Indices of Traffic Congestion on Major Roads in Akure, a Developing City in Nigeria

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Abstract— Indices of traffic congestion on major roads in Akure, a developing city in Nigeria, were determined. The routes considered were Oyemekun-Oba Adesida, Arakale and Ondo roads based on the fact that they were major routes critical to movement of persons and goods. Data on traffic volume on the roads were collected during the morning, afternoon and evening peak periods while data on headway, spot speed, density and delay at intersections were collected with the aid of Cine camera during June, 2015 to August, 2015. The data were analyzed with Microsoft Excel 2010 version and Traffic Analysis Spread sheet 2010 version. Values of Volume-Capacity ratio (V/C), Minimum allowable speed (P15), Jam density (kj) and Critical delay (dcrit) were determined as indices of traffic congestion. The results showed that FUTA junction to Ilesha garage segment with V/C of 0.74 and 0.73; P15 of 42 km/hr and 50 km/hr; kj of 430 pcu/km and 410 pcu/km and dcrit of 32.1 s/veh and 30.1 s/veh along both directions was moderately congested according to the Federal Highway Association (FHWA) and Pima Association of Governments (PAG) standards. Similarly, the segments connecting Isikan market to NEPA junction and Owena Barracks 1st gate to Isikan market were moderately congested using the same standards. Ilesha garage to Champion junction segment of Oyemekun-Oba Adesida road with V/C of 0.79 and 0.75; P15 of 33 km/hr and 40 km/hr; kj of 575 pcu/km and 460 pcu/km and dcrit of 56.7 s/veh and 46.6 s/veh along both directions was heavily congested. Similarly, the segments connecting Champion junction to Cathedral and Cathedral to Oba Osupa junction were heavily congested. A ten-year projection to 2025 indicated that FUTA junction to Ilesha garage segment (with V/C of 1.21 and 1.37 along both directions) would be severely congested, Isikan market to NEPA junction segment (with V/C of 0.96 and 0.95 along both directions) would be heavily congested while segments connecting Owena Barracks 1st Gate to Isikan market, Ilesha garage to Champion junction, Champion junction to Cathedral and Cathedral to Oba Osupa junction would be severely congested. It was recommended that provision of adequate parking facilities and lane marking; prohibition of on-street trading and parking; effective traffic management and efficient road maintenance programme should be put in place on the selected road segments to mitigate the problem of congestion.

Index Terms— Arakale road, Critical delay (dcrit), Indices of Traffic Congestion, Jam density (kj), Volume-Capacity ratio (V/C), Minimum allowable speed (P15), Oyemekun-Oba Adesida road, Ondo road.

1 INTRODUCTION

Road traffic congestion is one of the acclaimed indicators of a city's socio-economic "vibrancy". This has continually challenged the efforts of city and transport planners alike on highways, in terms of longer travel time and delay. It has equally created an artificial barrier to a cost effective flow of goods and persons along highways linking major towns.

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The traffic conditions across urban roads in Nigeria are in a grim situation caused by daily congestion and road crashes. Traffic congestion occurs when a city's road network is unable to accommodate the volume of traffic that plys it. This situation is caused by rapid growth in motorization and with less than corresponding improvement in the road network, traffic management techniques and related transport facilities. Thus, traffic congestion is a phenomenon that is associated with urban environment all over the world. This is because modes of transport are required to move from one place to another, especially when walking becomes impractible. While traffic congestion has been managed very well in some developed countries, it has continued to defy solutions in the developing world. The Global Traffic Volume (GTV) forecasted that the phenomenon would double between 1990 and year 2020 and also double by 2050 [1]. This type of growth pattern, as envisaged by the end of year 2020 and 2050, is an indication of what the future congestions would cause for people living in urban environment.

Research on indices of traffic congestion have been focused mainly on cities in developed country like United States [2], where the traffic situation is very different from those in developing countries; hence this study is intended to extend the concept of indices of traffic congestion in Akure, the capital city of Ondo State in Nigeria, with proffering

solutions to the problems of congestions in this city and its environs. The objectives are to evaluate the nature of traffic on the selected roads, determine the indices of congestion on the roads, and proffer solutions to the problem of traffic congestion in the study area.

Brief Literature Review

In determining the indices of traffic congestion, it is pertinent to put the phenomenon in proper perspective. The understanding of congestion influences what measures are introduced to address it. Many definitions have been proposed to describe traffic congestion on roadways in urban areas. However, there is no universally accepted definition of traffic congestion [3]. The definitions can be broadly categorized into three groups: (i) demand capacity related where traffic congestion is defined by [4] as state of traffic flow on a transportation facility characterized by high densities and low speeds, relative to some chosen reference state (with low densities and high speeds), (ii) delay-travel time related where traffic congestion is the presence of delays along a physical pathway due to presence of other users in accordance with [5], and (iii) cost related where traffic congestion refers to the incremental costs resulting from interference among road users [6].
Measures of traffic congestion can be categorized into four broad groups: (i) basic measures (ii) ratio measures (iii) level of service and (iv) congestion indices.

Basic measures are related to delay estimation. Delay has been defined as the additional time experienced by a road user in comparison to the free-flow travel or the acceptable travel time. Some of the researches that discussed the basic measures of traffic congestion are highlighted as follows:

Lomax *et al.* [7] developed (i) segment delay (equations 1 and 2), (ii) congested travel (volume or person weighted congested roadway length), and (iii) congested roadway length to estimate an individual segment delay. Total delay (volume or person weighted traffic delay) in a corridor or in an urban area is calculated as the sum of individual segment delays.

$$D_s = [TT_{ac} - TT_{ap}] \times V_p \quad (1)$$

$$D'_s = [TT_{ac} - TT_{ap}] \times V_{p\times}V_{oc} \quad (2)$$

where,

D_s = segment delay (vehicle-minutes)
D'_s = segment delay (person-minutes)
TT_{ac} = actual travel time (minutes)
TT_{ap} = acceptable travel time (minutes)
V_p = vehicle volume in the peak-period (vehicles)
V_{oc}= vehicle occupancy (persons/vehicle)

Ratio measures of traffic congestion are usually developed by dividing one travel time or delay element by another. The input of some researchers to discussion on the basic measures of traffic congestion are highlighted as follows:

Lomax *et al.* [7] developed several ratio measures (delay rate, relative delay rate and delay ratio) based on travel rate. The travel rate (in hours per kilometre) was defined as the rate at which a road segment is travelled. It is the reciprocal of speed multiplied by appropriate conversion factor. Acceptable travel rate was defined as the maximum rate of travel (or the lowest travel speed) at which a segment is traversed or a trip is completed without experiencing an unacceptable level of mobility. Delay rate, relative delay rate and delay ratio can be estimated by using the following equations:

$$DR = TR_{ac} - TR_{ap} \quad (3)$$

$$RDR = \frac{DR}{TR_{ap}} \quad (4)$$

$$DRA = \frac{DR}{TR_{ac}} \quad (5)$$

where,

Travel rate, $TR = TT/L_s = 3600/V$
DR = Delay rate (seconds per metre)
RDR = Relative delay rate
DRA = Delay ratio
TT = travel time (seconds)
L_s = segment length (metres)
V = travel speed (metre per second)
TR_{ac} = actual travel rate (seconds per metre)
TR_{ap} = acceptable travel rate (seconds per metre)

Traditionally, Level of Service (LOS) has been one of the most popular measures of traffic congestion. The LOS concept as adopted in [8] represents a range of operating conditions. The LOS of a facility is determined by traffic flow characteristics such as vehicle density, volume-to-capacity ratio, average speed and intersection delay, depending on facility type. The scale of LOS measure has six discrete classes ranging from A to F. The main advantage of LOS measure is that it is easily comprehended by most non-technical personnels.

Some researchers have developed index measures of traffic congestion by including several congestion related elements in an equation to produce a single measure as discussed below:

Taylor [9] and D'Este *et al.* [10] developed a congestion index. The congestion index is the ratio of link delay (the difference between actual and acceptable travel time) to acceptable travel time. Texas Transportation Institute, TTI has been quantifying congestion for major urban areas in the United States since 1982.

Schrank *et al.* [2] reported a Planning Time Index (PTI) of 498 urban areas in the 2012 urban mobility report, and proved that "urban areas where capacity increases matched the demand increase saw congestion grow much more slowly than regions where capacity lagged behind demand growth. PTI compares the travel time on the worst day of the month to travel time at free-flow conditions. This identifies the extra time that should be allowed to arrive on-time for a trip 19 times out of 20. Statistically, this is the 95th percentile and it speaks to the effects of a variety of events that make travel time unpredictable. A PTI of 1.80 implies that a traveller should plan to spend 36 minutes for a trip that takes 20 minutes in free-flow conditions, that is, 20 minutes x 1.80 = 36 minutes. The PTI is only computed for freeways and does not include Arterials.

Cottrell [11] developed the 'lane mile duration index' (LMDI) to measure freeway congestion in urban areas. This index was the summation of the product of congested lane miles and congestion duration for all freeway segments.

Density is a traffic parameter measured by counting the number of vehicles occupying 100 m section of a roadway and expressed as pcu/km. The delay, expressed as s/veh, was measured by taking note of how long a vehicle spent at the major intersection within the road segments before they manoeuvre and the number of vehicles on the queue were noted in order to determine the critical delay (that is, the delay with the highest number of vehicles).

The Study Area

Akure, a city in south-western Nigeria and capital of Ondo State is the study area. It also serves as the administrative capital of both Akure-South Local Government Area. Figure 1 is the map of Nigeria showing Ondo State. It is located in the Northern part of the state around latitude 7^0 15' North and longitude 5^0 15' East of the Greenwich Meridian and has an area of approximately 30.02 square kilometres [12]. It is located approximately 422 kilometres South West of Abuja, the Federal Capital of Nigeria and about 350 kilometres to Lagos the former capital of Nigeria. It is located within the tropical rain forest region of Nigeria where rainfall is high throughout the year [13]. This city has a population of 353,211 people according to 2006 census which consisted of 175,475 (49.68 %) males and 177,736 (50.32 %) females who are mainly civil servants, private businessmen and businesswomen, traders and peasant farmers [14], [15].

The town has a good road network system with the popular ones as Oyemekun-Oba Adesida road, Ondo road, Arakale road which serve as the major arterial routes in the city and a link to other towns. Over the years, the number of vehicles on its roads had increased greatly due to increasing socioeconomic activities. Increase in infra-structural

facilities such as housing, electricity, water supply and transportation caused rural –urban migration that imposed serious strains on existing transport infrastructure brought about various traffic problems. The natural pattern of development is linear along its main roads: Oyemekun-Oba Adesida and Arakale and Oda roads. These roads connect other street roads from Aiyedun, Isolo, Araromi, Oke-Ijebu, Elerinla, Fanibi, Isikan and Adegbola residential areas [16].

The traffic composition in Akure is mixed comprising of motorcycles, taxis, minibuses, Lorries and trucks (trailers); however, it is dominated by taxis, motorcycles (Okadas) and minibuses [17]. Figure 2 shows the road patterns of Akure metropolis.

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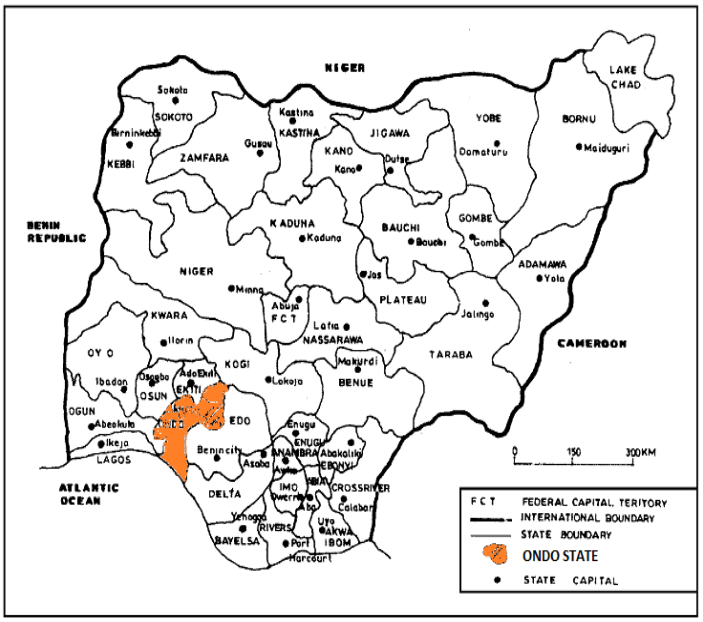

Fig 1: Map of Nigeria showing Ondo State at National Setting
Source: Ministry of Lands and Housing, 2015

2. METHODOLOGY

Field studies were conducted at three major roads namely along Oyemekun-Oba Adesida (FUTA junction to Oba Osupa junction), Arakale road (Isikan market to NEPA junction route) and Ondo road (Owena Barracks 1st Gate to Isikan market route) (Figure 3). They were selected based on the fact that they fall within the major route critical to movement of persons and goods in the study area. Oyemekun-Oba Adesida road was divided into four (4) segments designated by RA1, RA2, RA3 and RA4. Arakale road and Ondo road were designated by RB and RC respectively.

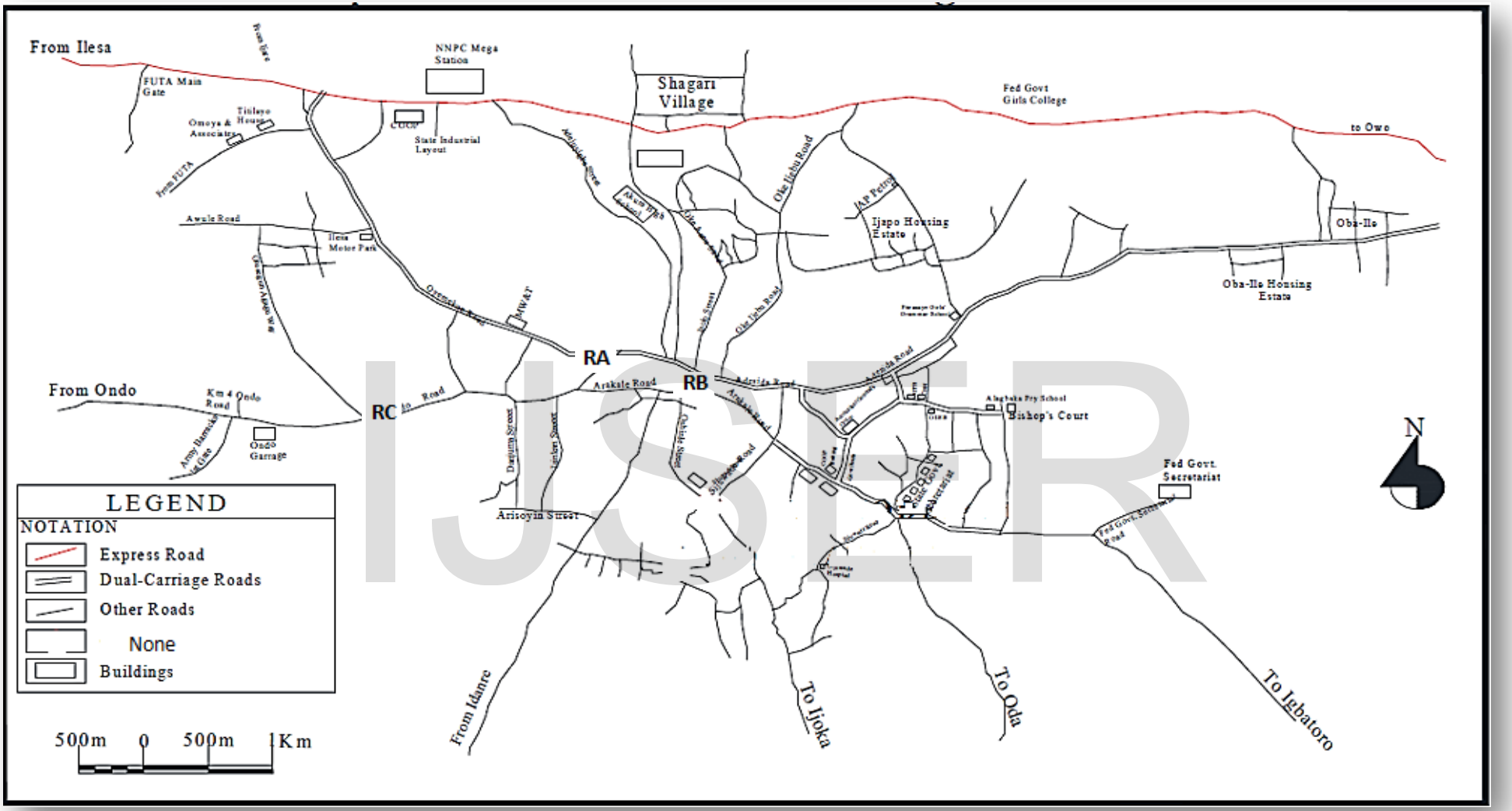

Fig. 2: Map of Akure showing the Road Pattern (Source: Ondo State Ministry of Works, 2015)

Traffic parameters were metered using cine camera placed at an elevated vantage point from the road section during the morning, afternoon and evening peak periods between 7:00–9:00am, 1:00–3:00pm and 4:00–6:00pm during weekdays and 10:00am–12:00noon, 1:00–3:00pm and 4:00–6:00pm on Saturdays respectively. Data on traffic volume (q), headway (h), density (K), speed (v), and delay (d) were deduced from the cine camera. The headways were measured between the vehicles while replaying the cine-camera and expressed as s.

Speed was measured along the selected routes in twelve (12) different locations, that is, eight locations on FUTA junction to Oba Osupa junction route, two locations each for both Isikan market to NEPA junction and Owena Barracks 1st Gate to Isikan market routes. The critical delay was determined from the measured delay. All the above-mentioned traffic parameters (volume, headway, density, spot speed and delay) were analysed with the use of Microsoft Excel and Traffic Analysis Spread sheet.

3. RESULTS AND DISCUSSION

The peak volumes with their corresponding time and day of the week varies according to the segments in question.

Table 1: Detailed Information on the Routes Considered

Route segments	Codes	Segment Length (m)	Roads
FUTA junction to Ilesha garage	RA1	3,300	Oyemekun-Oba
Ilesha garage to Champion junction	RA2	2,000	Adesida
Champion junction to Cathedral	RA3	2,400	
Cathedral to Oba Osupa junction	RA4	3,400	
Isikan market to NEPA junction	RB	4,300	Arakale
Owena Barracks 1st Gate to Isikan market	RC	5,200	Ondo

The routes are made up of segments RA1, RA2, RA3, RA4, RB and RC as shown in Table 1. Segments RA, RB and RC have total lengths of 11,100 m, 4,300 m and 5,200 m respectively.

Table 2: Standardized Measures of Traffic Congestion

V/C range	PAG Standard	FHWA standard
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: PAG [18] and FHWA [19]

The international standards used to determine their degree of congestion are shown in Table 2.

Table 3: Summary of the Indices of Traffic Congestion during the Peak Periods

Segments	Location 1	To (Direction 1)						From (Direction 2)						Location 2
		V_{peak} (pcu/hr)	V/C	P_{15} (km/hr)	$\bar{h}_{avg}$ (s)	k_j (pcu/km)	d_{crit} (s/veh)	V_{peak} (pcu/hr)	V/C	P_{15} (km/hr)	$\bar{h}_{avg}$ (s)	k_j (pcu/km)	d_{crit} (s/veh)	
RA1	FUTA Junction	1,924	0.74	42	1.9	430	32.1	1,885	0.73	50	2.0	410	30.1	Ilesha Garage
RA2	Ilesha Garage	2,051	0.79	33	1.7	575	56.7	1,944	0.75	40	1.8	460	46.6	Champion Junction
RA3	Champion Junction	2,072	0.80	31	1.7	710	84.6	2,021	0.78	37	1.8	490	51.6	Cathedral
RA4	Cathedral	2,314	0.89	21	1.6	935	98.9	2,188	0.84	23	1.7	760	92.2	Oba Osupa Junction
RB	Isikan market	1,539	0.59	34	2.4	380	26.5	1,514	0.58	35	2.5	352	16.3	NEPA Junction
RC	Owena Barracks 1st Gate	1,786	0.69	40	2.1	388	29.1	1,669	0.64	42	2.2	366	28.0	Isikan market

Table 4: Present Degree of Congestion of the Selected Routes during the Peak Periods

Segment	Location 1	To (Direction 1)			From (Direction 2)			Location 2
		V_{peak} (pcu/hr)	Present V/C	Remarks	V_{peak} (pcu/hr)	Present V/C	Remarks	
RA1	FUTA Junction	1,924	0.74	Moderately congested	1,885	0.73	Moderately congested	Ilesha Garage
RA2	Ilesha Garage	2,051	0.79	Heavily congested	1,944	0.75	Heavily congested	Champion Junction
RA3	Champion Junction	2,072	0.80	Heavily congested	2,021	0.78	Heavily congested	Cathedral
RA4	Cathedral	2,314	0.89	Heavily congested	2,188	0.84	Heavily congested	Oba Osupa Junction
RB	Isikan market	1,539	0.59	Moderately congested	1,514	0.58	Moderately congested	NEPA Junction
RC	Owena Barracks 1st Gate	1,786	0.69	Moderately congested	1,669	0.64	Moderately congested	Isikan market

It will be seen from Table 3, that the V/C, Jam density and Critical delay increase whereas the Minimum allowable speed and Average headway decrease along Oyemekun-Oba Adesida road in direction 1, that is, from segments RA1 to RA4 and vice versa in direction 2, that is, from segments RA4 to RA1. Along Arakale road, the V/C, Jam density and Critical delay decreases from 0.59 to 0.58, 380 pcu/km to 352 pcu/km and 26.5 s/veh to 16.3 s/veh as one changes from direction 1 (Isikan market to NEPA junction) to direction 2 (NEPA junction to Isikan market) whereas the Minimum allowable speed and Average headway increases from 34 km/hr to 35 km/hr and 2.4 s to 2.5 s as one changes from direction 1 to direction 2.

Likewise, the V/C, Jam density and Critical delay decreases from 0.69 to 0.64, 388 pcu/km to 366 pcu/km and 29.1 s/veh to 28.0 s/veh as one changes from direction 1 (Owena Barracks 1st Gate to Isikan market) to direction 2 (Isikan market to Owena Barracks 1st Gate) whereas the Minimum allowable speed and Average headway increases from 40 km/hr to 42 km/hr and 2.1 s to 2.2 s as one changes from direction 1 to direction 2.

The present degree of congestion on all the selected road segments were summarised as shown in Table 4 where segments RA1, RB and RC were moderately congested while segments RA2, RA3 and RA4 were heavily congested in both directions.

The projected peak volume and future V/C was calculated using

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

where,

$P_n = Projected\ Peak\ Volume$ (pcu/hr),
$P_o = Present\ Peak\ Volume$ (pcu/hr),
$r = Population\ growth\ rate$ (5 %),
$n = Number\ of\ projected\ years$ (10 in this case), and
$C = Capacity$ (2,600 pcu/hr)

Table 5: Future Degree of Congestion of the Selected Routes during the Peak Periods

Segment	Location 1	To (Direction 1)			From (Direction 2)			Location 2
		V_{peak} (pcu/hr)	Future V/C	Remarks	V_{peak} (pcu/hr)	Future V/C	Remarks	
RA1	FUTA Junction	3,134	1.21	Severely congested	3,564	1.37	Severely congested	Ilesha Garage
RA2	Ilesha Garage	3,341	1.29	Severely congested	3,292	1.27	Severely congested	Champion Junction
RA3	Champion Junction	3,375	1.30	Severely congested	3,167	1.22	Severely congested	Cathedral
RA4	Cathedral	3,770	1.45	Severely congested	3,071	1.18	Severely congested	Oba Osupa Junction
RB	Isikan market	2,501	0.96	Heavily congested	2,466	0.95	Heavily congested	NEPA Junction
RC	Owena Barracks 1st Gate	2,909	1.19	Severely congested	2,719	1.05	Severely congested	Isikan market

Table 5 shows the degree of congestion on all the selected road segments in the next 10 years in order to carter for improved urbanisation and motorisation. It can be seen that only segment RB would be heavily congested while the other segments RA1, RA2, RA3, RA4 and RC would be severely congested in both directions under the prevailing roadway and traffic conditions.

It will be inferred from the above tables that the present condition of FUTA junction to Oba Osupa road junction route, particularly Cathedral to Oba Osupa junction segment needs serious attention in order to address the problem of traffic congestion but all the segments on this route and Isikan market to Owena Barracks 1st Gate route would be in serious problem in the year 2025 if necessary solutions are not put in place.

4 CONCLUSION

The study has been able to identify the peak periods and determine the corresponding peak volumes, analyse the headway, spot speed, density and delay during these periods using data obtained from Akure in Nigeria. The peak period varies from segment to segment and the traffic composition varies from road to road. Traffic parameters such as headway, spot speed, density and delay were used to determine the indices of traffic congestion. However, the V/C, Jam density and Critical delay increase whereas the Minimum allowable speed and Average headway decrease along Oyemekun-Oba Adesida road in direction 1, that is, from segments RA1 to RA4 and vice versa in direction 2, that is, from segments RA4 to RA1. Along Arakale road, the V/C, Jam density and Critical delay decreases as one changes from direction 1 (Isikan market to NEPA junction) to direction 2 (NEPA junction to Isikan market) whereas the Minimum allowable speed and Average headway increases as one changes from direction 1 to direction 2. Likewise, the V/C, Jam density and Critical delay decreases as one changes from direction 1 (Owena Barracks 1st Gate to Isikan market) to direction 2 (Isikan market to Owena Barracks 1st Gate) whereas the Minimum allowable speed and Average headway as one changes from direction 1 to direction 2. The indices can be used to measure traffic congestion and used for planning and design of effective traffic control mechanisms in the study area and in other cities with similar traffic characteristics.

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