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Estimation of Bus Stops Spacing on Public Transport Routes in Kano Metropolis Using Minibus Stop Time Interval

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ABSTRACT: *For urban public transport system to be efficient, there is a need to provide a balance among the conflicting objectives of customer service, which include provision of reasonable walking distance to and from bus stop, and minimize the number of permissible bus stops along a route so as to reduce the frequencies at which a bus is required to merge into and exit from traffic stream. This study examined the characteristics of stop-time intervals of public transport minibus in Kano metropolis as a means for estimation of bus stops spacing and location of designated bus terminals for orderly pick-up and drop-off of passengers. Data were collected on minibus stop-time intervals on four major routes on which public minibus drivers operate in the city. Routes selected for the study were Gwarzo road, Katsina road, Maiduguri road and Zaria road. Though the stop-time intervals obtained from the study varied with respect to the observation conditions, statistical test carried out shows that there were no statistically significant differences in the values for the different periods and traffic directions. This could be as a result of similar characteristics exhibited by drivers who move for a short duration and stop to pick-up or drop passengers along the routes. The average values of stop-time interval of public transport minibus regardless of periods and traffic directions were found to be 0.98 minute, 0.82 minute, 1.04 minutes and 1.01 minutes for Gwarzo road, Katsina road, Maiduguri road and Zaria road respectively. Bus stops spacing of 817 m, 683 m, 867 m and 842 m were estimated for Gwarzo road, Katsina road, Maiduguri road and Zaria road respectively. The estimated bus stops spacings from this study can be useful in location of designated bus terminals on public transport routes network in Kano city for orderly pick-up and drop-off of passengers.*

KEYWORDS: *Kano Metropolis, Public Transport, Minibus, Stop-time Interval, Bus Stops Spacing, Bus Stop Locations*

I. INTRODUCTION

Efficient urban public transport system has been a challenge for many metropolises worldwide, especially large cities in developing countries. In many parts of Nigeria, minibuses (usually with a capacity of between 10 and 20 passengers) are used for public transport as means of moving relatively large number of people from one place to the other both within and outside cities, because of their size and relatively low price when compared with other means of transport such as taxicabs, tricycles and so on. The ancient city of Kano situated in the northern part of Nigeria is one of the cities whose substantial populace largely depends on minibus public transport for their daily movements. Kano is the second largest industrial and commercial city in Nigeria with a metropolitan population of 2.82 million and 9.3 million for the state[1]. Despite the significance utilization of this class of vehicles as a major means of public transport in Kano, the city lacks designated bus stops for orderly pick-up and drop off of passengers. The operation of this class of vehicles in the city is characterized by short stop-time interval as compared to those of private cars, taxicabs and other modes. Stop-time interval at which minibuses stop to pick-up and drop passengers seems not to be incorporated in the transportation policy and planning of many cities in Nigeria, Kano inclusive. Stop-time interval, also referred to as stop-time spacing is the time interval between two consecutive stops of a vehicle.

Operational mode of minibuses used for public transport in Kano metropolis particularly their recurring stops and take-ups to pick-up and drop passengers causes a lot of traffic hitches.These affect traffic flow in such away that other road users experience uncomfortable drive due to the perssistance signals by the minibuses to stop. Thus, making other road users to decelerate or stop for the minibus to stop or take-up before they continue to move. These stops (mostly parking on the road) and take-ups along the road does not allow for free and smooth traffic flow. Further, in most cases, these characteristics lead to traffic interruptions, non-freedom to manoeuvre and driving discomfort to other road users, and to some extent causing accidents. Problems associated with buses frequent merging into and exiting out of traffic stream along routes to pick-up and drop passengers are due to lack of regulations concerning designated locations for such. As the problems could be considerably minimized through a policy of imposing regulations upon the number of locations at which buses are permitted to stop [2].

This paper presents an examination of stop-time interval of minibuses used for public transport in Kano metropolis as a means for estimation of bus stops spacing in order to provide a balance among the conflicting goals of customer service. These include (i) provision of minimum walking distance to and from bus stop and (ii) minimizing the number of permissible bus stops along a route so as to reduce the frequencies at which a bus is required to merge into, and exit from traffic stream. Furthermore, this would provide for orderly pick-up and drop-off of passengers at designated terminals. Hence, the current study estimated bus stops spacings for public transport routes in Kano metropolis based on local public transport characteristics, operators' behaviour and local traffic conditions. This would avoid the application of estimates based on other countries' conditions that may not suitably fit the conditions of the area studied.

Findings from this study would be useful for the development of transportation policies and planning particularly for establishment of designated bus stops locations. This will enhance smooth operation of minibuses used for public transport services in Kano city; along with other vehicles classes. A bus stop is a designated place where buses stop for passengers to board or alight from. Provision of designated bus stops locations would minimize traffic interruptions, difficulties in manoeuvre within traffic stream, driving discomfort, and traffic accident. Further, appropriate location of designated bus stops minimizes the cost function for both users and operators as well as that of the overall transport system [3].

II. BACKGROUND

Stop-time interval of minibus used for public transport is the time interval between two consecutive stops of the bus either to pick-up or drop-off passenger(s). For typical unscheduled minibus service (with no designated bus stops), stop-time interval components is composed of (i) time spent accelerating to constant speed or decelerating from constant speed to stop, and (ii) time spent while the vehicle is in motion at a constant speed. Information on stop time interval characteristics can be used for estimation of bus stops spacing as well as locations of designated bus stops.

Several studies were conducted on bus stops spacing using different approaches in various parts of the world. A dynamic programming and geographic modeling was used to estimate optimal bus stop locations on bus routes in Boston, in which an average bus stops spacing of 400 m was established [4]. A study on bus routes in Oregon, based on optimization modeling [5] yielded a bus stop spacing of 930 ft (283.5 m). Huan and Robert [6] estimated a bus stops spacing of 1222 ft (372.5 m) in Portland, Oregon using optimal stop-spacing model based on minimizing access and riding costs.

A study on several bus stops spacings for urban areas around the world demonstrated that the average spacing ranges from 200 to 600 m [7]. Reilly [8], observed that while 2 to 3 bus stops per kilometer are designated in Europe, with a spacing varying from 330 to 500 m, in USA bus stops are spaced from 160 to 250 m. Demetsky and Lin [9] established that standards for bus stops spacing in some cities can reach 800 m. In São Paulo, Brazil, an average distance between consecutive bus stops of about 850 m was established as optimum [10]. In Netherlands, a study [11] was conducted to check the current standards on bus stops spacing. The study compared the estimates of optimum bus stops spacing with the existing average stops spacing in two different cities of Netherlands which ranges from 300 to 450 m and suggested for upward review of the existing standards to 500 - 800 m.

Bus stops spacing has a considerable effect on passengers travel time for both in-vehicle travel time and distance on foot to and from bus stop. When the spacing between bus stops increases, the distance on foot to and from bus stops also increases; however, the in-vehicle travel time becomes shorter because the vehicles have fewer locations to stop. Equally, if the distance between consecutive stops is shortened, access time (distance on foot to and from bus stops) to them is correspondingly reduced, but the buses have to stop in more locations for passengers to board or alight with resulting increase in overall travel time [12]. It is recommended that an appropriate walking distance from original location to the nearest bus stop should be around 400 m [13].

Several studies confirmed the disadvantages of locating too many bus stops and close spacing of bus terminals on urban routes. In a study related to estimation of optimum bus stops locations in Chennai, India confirmed that locating bus stops close to each other results in a waste of travel time and space [14]. The practice is also hazardous, posing danger to other vehicles and causing traffic congestion. Thus, a wider spacing of between 500 m as minimum and 2 km as maximum was suggested in order to alleviate the associated problems. Levinson [15] studied the performance of transit travel times and demonstrated that performance could be improved by keeping the number of bus stops to a minimum. Other researchers also established that roads with less number of bus stops have faster travel speeds (shorter travel times) as well as reduced associated operational costs [4, 16, 17]. It was also demonstrated that that reducing the number of bus stops on transit routes by locating them at wider spacing decreases travel delay due to unnecessary stops [18]. Even though bus stops spacing criteria are common, they are barely uniform; as such in deciding busterminals spacing on public transport routes, different agencies tend to have different standards and also operate based on local conditions [19].

III. METHODOLOGY

3.1 STUDY SITES

Four roads within Kano metropolis were used for this work. Of the many routes which minibuses operate for public transport service in Kano city, four were selected for the study. These are Gwarzo, Katsina, Maiduguri and Zaria roads. These roads were chosen for the study because they are particularly in good condition, attract reasonable number of minibus operators and traverse across mixture of land-use areas ranging from residential, business, institutional, etc. For the selected routes, Yankura/Bata (Central Business District in Kano city) served as origin, while Rijiyar zaki, Dawanau, Mariri and Na'ibawa motor parks served as distinations for Gwarzo, Katsina, Maiduguri and Zaria roads, respectively. The approximate lengths of the routes (from origin to final destination) are 10.2 km, 14.2 km, 13.6 km and 9.8 km for Gwarzo, Katsina, Maiduguri and Zaria roads, respectively. Figure 1 shows the location of the study area whose coordinates are $11^{0}59^{'}59.73^{''}$N and $8^{0}05^{'}58.98^{''}$ E.

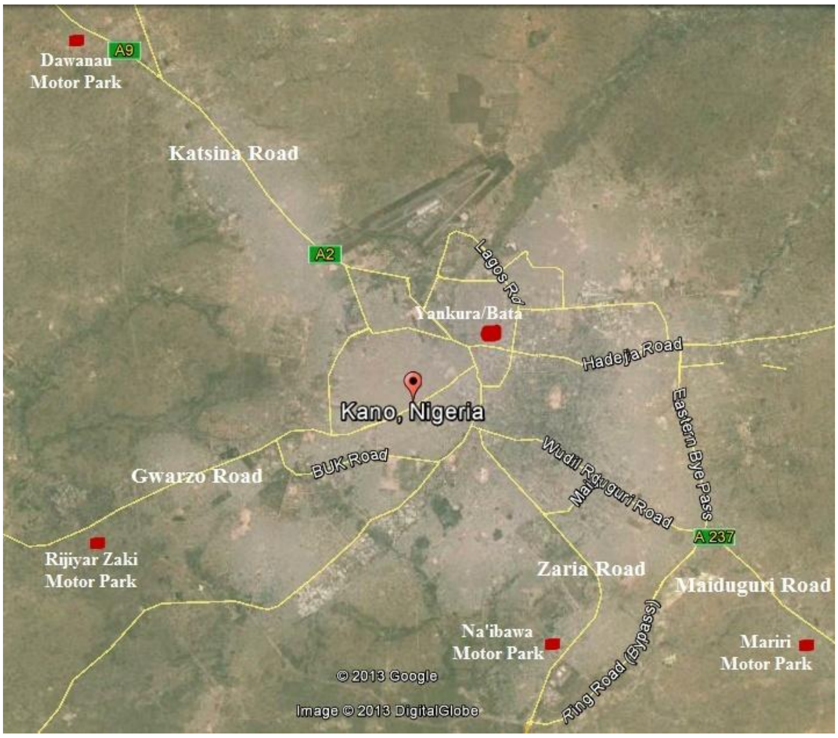

Figure 1: Location of Study Area

3.2 DATA COLLECTION

Data on stop-time intervals were collected by an observer in which the observer boards a minibus from the origin of a route under study to its destination and back to the origin and vice-versa. Minibuses were chosen as the sources for the information needed for this work because they seem to stop and take-up more frequent than other modes of public transport. Selections of a particular vehicle to board by the observer were made randomly. In this work, the stop-time interval was taken as interval between the moments when the minibus starts to move from rest and when it is brought to stop. A stopwatch was used to measure the time interval between any pair of minibus consecutive stops. This was done by starting the stop watch as soon as the vehicle moves with the observer inside the bus. Immediately the vehicle stops, the observer stops the watch and the time interval between the start and stop recorded. The stop watch was then reset and the process repeated as the minibus starts and stops along the chosen routes. This was conducted on both traffic directions (To and Fro) on all the routes at different times of the day; specifically, peak and off-peak periods for both morning and afternoon. All data were collected during the week days as more activities are deemed to happen compared to weekends. Stop-time intervals were then extracted from the data collected for all the routes studied. Using the average values of the stop-time intervals and the maximum speed limit of 50 km/h recommended for urban roads in Nigeria [20], a bus stops spacing for the roads studied were estimated.

IV. RESULTS AND DISCUSSIONS

As stated in the preceding section, data were collected for both morning and afternoon periods (peak and off-peak), and for both directions of travel (To and Fro) separately. Mean stop-time interval for each period and directions were then determined based on the total number of observed stop-times for each road as presented in Table 1.

Table 1: Mean Stop-time Intervals (minutes) for the Roads Studied

Routes	Periods								Average Stop-time Interval (minutes)
	Morning				Afternoon				
	Peak		Off-peak		Peak		Off-peak		
	Time To	Time Fro	Time To	Time Fro	Time To	Time Fro	Time To	Time Fro	
Gwarzo Road	0.69	1.14	0.84	1.29	0.95	0.99	0.90	1.07	0.98
Katsina Road	0.82	0.96	0.91	0.76	0.69	0.63	0.96	0.80	0.82
Maiduguri Road	1.11	1.00	1.32	1.05	1.22	0.78	0.65	1.20	1.04
Zaria Road	0.97	1.07	1.18	1.12	0.91	1.14	0.85	0.87	1.01

From Table 1, the overall average stop-time interval regardless of traffic directions and periods, were found to be 0.98, 0.82, 1.04 and 1.01 minutes for Gwarzo, Katsina, Maiduguri, and Zaria roads respectively. Katsina road was found to have the shortest stop-time interval of 0.82 minute among the routes studied. This could be due to difference in terms of the route's characteristics as compared to others; as this road traverses residential areas with high population density with many business areas along the route, such as major markets and a lot of road side trading activities and unrestricted parking along the road. These are expected to generate and attract considerable number of trips; hence, many passengers board buses and alight from frequently along the route which results in frequent stops as well as short stop-time separation. Next to Katsina road in terms of short stop-time interval is Gwarzo road, having an overall average of 0.98 minute. This road has similar adjacent land-use characteristics to Katsina road but of lower magnitude and density. This might be the reason why the stop-time interval for Gwarzo is slightly higher than that of Katsina road. Maiduguri road was found to have the longest stop-time interval of 1.04 minutes compared to the other routes, indicating fewer numbers of stops along the route. This is not surprising because the road passes through areas whose land-uses are more of public offices, government agencies, corporate offices, and their likes (with less dense of residential houses and road side activities) most of which parking by public transports are restricted. Zaria road with relatively longer stop-time interval compared to Katsina and Gwarzo roads might be as a result of the nature of areas traversed by the road. Although there are no designated bus stops along the route, yet there are well known locations at which most bus drivers stop to pick-up and drop passengers as dictated by the land-uses along the road. Popular land-uses along the road include motor parks, state secretariat, hospital, schools, shopping malls and banks. These land-uses made the number of stops being relatively few and hence relative long stop-time interval. Figure 2 depicts the graphical variation of the overall average stop-time interval of the roads studied.

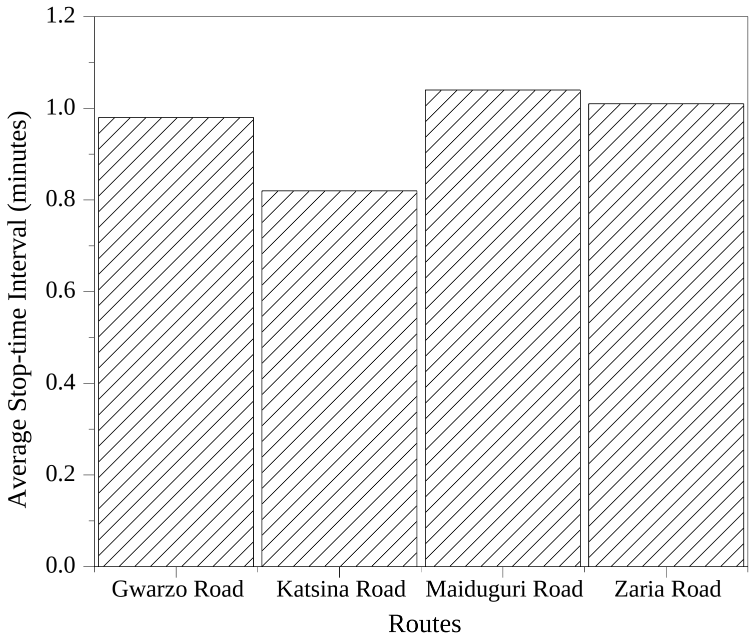

Figure 2: Variation of Average Stop-time Interval of the Roads Studied

Data obtained on stop-time intervals were categorized into various sets from which means and variances were derived for each set. Statistical tests were conducted on the various categories of data using t – test of difference of means in order to check whether there are differences between the various categories of data set collected or not. The test was carried out using equation 1, in accordance with Irwin, John [21].

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\left\{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2\right\}}} \sqrt{\frac{n_1 n_2 (n_1 + n_2 - 2)}{n_1 + n_2}} \qquad (1)$$

$\bar{x}_1$ and $\bar{x}_2$ are the means of observations for first and second sets of data respectively.
s_1^2 and s_2^2 are the variances of observations for first and second sets of data respectively.
n_1 and n_2 are number of observations for first and second sets of data respectively.
n_1+n_2-2 = degree of freedom.

Seven different sets of tests; grouped into three categories were carried out for each of the roads studied as follows:

(a) First Category:
Test 1: Test of difference of means for morning peak period (To) and morning off-peak period (To).
Test 2: Test of difference of means for afternoon peak period (To) and afternoon off-peak period (To).
Test 3: Test of difference of means for morning peak period (Fro) and morning off-peak period (Fro).
Test 4: Test of difference of means for afternoon peak period (Fro) and afternoon off-peak period (Fro).

(b) Second Category: This category of tests is irrespective of periods (peak of off-peak):
Test 5: Test of difference of means for morning periods (To) and (Fro).
Test 6: Test of difference of means for afternoon periods (To) and (Fro).

(c) Third Category: This test is regardless of periods (peak or off-peak) and directions (To or Fro).
Test 7: Test of difference of means for morning and afternoon.

4.1 STUDY HYPOTHESIS

The hypothesis put forth for testing in this study is as follows:

Null Hypothesis, $H_o: \mu_1 = \mu_2$

There are no period (peak and off-peak, morning and afternoon) and directional (To and Fro) differences in the stop-time intervals of public transport minibus in all the roads studied.

Alternate Hypothesis: $H_1: \mu_1 \neq \mu_2$

There are period and directional differences in the stop-time interval of public transport minibus in all the roads studied.

4.2 EVALUATION CRITERION

The null hypothesis is only be accepted if the experimental *t* value (*t*-calculated) from equation (1) is less than that of critical *t* value (derived from *t* – distribution table) at 0.05 level of significance (95% confidence level) and a predetermined degree of freedom.

4.3 COMPUTATION OF t – STATISTICS AND DECISION MAKING

This section presents an analysis of stop-time intervalsusing t – test of difference of means to check whether there exist significant differences between the various categories of data sets collected based on directions of traffic and periods (morning or afternoon and peak or off-peak) or otherwise. These tests were carried out in order to decide whether to accept or reject the null hypothesis. In other words, if there are no significant differences between the various data sets, the null hypothesis is accepted; otherwise, it would be rejected.

Tables 2 to 5 showed the summary of observations, t – statistics values and decision for each data set for all the roads studied. Table 2 presented the summary of the evaluation for Gwarzo road.

Table 2: Summary of Observations and t – Statistics Values for Gwarzo Road

Test No.	Variables									Decision
	n_1	n_2	$\bar{x}_1$	$\bar{x}_2$	s_1^2	s_2^2	df	t - Experimental	t - Table	
Test 1	20	18	0.69	0.84	0.29	0.92	30	-0.57	±1.96	NHA
Test 2	16	17	0.95	0.90	0.70	0.49	31	0.15	±1.96	NHA
Test 3	13	11	1.14	1.29	1.24	0.72	22	-0.38	±2.074	NHA
Test 4	17	13	0.99	1.07	0.43	1.00	28	-0.27	±2.048	NHA
Test 5	38	24	0.76	1.21	0.60	1.01	60	-1.89	±1.96	NHA
Test 6	33	30	0.92	1.07	0.59	0.68	61	-0.71	±1.96	NHA
Test 7	62	63	0.93	0.97	0.83	0.64	123	-0.27	±1.96	NHA

NHA = Null Hypothesis Accepted

Results in Table 2 indicated that for all the seven sets of tests conducted on the various categories of data sets, the values of t – experimental (calculated) were all less than (or within the range) those of t – table (critical value from t – distribution table). This implies that the null hypothesis is accepted for all the cases tested. Hence, there are no directional and period differences among the different data sets.

Tables 3, 4 and 5 presented the summary of the evaluations for Katsina road, Maiduguri road and Zaria road respectively. Similar results to that of Gwarzo road were obtained for these roads in which for all the sets of tests, t – experimental values were all less than those of t – table. Accordingly, the null hypothesis is also accepted for all the tests, signifying that there are no directional and periods differences among the different data groups.

Table 3: Summary of Observations and t – Statistics Values for Katsina Road

Test No.	Variables									Decision
	n_1	n_2	$\bar{x}_1$	$\bar{x}_2$	s_1^2	s_2^2	df	t - Experimental	t - Table	
Test 1	17	15	0.82	0.91	0.15	0.48	30	-0.49	±1.96	NHA
Test 2	21	16	0.69	0.96	0.20	0.35	35	-1.55	±1.96	NHA
Test 3	16	18	0.96	0.76	0.55	0.14	32	1.00	±1.96	NHA
Test 4	20	19	0.63	0.80	0.12	0.18	37	-1.34	±1.96	NHA
Test 5	34	34	0.86	0.88	0.31	0.35	64	-0.15	±1.96	NHA
Test 6	37	39	0.81	0.71	0.29	0.16	74	0.94	±1.96	NHA
Test 7	66	76	0.87	0.75	0.33	0.22	140	1.31	±1.96	NHA

NHA = Null Hypothesis Accepted

Table 4: Summary of Observations and t – Statistics Values for Maiduguri Road

Test No.	Variables									Decision
	n_1	n_2	$\bar{x}_1$	$\bar{x}_2$	s_1^2	s_2^2	df	t - Experimental	t - Table	
Test 1	8	5	1.11	1.32	0.62	0.90	11	-0.44	±2.201	NHA
Test 2	6	7	1.22	0.65	0.61	0.13	11	1.72	±2.201	NHA
Test 3	13	10	1.00	1.05	1.13	1.10	21	-0.10	±2.08	NHA
Test 4	11	11	0.78	1.20	0.19	1.02	20	-1.26	±2.086	NHA
Test 5	13	23	1.19	1.02	0.75	1.12	34	0.48	±1.96	NHA
Test 6	13	22	0.91	0.99	0.48	0.67	33	-0.28	±1.96	NHA
Test 7	36	35	1.08	0.96	0.99	0.60	69	0.57	±1.96	NHA

NHA = Null Hypothesis Accepted

Table 5: Summary of Observations and t – Statistics Values for Zaria Road

Test No.	Variables									Decision
	n_1	n_2	$\bar{x}_1$	$\bar{x}_2$	s_1^2	s_2^2	df	t - Experimental	t - Table	
Test 1	19	15	0.97	0.18	0.77	0.66	32	-0.70	±1.96	NHA
Test 2	21	23	0.91	0.85	0.81	0.34	42	0.26	±1.96	NHA
Test 3	22	18	1.07	1.12	0.65	0.95	38	-0.18	±1.96	NHA
Test 4	16	22	1.14	0.87	0.69	0.31	36	1.20	±1.96	NHA
Test 5	34	40	1.06	1.10	0.73	0.79	72	-0.18	±1.96	NHA
Test 6	44	38	0.88	0.99	0.57	0.50	80	-0.68	±1.96	NHA
Test 7	74	82	1.08	0.93	0.76	0.54	154	1.19	±1.96	NHA

NHA = Null Hypothesis Accepted

Though the average stop-time intervals of the roads varied, but statistical analysis shows that there were no statistically significant difference in the values obtained between peak and off-peak periods, and directions of traffic. This could be due to similar characteristics exhibited by drivers who move for a short duration and stop to pick-up or drop passengers along the routes. For the reason that the various classes of the data groups for all the roads studied do not differ significantly, it means that the stop-time intervals for each of the roads do not differ significantly with respect to periods and directions. Hence, the overall average value of stop-time interval for each road from Table 2 was used to estimate bus stop spacings along each of the routes.

4.4 ESTIMATION OF BUS STOPS SPACING

Based on the overall average stop-time interval values of minibuses for the routes studied and the recommended maximum speed limit of 50 km/h for urban roads in Nigeria [20], the bus stops spacings (distance between consecutive terminals) were estimated as presented in Table 6.

Table 6: Estimates of Bus Stops Spacings for Studied Routes

Routes	Average Stop-time Interval (minutes)	Average Bus Stop Spacing (m)
Gwarzo Road	0.98	817
Katsina Road	0.82	683
Maiduguri Road	1.04	867
Zaria Road	1.01	842

From Table 6, it could be seen that the average bus stops spacing for the roads studied were found to be 817 m, 683 m, 867 m and 842 m for Gwarzo road, Katsina road, Maiduguri road and Zaria road, respectively. Katsina road has the least bus stops spacing of 683 m which is consistent with its shortest stop-time interval compared with the other roads. This could be attributed to the nature of the land-use setting along the route which composed of mixture of residential areas with high population density and many business areas along the route, such as major markets and road side trading activities, and unrestricted parking along the road. These are expected to generate and attract considerable number of trips; hence, many passengers board buses and alight from frequently along the route which results in shorter stop interval as well as shorter bus stops spacing. Estimated spacings for Gwarzo, Maiduguri and Zaria roads could also be as a result of characteristics of the roads adjacent land-uses settings along the respective routes as described in section 4.0.

While previous studies [4, 6-11] in many parts of the world reported optimum bus stops spacings in the range of 160 m to 850 m for urban areas, estimates from this study fall in the range of 683 m to 867 m. This signifies that estimated bus stops spacing values for Gwarzo, Katsina and Zaria roads fall within the estimates in the existing literature. However, estimate for Maiduguri road with a spacing of 867 m is slightly higher than the values reported by others; this could be due to variations in local conditions as highlighted by Benn [19]. Further, Sankar, Kavitha [14] suggested even a higher spacing ranging from 500 m to 2 km in order to alleviate the problems associated with waste of travel time (due to many stops) and space when bus terminals are closely located. Although the estimated bus stops spacings obtained in this study tend to be close to the upper limit of the ranges reported by other researchers, yet when applied, it will reduce the in-vehicle travel times because the buses will have fewer locations to stop and hence a shorter overall travel time.

V. CONCLUSIONS

This paper examined the stop-time interval of minibuses used for public transport in Kano metropolis as a means of estimating bus stops spacing for locations of designated bus terminals for pick-up and drop-off of passengers. The most important findings of this study are:

1. There are no periods and directional differences in the stop-time intervals of public transport minibus in all the four roads studied.
2. The average values of stop-time interval of minibus regardless of periods and traffic directions are 0.98 minute, 0.82 minute, 1.04 minutes and 1.01 minutes for Gwarzo road, Katsina road, Maiduguri road and Zaria road, respectively.
3. Bus stops spacing of 817 m, 683 m, 867 m and 842 m were estimated for Gwarzo road, Katsina road, Maiduguri road and Zaria road, respectively.
4. Estimated bus stops spacings can be useful in location of designated bus terminals on public transport routes network in Kano metropolis for orderly pick-up and drop-off of passengers.

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