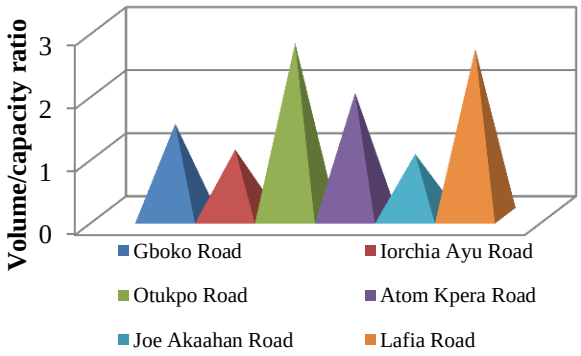

Fig 6. Pictorial comparison of future v/c ratio on the studied roads in Direction 1.

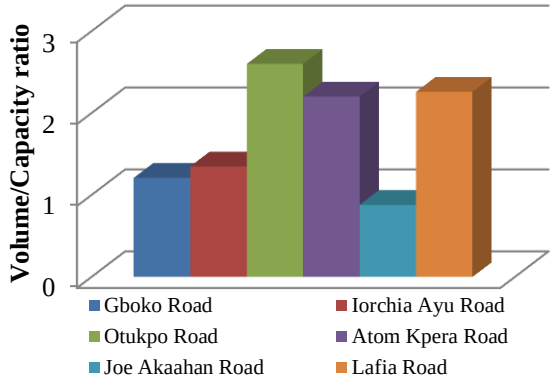

Fig 7. Pictorial comparison of future v/c ratio on the studied roads in Direction 2.

3.10 Intelligent Transportation System in Urban Movement

An intelligent transport system through an urban road network can be assured by effective traffic management on the road segments. Just-in-time movement or service delivery can be achieved appropriately when enough information or prediction of an estimate of the degree of congestion or traffic condition is known. Knowledge of the present and future traffic condition on an urban road network of a developing city can then be applied in the choice of route in the urban setting for effective management of traffic flow of urban roads in a developing economy. Also, it is a decision making function to ensure intelligent movement through the corridors of an urban road network. Therefore, the developed traffic database and parametric congestion index model can be adopted as a tool for application in the intelligent transportation system for developing cities.

4. Conclusions

The following conclusions were made from the study;

i. traffic on Makurdi road networks were dominated by cars of 38.09-61.87%, motorcycles of 15.58-22.85%, minibuses of 10.63-31.33%, and tricycles, luxurious buses, lorries/trucks, trailers/tankers of 0.03-7.75%; with operating significant parameters at peak period of 2322-3134 pcu/h., 305-990 pcu/km., 1.7-2.2 s and 17-40 km/h for the volume, density, headway and speed, respectively;

ii. the degree of congestion on the Makurdi urban roads on each of the selected routes were moderate to severe (volume capacity ratio of 0.51-1.32) and substantially dependent on the operating significant parameters;

iii. predictive model for the roadway traffic congestion index, $CI = 107.071+0.028v+10.054Sl +0.013c$ with $R^2 = 0.97$, was generated with volume (v), segment length (Sl) and capacity (c); and;

iv. a 15-year projection indicated that Joe Akaahan Road would be heavily congested. All other segments would be severely congested. The present and 15-year projected CI values were 1.83 and 3.77 respectively, indicating extra vehicle kilometer travel due to congestion of 377%.

The following recommendations were made;

i. the developed database for congestion indices can be useful for effective planning and management of traffic flow on urban road network of a developing city;

ii. a model for the roadway traffic congestion index, $CI = 107.071+0.028v+10.054Sl +0.013c$ developed for Makurdi road network as well as an evaluated CI of 1.83 and 3.77 for present and 15 – year condition are recommended to be adopted as tools for urban traffic analysis and design to proactively manage traffic congestion problems for urban roads of a developing city.

Conflict of Interest

The authors declares that they have no conflict of interest

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