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Road Connectivity Approach to Eased Traffic Congestion on Market Roads in Benin Metropolis, Nigeria

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Abstract: *This paper examines road connectivity as a management approach to eased traffic congestion on market roads in Benin metropolis, Nigeria. From the twenty (20) markets identified, nine (9) were surveyed. Systematic sampling was used to administer 407 questionnaires, and analysed using descriptive and bivariate tests. Electronic traffic count and graph theory analysis were also used to collect data. From the findings, mini-buses (48.4 %) and private cars (33.2%) were the dominant transit modes. Market contributed 95.6% and was significant at $p<0.05$ to traffic congestion ($r_s=0.404$). The connectivity matrix revealed Yanga market and Eki-Oba with an index of 10 each were most connected, accessible and patronised. Gamma value (0.71) calculated presented a high degree of road connectivity. Policy measures were offered based on research findings.*
Keywords: *Benin City, Connectivity, Marketplace, Road network, Traffic congestion*

I. INTRODUCTION

The quality of life and economy of a society depend on efficient, comprehensive and coordinated multimodal transport system that provides quick movement of goods and services [1]. [2] Reports that transportation system involves the flow of people, ideas, materials, goods and services from one location to another, causing the spatial distribution of resources. Transportation, movement and exchange of goods and services are obligatory features of modern life [3] because of its multi-dimensional functions, the inevitability of interaction and dynamic structure. A road could be described as the lifeblood of human civilisation [4] and social interaction, Therefore, the economic prosperity of a place is sharpened by its road network at intra and inter-regional levels. Human settlement is seen to be naturally heterogeneous, but a symbiotic system. One major part of the system is the marketplace, critically influenced by factors like modes of transit, socio-economic characteristics, distance, location and range of goods [5]. Urban landuses require adequate, convenient and efficient transportation system especially the commercial landuse such as a marketplace. [6] Observes that a marketplace serves as a hub of economic activities and attraction, especially from residential landuse. Thus, availability of a convenient and acceptable location for trading activities as well as proximity constitutes significant factors in urban development. Commercial activities such as buying and selling are major traffic attractors and circulators that tend to concentrate more along road corridors for easy access. As a result, initiating road connectivity to reduce traffic problems in these market areas would attract minimal cost and reduce man hours crucial to urban growth and development. But, the unplanned and uncoordinated pattern of development characterised by massive urban sprawl in all direction have met many roads unprepared [2], and this has impeded traffic flow as well as constrained road connectivity. [7] emphasises that the form and pattern of distribution of structures to promote good health, accessibility, convenience and harmonious land use in an environment are functions of the rights and methods of dealing with land.

Road network as one of the oldest infrastructure occupies significant locality in modernisation, sustainable development, and daily activities in ancient and modern times [8]. As a result, high-quality roads and good connectivity would improve national economic output, reduce trip time and cost, and make the planning regions more economically attractive and viable. [5] Reports that a market is fundamental to the socio-economic, cultural, religious and political life of people; stressing further that, despite poor recognition given to market development in the post-independence periods, it promotes the integration of production and consumption platforms of the economies on which they stand. Traffic congestion occurs when a road capacity exceeds the volume of traffic it is expected to accommodate. This is caused by increased motorisation, inadequate road network and related facilities, human, socio-economic and physical factors. [9] Says traffic congestion increases travel cost, physical and psychological discomfort. It could also lower productivity, cause

lateness to work, school and business, and poverty of urban infrastructure as a result of overstretching. Therefore, traffic management strategy is inevitable A graph shows the relationship between items that consists of a set of objects called nodes connected by links called edges. Graphs are useful because they serve as mathematical models of network structures [10]. The markets in Benin metropolis could be referred to as 'nodes' and roads as 'edges' connecting the markets and other activity areas. According to [11], connectivity refers to the density of connections of road network and the directness of links. As connectivity increases, travel distance decreases but the route options increase, thereby allowing more direct travel between destinations, creating a more resilient, effective and accessible system. [12] Find road connectivity as the second greatest impact on travel activity, after regional accessibility of all landuse factors. Traffic modelling by [13] suggest that improved local street connectivity would reduce traffic volumes, and traffic congestion on major arterials. However, [14] corroborates that increased street connectivity, more pedestrian-friendly environment and shorter route options have a positive impact on performance (per-capital vehicle travel, congestion, delays, traffic accidents and pollution).

Benin City, with its well-structured road network, experiences diverse transportation challenges of easy and quick access to and through market locations. Some of these markets have historical and cultural significance in their locations which contribute to the high traffic flow around them. Investigation shows that it is somehow difficult to navigate freely within Benin City without wasting useful man-hours daily. However, studious effort to fix a number of roads to complement existing traffic management measures has not assuaged the traffic problems bedevilling the metropolis hence, road connectivity approach is canvassed. On the other hand, many of the roads in the city are congested because the same road space provided and used by few people and vehicles have not varied correspondingly with increasing human population and traffic volume. More importantly, the pattern of market distribution influences traffic flow in Benin metropolis where many of the markets are located along road corridors.

Against this background, this study establishes the existence of traffic congestion in Benin metropolis, examines the role of the market in traffic congestion, and assesses the degree of connectivity of routes linking the markets. Road connectivity as a management approach to eased traffic congestion on roads linking the markets in Benin metropolis was therefore recommended.

II. MATERIALS AND METHODS

2.1 Research Locale

Benin City is located within the coordinates of Latitude 06°19'N and 06°21'N, and Longitude 05°34'E and 05°44'E. It is situated in the south-south geopolitical zone of Nigeria at an elevation of 77.8m above sea-level. Benin is a pre-colonial city, the capital of defunct Mid-West and Bendel States, and present Edo State. It is underlain by a sedimentary formation of Miocene-Pleistocene-age often referred to as the Benin formation [15]. The city is located in the humid tropical rainforest belt of Nigeria with a population of 1,086,882 [16] and a projected population of 1,481,310 in 2016 at 3.5% growth rate. The Rainy season begins in March/April and ends in October/November. The rainfall is of high intensity and double maxima with a dry little spell in August commonly called 'August Break'. Apart from demographic transition, Benin City has witnessed rapid territorial expansion owing to rural-urban migration as well as a tourist destination for bronze casting and the great Benin moat. Property developers have erected structures in different parts of the city and often without adherence to town planning regulations [17]. The term "Edo" refers to a place, dialect, language and people of Bini. Individuals from the Bini Kingdom origin call themselves "Oviedo" or "Ovioba". The Bini Kingdom was redefined (by the British) after the restoration of the monarchy in 1914 and limited to the new Benin Division (comprises of the Binis).

2.2 Methods

The data for this research was obtained from both primary and secondary sources. Questionnaire and physical surveys were used to collect the primary data from the study area. Systematic sampling method was used to administer the questionnaire to road-users (vehicle operators and commuters) for data collection on modes of transit, market location, trip frequency, traffic impedance and congestion along the market routes. The physical survey was conducted on the roads to gather data on road condition; electronic and manual traffic counts were adopted to estimate the volume of traffic. The primary data were supported by literature reviewed as secondary data and sources. Information on the connectivity of the market routes was gathered from the road network map of Benin City got from Edo State ministry of lands and surveys. Fig. 1 shows the roads and marketplaces (identified by their traditional names) in the study area. Out of the twenty (20) markets identified in the study area, nine (9) with the roads leading to them were surveyed based on geographical location, periodicity, historical and cultural significance, central business district (CBD) function and traffic confluence. Road-users that ply the market roads were interviewed systematically in every tenth vehicle using structured questionnaire. Traffic count was conducted along the roadside in both directions for twelve (12) hours between

6.00am and 6.00pm daily from Monday to Sunday. During the survey, 407 vehicle operators and commuters respectively were interviewed. To ascertain the level of connectivity of roads linking the markets in Benin metropolis, the road network map was converted to linear graph regardless of the width, standard and quality. The markets were denoted as vertices (v) and roads as edges (e). The data analysis was by simple descriptive statistics (tables and figures), bivariate correlation (Spearman's rho and Kendall's tau tests) as well as graph-theoretic analysis (Gamma and cyclomatic indices, and Shimbel connectivity matrix)

III. RESULTS AND DISCUSSION

Findings from the study are discussed under modes of transit and traffic congestion, market location and traffic impedance, market location and traffic congestion, and degree of road connectivity.

2.1 Modes of Transit and Traffic Congestion

Safety and timely arrival at one's destination are factors of an effective transportation system. Inefficient transport modes and the paucity of transport infrastructural facilities affect patronage and sustainability of markets. Where these challenges abound, traffic congestion likely sets in, especially, when the carrying capacity of the dominant operational transport mode is low. Fig. 2 shows that 48.40% of the respondents used mini-buses, while private and taxi cars accounted for 33.20% and 9.80%. About 5.50% of the used foot, trucks (1.50%) and 1.2% keke-napep (Tricycle) to the markets. The number of car use was quite high considering the occupancy capacity of not more than five (5) passengers, whereas a bus would conveniently carry above eight (8) passengers per trip. This implies that the traffic problem experienced in Benin is exacerbated by increased use of private and taxi cars. The result of relationship between modes of transit and traffic congestion in Benin metropolis is presented in Table 1. Spearman's rho (r_s) and Kendall's Tau (τ) correlation tests were conducted on traffic congestion (CONGEST), means to convey goods (CONVEY), traffic impedance (IMPED), market location (MALOC), modes of transit (MODE), and car use (CAR-USE). Spearman's rho correlation test conducted reveals that the coefficient between traffic congestion and traffic impedance was $r_s = 0.468$ significant at $p<0.05$. This indicates that the higher level of congestion impeded free traffic in Benin City. Similarly, a coefficient of $r_s = 0.404$, $p<0.05$ was found to exist between traffic congestion and market location as a source of the traffic problem. This relationship implies that where markets are located along transit routes, traffic problems are likely to occur.

In addition, the coefficient between traffic impedance and market location as the source of traffic problem showed a significant ($P<0.05$) correlation coefficient ($r_s = 0.338$). This suggests that the more markets are located along transit corridors, the higher the tendency of the market activities to impede free traffic. A significant coefficient ($r_s = 0.337$, $p<0.05$) was found to exist between traffic impedance and personal car use. This relationship reveals that car use is one of the factors that impede traffic and thus contributes to traffic congestion in Benin metropolis.

Kendall's Tau (τ) correlation test conducted reveals that a coefficient of $\tau = 0.628$ significant at $p<0.05$ existed between means to convey goods and car use. The relationship suggests that car use increases the means to convey goods ($\tau = 0.628$, $n=407$, $p <0.05$) in the study area. Between car use and modes of transit $\tau = 0.499$ ($p<0.05$) was estimated. This implies that car use contributed to the modes of transit operational in Benin. Looking at the relationship between traffic impedance and means to convey goods, a coefficient of $\tau = 0.314$ was found to be significant at $P<0.05$. This indicates that the means of conveying goods to the market could impede the flow of traffic. A significant coefficient ($\tau = 0.313$, $p<0.05$) occurred between traffic congestion and means to convey goods in the study area. This shows that the means to convey goods and services accentuates traffic congestion along the routes linking marketplaces in the City. Similarly, Table 2 presents the average hourly traffic volume per route per day along the market routes in Benin metropolis. The peak hourly traffic flow indicates that the intensity is higher early in the morning between 7:00am and 9:00am when the journey to work, school and business are undertaken. Evening peak periods between 4:00pm and 6:00pm show that most people are either returning from their daily activities or going for recreation.

2.2 Market Location and Traffic Impedance

Fig. 3 indicates that 42.80% of the respondents reported that traffic impedance was strong along the market routes and 24.10% said traffic obstruction was very strong. Similarly, an average of 23.80% was calculated to impede traffic, while 4.90% reported that traffic inhibition was fairly strong in the metropolis. Although, 4.40% of the respondents said traffic impedance exists but not strong in the City. An aggregate of 66.90% calculated validates the presence of strong traffic impedance along the market routes. This could be caused by market location, road condition, traffic volume, pedestrian conflict with vehicles, street trading and parking, and driver's attitude. Fig. 4 shows the traffic situation along West Circular (Television) road leading to Eki-Oliha and Eki-Uwa. Eki-Oliha that is famous for the sales of traditional items and other commodities and

Eki-Uwa is known for the sales of bushmeat are held daily. Street parking, trading and alms begging impede the free flow of traffic on this route. The absence of designated motor parks, eroded road surface, and absence of drainage which causes flooding are other factors inhibiting the free flow of traffic along West Circular (Television) road. Fig. 5 reveals the condition of traffic along Oba Market road leading to Eki-Oba and Yanga market. Eki-Oba, where all manner of goods are sold and Yanga market about 189m away known for the sale of fresh seafood are located around the city centre (Ring road). More importantly, these markets are held daily.

Incautious street trading and parking, activities of revenue collectors, abandonment of motor parks, and uncontrolled human interference with vehicles were visible impediments to traffic flow. Others included the attitude of commercial drivers, poor enforcement of existing traffic management measures, and indiscriminate waste disposal that encroaches the walk and driveways. The use of umbrellas as shed by street traders also obstructs sight-distance of road users.

2.3 Market Location and Traffic Congestion

On possible influence of market location on traffic congestion in Benin metropolis, 38.3% of the respondents said the market location was very regular at causing traffic congestion while 34.90% held it was a regular factor (Fig. 6). Other respondents said average traffic congestion was 17.40% and 4.90% slightly regular in market location. Also, market location accounted for 4.40% irregular traffic congestion in Benin. The divergent views of respondents on the regularity of market contribution to traffic congestion are perhaps based on periodicity and nature (range of goods) of the markets. Although a negligible 4.40% did not experience traffic congestion, a total of 95.60% confirmed the presence of traffic congestion at one time or the other in the metropolis in terms of traffic intensity and duration.

2.4 Road Network Analysis and Degree of Connectivity

[18] And [8] observe that the fundamental properties of transportation network are measured by Alpha index, Beta index, and/or Gamma index. Calibration of connectivity index requires the road network (edges/links) and junction (vertices/nodes). These indices are useful to identify the growth within a network structure and also for change detection system. Fig. 7 reveals graph connection irrespective of the road grade linking the markets (vertices). Thus, given the number of vertices (v) as nine (9) and fifteen (15) edges (e), it is possible to estimate the degree of connectivity in the study area. The Gamma index (γ) was adopted to investigate the degree of connectivity of the network and its completeness was verified with Cyclomatic index (μ).

Gamma index (γ) is a ratio of the actual number of edges to the maximum possible number of nodes in the network [18], but with greater value when the network is well connected [8]. The value ranges between 0.00 (showing no connection between nodes) and 1.00 (maximum number of connections with a direct link to all nodes).

$$\text{Gamma index } (\gamma): = \frac{e}{3(v-2)} \quad \text{---------- (1)}$$

γ = Gamma index, e = number of edges (links/routes), v = number of vertices (nodes).

Given that: $\gamma = ?$ $e = 15$, $v = 9$

Substituting equation 1: $\gamma = \frac{e}{3(v-2)}$; $\gamma = \frac{15}{3(9-2)} = \frac{15}{3(7)} = \frac{15}{21}$ $\gamma = 0.71$

A value of 0.71 (71%) calculated from equation 1 implies that a high degree of road connectivity exists in Benin City, which positively influences traffic attraction and circulation with or without a substitute for intervening opportunities of trips.

Cyclomatic index (μ): The completeness of the connectivity network of the markets in Benin was evaluated using the Cyclomatic index (μ) given as:

$$\mu = e - v + 1 \quad \text{---------- (2)}$$

Where μ= Cyclomatic index, e = number of edges, v = number of vertices

$\mu = ?$ $e = 15$, $v = 9$

Substituting the respective values in equation 2;

$\mu = e - v + 1$, $\mu = 15 - 9 + 1$, $\mu = 7$.

The inference of equation 2 is that the network is highly developed with short route connectivity. This is because 70% of the network of markets has developed to have shortest possible routes in relation to other markets outside the network with 30%. Furthermore, a connectivity matrix developed from the road network graph (Fig. 7) shows the number of nodal points (markets) to which a node (market) is directly associated. The node with the highest number of points is said to be most connected. From Table 3, the most connected markets

are Yanga market and Eki-Oba with an index of six (6) each. This means that each of the markets has a direct link with six (6) other markets (Walter Christaller principle). This is followed by Eki-Osa and Eki-Edo with four (4) direct links each to other markets, and Eki-Oliha links three (3) other markets. Eki-Ogiso, Eki-Agbado and Vegetable market have two (2) direct links respectively to other markets, whereas Eki-Uwa has a direct link to Eki-Oliha. The diagonal is coded zero (0) because it represents single origin-destination trips thereby making the trips redundant since the matrix is rarely concerned with the number of ways a location is connected to itself.

IV. CONCLUSION AND POLICY GUIDELINES

This study highlighted the effect of inadequate road connectivity and high traffic volume on the roads linking the markets in Benin metropolis. It has identified a high rate of traffic congestion caused by market location, activities and patronage, street parking and trading and incomplete road connectivity. Others included activities of revenue collectors and poor enforcement of traffic laws. Structured questionnaire and traffic count surveys were used to collect data from the road users, and graph theory was employed to investigate the degree of road connectivity in the study area. The results showed that minibuses and cars were common modes of transit used, and the peak periods were from 7:00am to 9:00am and 4:00pm to 6:00pm. From Table 1, the coefficient of car as mode of transit (χ =0.499) as well as means to convey goods (χ =0.628) impeded traffic (r_s =0.337) and caused traffic congestion (r_s =0.297) was found to be significant at $p<0.05$ alpha level. Market location as impedance (r_s =0.338) intensified traffic congestion (r_s =0.404) at $p<0.05$ alpha level. The graph theory-based study revealed that good road connectivity existed among the marketplaces, but was 30 percent incomplete. Eki-Oba and Yanga market were found to be most connected, accessible and patronised because of their locational advantage at Oba Ovoranmwen Square (the City centre)

Generally, traffic congestion suggests a situation where the demand for road space exceeds supply. It is a situation where road users cannot drive at desired speed because they are constrained by the presence of other road users. As the number of interaction increases, average speed decreases eventually, traffic becomes congested and flow conditions unstable. Drivers, therefore, opt for alternative routes in an attempt to reach their destination faster, than simply joining a queue. But the route choice is based on the availability of connections and drivers' familiarity with a network. In the light of the findings, the following recommendations were made to ease traffic flow in Benin City; Effective high occupancy vehicles (mass transit), and parking charges and tolls on cars along market roads would discourage frequent use of cars and minibuses; introduction of bus priority lanes and lay-bys along market routes would reduce street parking and loading.

Provision of signage at road junctions to identify alternative routes for non-market destinations, route assignment for Edo City Transport Service (ECTS) buses, and motor parks for direct transit. Motor parks for private and public vehicles should be provided in all the markets to prevent street parking. All the access routes (West Circular and Federal government college roads, and Lagos, Plymouth and Igun streets) should be rehabilitated as a possible alternative to bye-pass the marketplaces for none-market trips as well as to further improve the road network. A direct link from Eki-Uwa (Television road) through Lawani street to Eki-Edo (New Lagos road) would improve the connectivity of roads in the metropolis.

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Figures

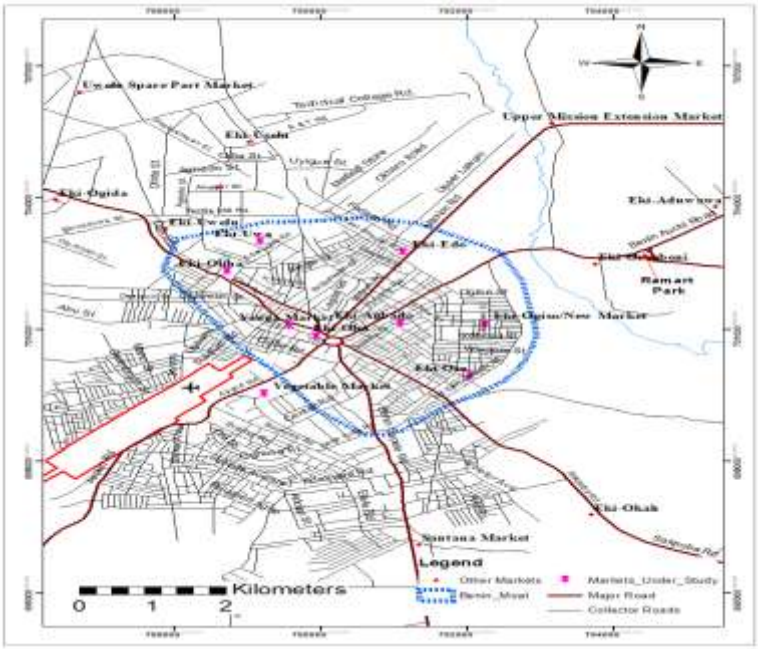


Figure 1: Showing Road Network and Market Places in Benin metropolis
Source: Edo State Ministry of Lands and Surveys, Benin City.

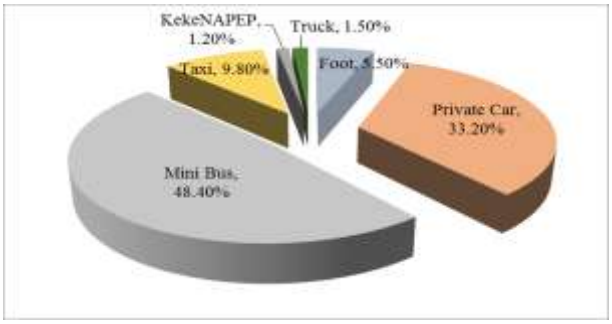


Figure 2: Modes of transit Used in Benin Metropolis
Source: *Author's Fieldwork, 2016*

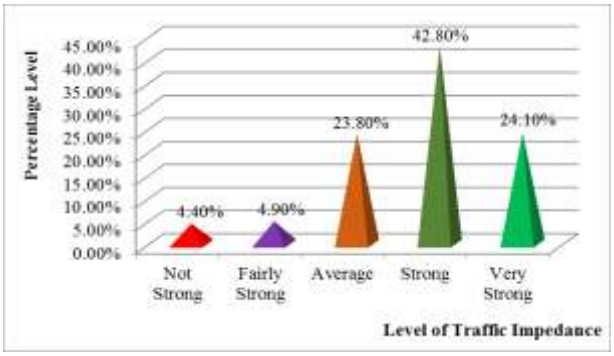


Figure 3: Traffic Impedance on Roads in Benin Metropolis
Source: *Author's Fieldwork, 2016*

Figure 4: West Circular (Television) road leading to Eki-Oliha and Eki-Uwa
Source: Fieldwork, 2016

Figure 5: Oba Market Road leading to Eki-Oba and Yanga Market
Source: *Author's Fieldwork, 2016*

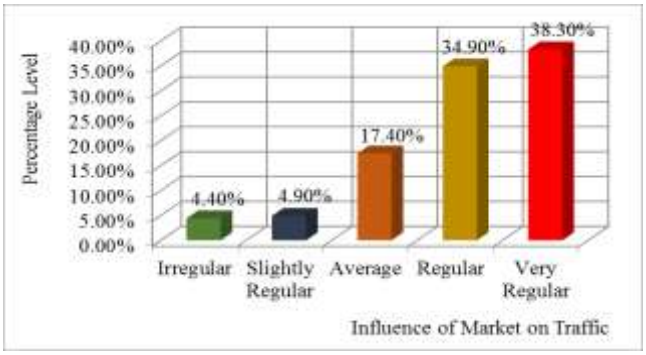
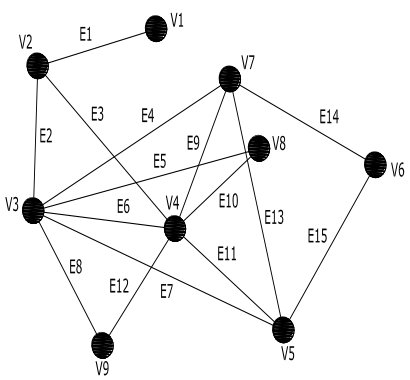


Figure 6: Regularity of Traffic Congestion at Market Locations
Source: *Author's Fieldwork, 2016*



Key

Vertex (Market)	Edge/ Node (Road)
V1: Eki-Uwa	E1: Television
V2: Eki-Oliha	E2: Siluko
V3: Yanga	E3: Ekenwan
V4: Eki-Oba	E4: Mission
V5: Eki-Osa	E5: Akpakpava
V6: Eki-Oglso	E6: Ekenwan
V7: Eki-Edo	E7: Sakpomba
V8: Eki-Agbado	E8: Airport
V9: Vegetable	E9: Mission
	E10: Akpakpava
	E11: Sakpomba
	E12: Airport
	E13: Murtala Muhammed Way
	E14: New Lagos
	E15: 2nd East Circular

Figure 7: Road Network Graph Analysis of the Selected Market Places
Source: *Fieldwork Analysis, 2016*

Tables

Table 1: Results of Relationship between Modes of Transit and Traffic Congestion Variables

Traffic Congestion Variables	CONGEST	Spearman's Rho Correlation IMPED	MALOC	CAR-USE
CONGEST	1.000	0.468**	0.404**	0.297**
IMPED		1.000	0.338**	0.337**
MALOC			1.000	-0.066
CAR-USE				1.000
		Kendall's Tau Correlation		
CONVEY	0.313**	0.314**	0.048	0.628**
MODE	0.106*	0.140**	0.143**	0.499**

**Correlation is significant at the 0.01 Alpha level.
*Correlation is significant at the 0.05 Alpha level.
Source: *Author's Fieldwork, 2016*

Table 2: Average Hourly Traffic Volume per Market Route per Day in Benin City

Time/Route	West Circular	Siluko	Oba market	3rd East Circular	2nd East Circular	New Lagos	Akpakpava	Airport	Total	Period
6am-7am	412	632	1,306	896	161	1,262	1,307	681	6,657	
7am-8am	627	816	1,427	1,323	389	1,343	1,482	1,327	8,734	Peak
8am-9am	661	902	1,396	1,350	378	1,512	1,644	1,349	9,192	Peak
9am-10am	514	714	1,286	1,258	248	1,481	1,689	1,174	8,364	
10am-11am	321	648	1,189	1,070	178	1,378	1,592	609	6,985	
11am-12pm	204	511	1,167	841	126	1,183	1,378	441	5,851	Off
12pm-1pm	184	415	938	832	135	1,018	1,192	411	5,152	Off
1pm-2pm	236	436	889	1,005	186	1,042	1,145	556	5,495	Off
2pm-3pm	308	651	1,263	1,148	208	1,194	1,316	697	6,785	
3pm-4pm	425	746	1,354	1,279	312	1,241	1,386	916	7,659	
4pm-5pm	616	845	1,409	1,301	371	1,414	1,509	1,274	8,739	Peak
5pm-6pm	552	811	1,463	1,317	326	1,421	1,623	1,332	8,845	Peak
Total	5,060	8,127	15,087	13,620	3,018	15,489	17,263	10,676	88,431	

Source: *Author's Fieldwork, 2016*

Table 3: Shimbel Binary Connectivity Matrix (One Step or Direct Link)

Edge	Node	1	2	3	4	5	6	7	8	9	Total Nodes (Indices)
1. Eki-Uwa		0	1	-	-	-	-	-	-	-	1
2. Eki-Oliha		1	0	1	1	-	-	-	-	-	3
3. Yanga Market		-	1	0	1	1	-	1	1	1	6*
4. Eki-Oba		-	1	1	0	1	-	1	1	1	6*
5. Eki-Osa		-	-	1	1	0	1	1	-	-	4
6. Eki-Ogiso		-	-	-	-	1	0	1	-	-	2
7. Eki-Edo		-	-	1	1	1	1	0	-	-	4
8. Eki-Agbado		-	-	1	1	-	-	-	0	-	2
9. Vegetable Market		-	-	1	1	-	-	-	-	0	2

Sum = 18
Source: *Author's Fieldwork, 2016*