

Time Headway as Indices of Traffic Congestion

Emmanuel, A.A. and Mohammed, H.

Abstract: Urban mobility problem in Nigeria is on the increase, due to rapid growth in traffic that is not matched with the existing transport infrastructure, resulting in traffic congestion. Headway, a measure of level of service of a roadway, could be instructive in addressing this problem, hence this study. Headway, traffic flow and travel speed were collected for morning and evening peak periods for three consecutive weeks for two selected sections of a road in Ile-Ife, Osun state, using normal procedure. The obtained headway data were subjected to statistical analysis. Headway models were developed using regression analysis and the developed models were evaluated using Adjusted Coefficient of determination (R^2). The results showed that the traffic along the road was heterogeneous. The maximum safe speed (85th percentile speed) was 31.20 km/hr, while the minimum allowable speed (15th percentile speed) was 28.50 km/hr. The ratio of flow to capacity (v/c) of the road was 0.65 and thus characterised to operate at level of service C. The headway models were $h = 0.001n^2 - 0.418n + 35.401$, $h = 0.002n^2 - 0.569n + 42.122$, R-square values of 0.942 and 0.928 and minimum headway values of 5.35 sec. and 5.52 sec. For sections one and two respectively. The road is therefore prone to congestion.

Keywords: Urban mobility, Transport infrastructure, Headway, Congestion

I. Introduction

Headway is defined as the time between two consecutive vehicles (in seconds) when they pass a single point on a roadway, and is measured as the time between the same common features of two consecutive vehicles (e.g. front bumper) [1]. Headway is one of the important microscopic traffic flow parameters which is extensively applied in planning, analysis, design and operation of roadway systems [2]. Consequently, the distribution of headways has an effect on platoon formation and delays.

In [3] the level of service on two-lane rural highways is approximated by the proportion of headways less than five seconds; thus

making a connection between the headway distribution and the level of service. Accurate modelling and analysis of vehicle headway distribution helps traffic engineers to maximize roadway capacity and minimize vehicle delays.

Urban mobility problems in Nigeria have been increasing significantly in the last few decades and this trend seems to continue. This is due to rapid increase in population in urban areas, which is not matched with growth in transport facilities such as road networks, transport complimentary facilities, transport services and traffic management techniques [4].

[5] defined urban congestion as “a condition in which the number of vehicles attempting to use a roadway at any given time exceeds the ability of the roadway to carry the load at generally acceptable level of service”. There are two types of congestion: recurring and

Emmanuel, A. A Mohammed, H., (Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria)

Corresponding author: hmedstecm@yahoo.com

Phone Number: +234-803-725-2038

non-recurring. Typically, recurring congestion occurs during the morning and afternoon rush hours as commuters travel to and from work. Non-recurring congestion is caused by random incidents, most often by disabled vehicles and accidents. Recurring congestion is most easily identified as the characteristics of rush hour traffic are well documented. Incidents are random events, and traffic patterns and characteristics are not well defined [6].

Traffic congestion has a negative impact on the economy and on the quality of people's lives. Road users experience delay and stress, and environmental pollution increases. Congested traffic flow is characterized by a situation in which road users cannot drive at their desired speed because they are constrained by the presence of other road users.

In contrast, a free flow situation occurs when road users do not influence each other's behaviour. Smooth traffic flow can suddenly change due to a decelerating or slow moving vehicle or a partial blocking of the road [7]. The basis of travel time measure is rooted in the interests of travelers and urban residents. Travel time indices are good measures of the effects of congestion; they rely on an estimate of the speed that travelers choose to travel if there is no congestion (in this case, 90 km/h (60 mph) for freeways and 45 km/h (30 mph) on streets [8]. [9] noted that, if the volume over capacity ratio (v/c) is greater than or equal to 0.77, then there is congestion.

Management of traffic has become a critical issue as the number of vehicles in metropolitan areas is nearing the existing road capacity, resulting in traffic congestion. In some areas, the volume of vehicles has met and/or exceeded road capacity [10]. The development of headway models is therefore justifiable, because it helps traffic engineers to

verify how traffic properties and characteristics such as speed, flow, headway and density among others can be used to determine the effectiveness of traffic flow. Among the factors that may justify a transportation project are improvements in traffic flow and safety, energy consumption, travel time, economic growth, and accessibility [11]. Time headways as indices of traffic congestion could give policy guide for the improvement on the quality services of urban traffic movement.

II. Materials and Method

The data collection process was undertaken from the section (located between chainage 3+532 and 3+832) on an urban two-lane two-way road along Sabo junction – Obafemi Awolowo University Teaching Hospital's Complex (OAUTHC) section (Fajuyi road) in Ile-Ife city in Osun State, South-West of Nigeria. Figure 1 shows the study route. At the point of observation, the road alignment is on tangent with a clear sight distance of approximately 260 m, and there are no intersections that could cause diversion of traffic within 200 m.

The roadway section chosen for this study was single carriageway (two-lane, two-way roadway) paved with asphalt concrete, free from commercial activities, and was a major urban road (not a bypass). This road carries a composite traffic volume of passenger car, truck, buses, pick up, coaster, motorcycles and minibuses; the road carries a large proportion of the daily traffic volume.

Headway measurement was conducted with an automatic stopwatch. Headways of vehicles traversing the road segment were measured at every 15-minute intervals throughout the duration of observation. Traffic volume was obtained at the selected

sections using video camera. The video camera was mounted on the stand and placed at a vantage point (a storey building) so as to cover the entire length of trap. The recorded film was replayed in the laboratory to extract the traffic volume in both directions of the sections. The spot speeds were obtained using stopwatch with known two reference points.

The data collected which included, spot speed, traffic flow and headway for the study period of 2 hours (6:30am – 8:30am) for morning peak, and 1 hour (3:30pm – 4:30pm) for evening peak condition, for three (3) weeks (Monday – Friday), consecutively [12].

The headway data collected were analysed, and traffic parameters were derived from equations (i) to (iii) and reduced to characterize the road. Selection of the proper statistical techniques for analysing the headway results and utilization of the reduced data in the development of the regression models using SPSS. Adjusted coefficient of determination was used as the main evaluation in selecting the model that best fitted the field data.

Traffic density is given by;

$$K = \frac{Q_{agg}}{U_s} \quad (1)$$

where Q_{agg} is the Mean traffic Flow (pcu/hr/ln), U_s is the Max. Space mean speed (km/hr).

The Traffic Flow (vehicles per second) is given as;

$$T = \frac{1}{h} \quad (2)$$

where h is the average headway.

The capacity which represents the maximum flow is as expressed in Equation (3).

$$Q_m = K_o \times U_o \quad (3)$$

where U_o is the optimum speed while K_o is the Optimum density.

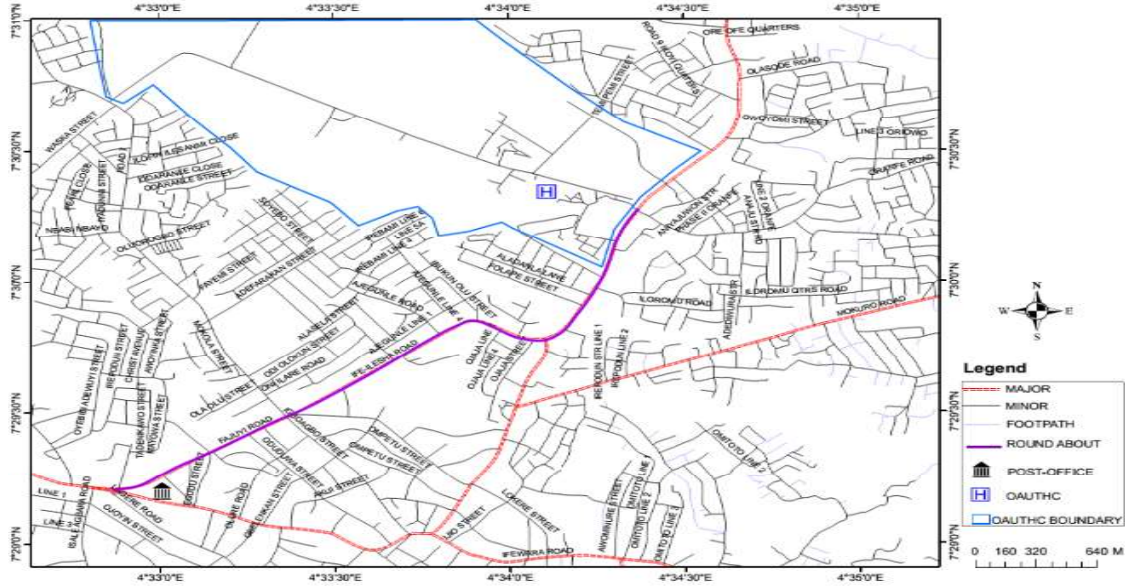
III. Results and Discussion

The selected road segment is 2.685 km long with a total carriageway of 12.10 m (lane width of 3.65 m) and unpaved shoulder of approximately 3.8 m, there are open line drains of 0.6 m x 0.9 m on both sides of the road and the roadway section was single carriageway (two-lane, two-way roadway) paved with asphalt concrete, free from commercial activities, and was a major urban road.

The traffic flow ranged from 784pcu/hr/lane to 1000pcu/hr/lane. The composition of the traffic on this route is classified as heterogeneous and was composed of 40% Motorcycles, 38% Buses, 21% Cars and Sport Utility Vehicles (SUVs), and 1% Trucks, (Figure 2). Mohan and Tiwari (2000) [13] reported that heterogeneous traffic flow consists of modes of varying dynamic and static characteristics sharing the road space, also, the large percentage for motor cycles is typical of urban passenger transport system [4].

The speed pattern on the route is typical of movement trends of traffic in urban centres. The maximum travel speeds were 34 km/hr at the early part of the morning (6.30 am – 7.00 am) and dropping to 28 km/hr (7:01 am – 7:15 am), when most commuters join the traffic for their various places of work. The speed picks up thereafter and drops again (4.15 pm – 4.30 pm), when commuters once again hit the road returning back home (Figure 3).

The peak traffic flow on the road at morning peak period was 978 pcu/hr/lane between 7:31 am and 7:45 am, and the peak traffic flow for evening peak period was 946



Note; The blue line indicate the selected road

Figure 1: The Study Location with some Features

$pcu/hr/lane$ between 3:46 pm and 4:00 pm, (Table 1). These observed periods always serve as the time the number of vehicles near the existing road capacity and when people are urged to reach their various places of work or get back home from work.

Also, the maximum headways on the road at morning peak period were 8.94 seconds and 9.32 seconds with observed flows of 784 $pcu/hr/lane$ and 877 $pcu/hr/lane$ for OAUTHC and Sabo directions respectively between 6:30 am - 6:45 am and 6:46 am – 7:00 am. The maximum headways on the road at evening peak period were 6.26 seconds and 8.42 seconds with observed flows of 946 $pcu/hr/lane$ for OAUTHC and Sabo directions respectively between 3:46 pm - 4:00 pm. The theoretical traffic flow showed variability between the observed headway and theoretical headway. These values of headway obtained are suitable because they are higher than the minimum safe headway of 5 seconds as postulated in [1].

An optimum speed (U_o) and optimum density (K_o) of 32.05 km/hr and 27.66

$pcu/km/lane$, were obtained respectively. The road operating capacity (Q_m) value was therefore, 887 $pcu/hr/lane$. Table 2 shows a comparison of the determined capacity and operating speed with that recommended for a two-way two-lane road by the [13]. The values obtained; 32.05 km/hr and 887 $pcu/hr/lane$ for speed and operating capacity respectively were short of the specifications for an urban a two-way, two-lane road [14]. Ratio of flow to capacity (v/c) of the road was 0.65; the selected road operates at level of service C, as shown in Table 3.

Tables 4 and 5 show the model summary and parameters estimates. The best model is the Second Order Polynomial. The equations representing the headway models are;

$$h = 0.001n^2 - 0.418n + 35.401 \quad (4)$$

$$\text{and } h = 0.002n^2 - 0.569n + 42.122 \quad (5)$$

with their corresponding R-square values of 0.942 and 0.928 for Sabo and Obafemi Awolowo University Teaching Hospital's Complex directions respectively (Figures 4

and 5), where h is the average headway (Sec.), and n is the number of headway observations (sample sizes).

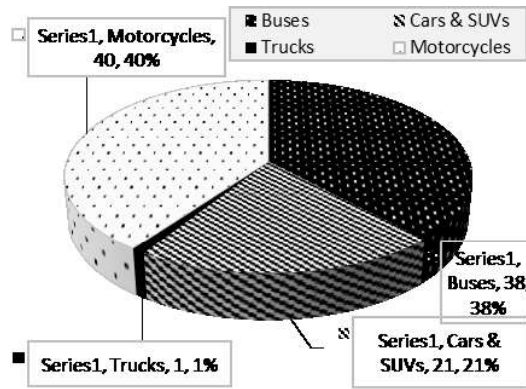


Figure 2: Traffic Composition for the Road

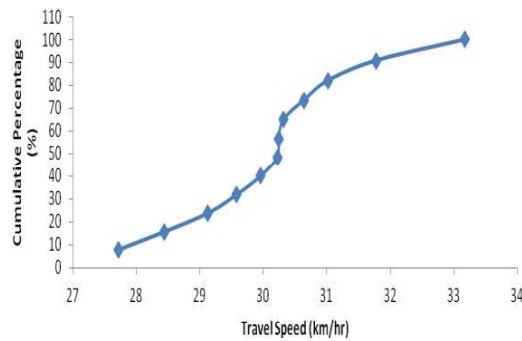


Figure 3: Percentage Cumulative of Average Travel Speed

Table 1: Average Headway, Observed and Theoretical Traffic Flow data

Time Interval	Observed Traffic Flow (Q_a)	Theoretical Traffic Flow	Average Headway (h_a) (Sec)	
	15 Days Average		Sabo Direction	OAUTHC Direction
6:30 – 6:45	784	865	9.23	8.94
6:46 – 7:00	877	859	9.32	8.39
7:01 – 7:15	922	954	7.98	7.43
7:16 – 7:30	954	1017	7.09	6.74
7:31 – 7:45	978	1070	6.36	6.09
7:46 – 8:00	910	978	7.65	6.87
8:01 – 8:15	896	928	8.35	7.64
8:16 – 8:30	862	876	9.07	8.00
3:31 – 3:45	909	865	9.23	7.23
3:46 – 4:00	946	923	8.42	6.26
4:01 – 4:15	893	855	9.37	7.99
4:16 – 4:30	895	889	8.90	8.45

Table 2: Capacity and operating speed (km/h) compared with the desired values

	Capacity (pcu/h/ln)	Operating Speed (km/h)
Highway Design Manual (HDM)	1500	50 – 60
This study	887	39.71

Table 3: 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

Table 4: Model Summary and Parameter Estimates for Sabo direction

Equation	Model Summary				Parameter Estimates			
	R-Square	F	df1	df2	Sig.	Constant	b1	b2
Linear	0.833	890.476	1	178	0.000	22.646	-0.151	
Logarithmic	0.839	927.495	1	178	0.000	74.338	-14.524	
Quadratic	0.942	469.945	2	177	0.000	35.401	-0.418	0.001
Power	0.849	1001.107	1	178	0.000	29770.619	-1.804	
Growth	0.850	1006.382	1	178	0.000	3.888	-0.019	
Exponential	0.850	1006.382	1	178	0.000	48.808	-0.019	

Table 5: Model Summary and Parameter Estimates for OAUTHC direction

Equation	Model Summary				Parameter Estimates			
	R-Square	F	df1	df2	Sig.	Constant	b1	b2
Linear	0.794	684.573	1	178	0.000	20.371	-0.130	
Logarithmic	0.811	761.684	1	178	0.000	67.219	-13.010	
Quadratic	0.928	425.011	2	177	0.000	42.122	-0.569	0.002
Power	0.841	938.518	1	178	0.000	18551.322	-1.705	
Growth	0.832	884.201	1	178	0.000	3.697	-0.017	
Exponential	0.832	884.201	1	178	0.000	40.321	-0.017	

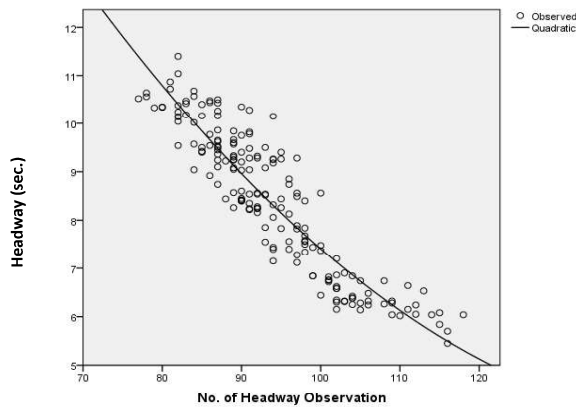


Figure 4: Headway model (Sabo direction, Section 1)

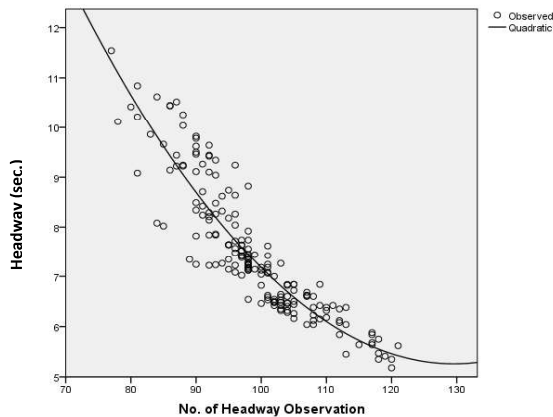


Figure 5: Headway model (OAUTHC direction, Section 2)

IV. Conclusion

Based on the findings of the study it can be deduced that the Second Order Polynomial model best fit headway-traffic flow relationship for an interrupted flow condition. The capacity and operating speed of the road were less than the required values of 1500 pcu/hr/lane and 50 – 60 km / h respectively for an urban two-way two-lane highway [14].

Furthermore, the minimum headway values of 5.35 sec. and 5.52 sec. obtained for Sabo (section 1) and Obafemi Awolowo University Teaching Hospital's Complex (section 2) directions respectively, are higher than the 5

sec., postulated by [1]. The road is therefore prone to congestion. The developed models could be used to predict vehicles arrival patterns at any point.

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