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Spatio-Temporal Analysis of Road Network of Selected Major Routes in Port Harcourt City, Nigeria

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Abstract— The study evaluated the spatio-temporal analysis of road network of selected major routes namely Choba-Rumuola-Eleme Junction route and Choba-Rumuokoro-Eleme Junction route. The use of counting method was employed to estimate the vehicular movement (inflow and outflow). The impedances on the two roads were recorded and mapped using Global Positioning Systems. Stopwatch was used to record the time taken in each of the impedance location. Findings revealed that the total vehicular inflow along Choba-Rumuola-Eleme Junction route was highest on Wednesdays with 1159 vehicles and least on Sundays with 677 vehicles. The outflow was least on Sundays and highest on Mondays with 715 and 1224 vehicles respectively. Furthermore, the total inflow was highest in the evening (2622 vehicles) and the least was observed in the afternoon (1826 vehicles). The total vehicles plying Choba-Rumuola-Eleme Junction route were 13786 vehicles while along Choba-Rumuokoro-Eleme Junction route were 6545. Time lost during the vehicular inflow along Choba-Rumuola-Eleme Junction route was highest at Rumuokwuta Junction (6708.6s) while along Choba-Rumuokoro-Eleme Junction route, time lost was highest at Rumuokoro Roundabout (5210.4s). The total time lost along Choba-Rumuola-Eleme Junction route was higher (42105.21s) than that of Choba-Rumuokoro-Eleme Junction route (25233.0s) whereby cars were the highest (>70%) type of vehicles recorded along the two routes. The study recommended among others that motorist should try to avoid both Rumuokoro Roundabout and Rumuokwuta Junction when plying these roads.

Index Terms: Network, Vehicular, Routes, Port Harcourt, Impedances

I. INTRODUCTION

Road networks are observed in terms of its components of accessibility, connectivity, traffic density, level of service, compactness, and density of particular roads [1; 2; 3]. Analysis and proper mapping of road network is a key to economic development as well as improvements in per capita income and expenditure of the community [4; 5]. Also, cities with higher levels of agglomeration of transport network tend to have higher GDP per capita and higher levels of productivity [6].

Transportation which is the movement of people and goods from one location to another is being controlled by the nature and characteristics of the network system [2]. Motorized transportation in some form or other has become a global, urban standard that the most zealous coverage for greener planet cannot hope to eradicate [7; 8]. In the developed and developing nations of the world, public and private transportation of people, goods and services has evolved significantly over the centuries for the reason that most people wish to reach or shift things to specific dominations as hostel free as possible [9].

With respect to road travel, it is important to evaluate the extent and quality of the network. In the recent time, many rural and urban roads have not received adequate maintenance and this has constituted traffic problems of varying degrees in different places at a particular time or season. [10] reported that poorly maintained roads are particularly problematic in the rainy season. The most important transport problems are often related to urban areas and this takes place when transport system for a variety of reasons cannot satisfy the numerous requirements of urban mobility [11]. However, urban productivity is highly dependent on the efficiency of its transport system to move labour, consumers and freight between multiple origins and destinations. Thus, many developing projects have serious dependence in transport network [12]. Port Harcourt being a city that has a high level of accumulation and concentration of economic activities is subjected to traffic problems especially in the major roads of the city. Finding a route that is devoid of jams or pot holes which can support reaching the destination at the right time is almost impossible. Thus, proper road network mapping of a region can effectively reduce traffic congestion and for bottlenecks, creates easy access to places that are far and near, reduces delay and increases accessibility of industries to their targeted customers. Studies on spatial assessment of road network in Port Harcourt city is very few among which include [13] study which concentrated on the spatial assessment of road network in Trans-Amadi. The study made use of GIS and remote sensing technologies but did not address the issues of spatial location of impedance and time taken in a traffic jam. Therefore, this present study evaluated and assessed the condition of major routes in Port Harcourt metropolis. The study also focused on locating the impedances along these routes and investigating periodic vehicular movements and time spent due to impedance along these selected routes. The study also determined the relationship between volume of traffic and time taken.

II. MATERIALS AND METHODS

The study area was Port Harcourt city, Port Harcourt lies between latitudes 4o46'N and 4o 49'N and between longitudes 07o 1'E and 7o 5'E. Port Harcourt enjoys a tropical monsoon climate with lengthy and heavy rainy

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season and short dry season. Average temperatures throughout the year are between 25oC and 28oC [14]. The mean annual temperature is 28oC while the relative humidity is high with mean annual of 85%. The monthly rainfall follows a temporal sequence of increase towards July to August before decreasing in the dry season between November and February. Rainfall is at its peak in July and September with a little dry season in August [15]. The topography is relatively uniform and the relief is generally [16]. There are many industries and other commercial centres in Port Harcourt city. Two major roads were selected for the study and these included Choba- Rumuokoro- Eleme road and Choba-Rumuola-Eleme road. Choba was taken as the origin while Eleme junction was taken as the destination. Global Positioning System (GPS) was used to determine the coordinates of the impedances along the selected road. The time spent in an impedance was recorded with the use of a stopwatch. The vehicular flow (inflow and outflow) was recorded in specific locations along the selected route. The width of the roads was also determined using tape rule. Along Choba-Rumuokoro-Eleme junction, there were two locations of counting. One location was between Choba and Rumokoro second was between Rumuokoro and Eleme Junction. There were three locations of counting along Choba, Rumuola Elemen junction. First one was between Choba and Rumuokwuta, second was between Rumuokwuta and Rumuola and third one was between Rumuola and Eleme junction. The counting was done at the same time by field assistants in the morning (7am-10am), afternoon (12pm-3pm) and evening (4pm-7pm) for a month. The locations of impedances were mapped in ArcGIS 9.3. Descriptive statistics was employed for the analysis to describe the spatial temporal inflow and outflow vehicular data.

III. RESULTS

A. *Vehicular movement along the sampled routes*

The vehicular movement along Choba-Rumuola-Eleme route and Choba-Rumuokoro-Eleme are presented in Table 1 and Table 2 respectively. In Table 1, the total inflow was highest on Wednesdays with 1159 vehicles while it was least on Sunday with 677 vehicles. The outflow was still least on Sundays and highest on Mondays with 715 and 1224 vehicles respectively. Considering the inflow and outflow during each period, (morning, afternoon and evening), it is revealed that the inflows in the morning, afternoon and evening were 2,244, 1826 and 2622 vehicles respectively while the total outflows in the morning, afternoon and evening was 2,337, 1,821 and 2737 vehicles respectively. This shows that both inflow and outflow vehicular movement was highest in the evenings and relatively high in the mornings and lowest in the afternoon. The inflow and outflow of vehicles on Tuesdays and Saturday were relatively low. In Table 2, the total inflow along Choba-Rumuokoro-Eleme route was highest on Thursdays with 641 vehicles plying the route while the total inflow was lowest on Sundays with about 400 vehicles. The outflow was lowest on Sundays and highest on Fridays with 402 and 601 vehicular movements respectively. The total inflow in the morning, afternoon and evening was 1158, 1096 and 1531 vehicles respectively while the total outflows were highest in the evening and relatively high in the afternoons.

Table 1- Vehicular movement along Choba-Rumuola-Eleme Route

Days	Morning (7am-10am)		Afternoon (12pm-3pm)		Evening (5pm-8pm)		Total inflow	Total outflow	Total
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Mon.	370	411	221	291	441	522	1032	1224	2256
Tue	340	378	113	123	432	496	885	997	1882
Wed	421	413	300	330	438	419	1159	1162	2321
Thur	341	377	353	258	365	405	1059	1040	2099
Fri	331	322	334	320	359	358	1024	1000	2024
Sat	249	248	321	274	286	235	856	757	1613
Sun	192	188	184	225	301	302	677	715	1392
Total	2244	2337	1826	1821	2622	2737	6692	6895	13587

Table 2- Vehicular movement along Choba-Rumuokoro-Eleme Route

Days	Morning (7am-10am)		Afternoon (12pm-3pm)		Evening (4pm-7pm)		Total inflow	Total outflow	Total
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Mon	164	155	131	122	206	196	501	473	974
Tue	165	147	113	123	198	176	476	446	922
Wed	202	183	165	130	247	219	614	532	1146
Thur	207	175	189	203	245	220	641	598	1239
Fri	185	188	188	189	229	224	602	601	1203
Sat	143	115	172	173	196	168	511	456	967
Sun	92	87	138	132	210	183	440	402	842
Total	1158	1050	1096	1072	1531	1386	3785	3508	7293

B. *Spatial distribution of Impedances and their corresponding time spent (Delay)*

The locations of impedances and time spent at each impedance along Choba-Rumuola-Eleme route and Choba-Rumuokoro-Eleme route are presented in Table 3 and Table 4 respectively. Along Choba-Rumuola-Eleme route, there were 12 impedances in which 2 (16.7%) were police check points, 5 (41.7%) were traffic warden, 4 (33.3%) were traffic light while 1 (8.3%) was pothole. The total time taken due to potholes was 762s, police check points had 3236.4 seconds, traffic warden took 24535.2 seconds while traffic light took 16911.6 seconds. A total of 762 seconds was spent at potholes, 3236.4 seconds at police check points, 24535.2 seconds at traffic warden and 16911.6 seconds at traffic light. It is observed that the highest inflow time spent along the route was found at the traffic light at 2nd Artillery junction with about 3,844.8 seconds in a day while at the traffic warden point at Rumuokwuta junction, 3421.2 second was spent. The lowest vehicular time lost along the route was observed at the traffic light at the College of Arts and Sciences junction. The vehicular outflow delay was lowest at the pothole at Owipa and highest at Rumuokwuta junction with 3287.4 seconds. Considering the inflow and outflow time lost during each period of the day, it is observed that the total inflow time lost in the morning, afternoon and evening periods are 8925.2 seconds, 4,019.4 seconds and 13,596.6 seconds respectively while the total outflow time lost was 4122.65 in the morning, 3176.4 seconds in the afternoon and 11604.6 seconds in the evening. The analysis shows that total inflow and outflow time lost along Choba-Rumuokwuta-Eleme junction route due to impedance was high in both evenings and mornings. More time that is wasted both in the morning and evening periods of the day may be attributed to people's hurries to reach their places of work at the right time or hours in the evening.

Along Choba-Rumuokoro-Eleme route, 11 impedances were identified, out of which 2 (18.2%) were police check

points, 7 (63.6%) were traffic warden while 2 (18.2%) were pot holes. A total of 22363.8s was spent at traffic wardens, 1024.8s was spent at potholes and 1844.4s was spent at police check points. The total time lost in the morning, afternoon and evening periods was 7,536.6 seconds, 34745 seconds and 14222.45 seconds respectively. The total time lost across all impedances was highest in the evenings and relatively higher in the morning and least in the evening. The highest time lost along the route can be seen at the traffic warden at Rumuodara junction with about 7,905.65 seconds while the least time lost was observed at the pothole between Eliozu junction and Rumuokoro roundabout with about 388.85 seconds.

Table 3- Impedance and Time Lost along Choba-Rumuola-Eleme Route

Type of impedance	Location of impedance	Time taken (Seconds) at each impedance			Total
		Morning (7am-10am)	Afternoon (12pm-3pm)	Evening (4pm-7pm)	
Pothole	Owipa Road	28.8	48.6	684.6	762
Police check point	Mgbuoba Police Station	161.4	220.8	1171.8	1554
Police check point	Obrikwere junction	220.8	158.4	1303.2	1682.4
Traffic warden	Rumuokwuta junction	1823.4	1434.6	3450.6	6708.6
Traffic light	College of Arts and Science	34.8	115.2	674.4	824.4
Traffic light	Under Rumuola Bridge	1831.8	736.8	2733.6	5302.2
Traffic light	Bori Camp	1463.4	643.2	2470.2	4576.8
Traffic warden	Air Force base junction	1627.8	892.8	2565.6	5086.2
Traffic warden	Market junction	1625.4	447	1957.2	4029.6
Traffic warden	1st Artillery junction	1201.2	835.2	3277.8	5314.2
Traffic light	2nd Artillery junction	2017.2	1274.4	2916.6	6208.2
Traffic warden	Oil Mill Junction	1012.2	388.8	1995.6	56.61
Total		13048.2	7195.8	25201.5	42105.21

Table 4: Impedance and Time Lost along Choba-Rumuokoro-Eleme Route

Type of impedance	Location of impedance	Time taken (Seconds) at each impedance			Total
		Morning (7am-10am)	Afternoon (12pm-3pm)	Evening (4pm-7pm)	
Police check point	Between Rumuosi & UPTH	144	31.2	727.2	902.4
Traffic warden	Rumuosi junction	459.6	112.2	888.6	1460.4
Police check point	Obirikwere junction	33	0	909	942
Traffic warden	Nkpolu junction	189	0	838.8	1027.8
Traffic warden	Rumuokoro roundabout	1382.4	1495.2	2332.8	5210.4
Pothole	Between Eliozu & Rumuokoro	103.2	28.8	256.8	388.8
Traffic warden	Eliozu junction	528	128.4	1008	1664.4
Traffic warden	Between Rumuodara and Eliozu	0	21.6	534.6	556.2
Traffic warden	Rumuodara junction	2881.2	992.4	4032	79.05.6
Pothole	Before tank junction	116.4	0	519.6	636
Traffic warden	Tank junction	1699.8	664.2	2175	4539
Total		7536.6	3474	14222.4	25233

C. Types and Frequency of Vehicles Plying the Sampled Routes

The type and frequency of vehicles plying Choba-Rumuola-Eleme junction route and Choba-Rumuokoro-Eleme route are presented in Table 5 and Table 6 respectively. The analysis shows that 3707 (34.1%) cars, 790 (28.6%) buses and 48 (32.2%) heavy duty vehicles were counted along Choba-Rumuola-Eleme route in the morning. The same trends were observed in the afternoon and evening whereby the frequency of cars was the highest and the lowest was the heavy duties. Considering the frequency of each type of vehicle in different periods along this route, cars were 3707 in the morning, 3139 in the afternoon and 4024 in the evening. Buses were 790, in the morning, 843 in the afternoon and 1134 in the evening. Heavy duties were 48 in the morning, 39 in the afternoon and 62 in the evening.

On the other hand, along Choba-Rumuokoro-Eleme junction route, cars dominated the frequency, followed by buses and the least was the heavy duty. Considering the temporal variation in the frequency of each vehicle type in the morning, 1950 cars were recorded, 1744 cars and 1795 cars were recorded in the afternoon and evening respectively. Buses were 398 in the morning, 212 in the afternoon and 342 in the evening. Heavy duty vehicles were 27 in the morning, 46 were recorded in afternoon while 31 were recorded in the evening.

Table 5- Types and frequency of vehicles plying Choba-Rumuola-Eleme Route

Type of vehicle	Frequency			Total
	Morning (7am-10am)	Afternoon (12pm-3pm)	Evening (4pm-7pm)	
Cars	3707	3139	4024	10870 (78.8%)
Buses	790	843	1134	2767 (20.1%)
Heavy duties	48	39	62	149 (1.1%)
Total	4545	4021	5220	13786 (100%)

Table 6- Types and frequency of vehicles plying Choba-Rumuokoro-Eleme Route

Type of vehicle	Frequency			Total
	Morning (7am-10am)	Afternoon (12pm-3pm)	Evening (4pm-7pm)	
Cars	1950	1744	1795	5489 (83.9%)
Buses	398	212	342	952 (14.5%)
Heavy duties	27	46	31	104 (1.6%)
Total	2375	2002	2168	6545 (100%)

IV. DISCUSSION

The study has provided a spatial network analysis on the sample routes; Choba-Rumuokoro-Eleme junction routes. The vehicular inflow and outflow in the selected major roads varied with higher being recorded in Choba-Rumuola-Eleme Junction route, though at different time of the day. The difference at the different time of the day could be attributed to the fact that frequency of vehicles plying a particular road at a particular time varies. According to [17], traffic densities are not constant throughout the daytime; hence a limitation of this study is that it doesn't consider the dynamic nature of changing crowd on the roads. The analysis shows that more impedance was observed in Choba–Rumuola-Eleme junction route which shows that more time may be spent from the

origin to destination along the route. [18] reported that road impedance is used to describe the resistance of vehicle in the process of driving along the road and reflects degree of road smooth; and as such it determines route choice because road impedance defines the distance, time, speed, and cost to reach a destination. The number and severity of impedance would affect the smooth run of vehicles which can eventually leads to congestion and the congestion would therefore increase the travel cost. [19] reported that congestion has an impact on the travelers (the added time) as well as increase costs of vehicle operators (fuel and spare parts) which are the key components of travel system inefficiency. Similarly, [20] pointed out that traffic holdup which can be equated to traffic congestion is a major impediment to free flow of traffic which is being experienced in Nigerian major cities. The study revealed that Mondays, Wednesdays, Thursdays and Fridays are not really good to travel through Choba-Rumuola-Eleme Junction. This may be likened to market activities happening along this route on the afore-mentioned days of the week. There are more cars than other types of vehicles along the two major routes considered for this study. The main reason is that majority of the cars were used for public transport to convey goods and services from one place of the city to another place. Time of delay along Choba-Rumola-Eleme Junction route was far higher than that of the Choba-Rumuokoro-Eleme Junction route. This can be linked to the higher number of vehicles plying Choba-Rumuola-Eleme Junction route and increase in the number of impedances along the same route [18].

V. CONCLUSION

The study has assessed the vehicular movements along the two major routes within Port Harcourt Metropolis, and it can be concluded that more vehicles ply Choba-Rumuola-Eleme Junction route than that of Choba-Rumuokoro-Eleme junction route. Also, the number of impedances along the two routes was relatively the same but the time lost along Choba-Rumuola-Eleme Junction route was higher than that of Choba-Rumuokoro-Eleme Junction route. Time lost was highest in the evening along Choba-Rumuola-Eleme Junction route while it was highest in the morning along Choba-Rumuokoro-Eleme Junction route. It is therefore recommended that Rumuokwuta junction and Rumuokoro Roundabout should be avoided whenever an individual wishes to ply Choba-Rumuola-Eleme Junction route and Choba-Rumuokwuta-Eleme Junction route respectively. Furthermore, this research can be extended to more routes (minor roads inclusive) to understand the influence of vehicular flow on time spent on the road.

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