

Impact of Landuse Morphology on Urban Transportation

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Abstract

People, cities, nations and the world, in general, would remain largely underdeveloped without transportation systems. However, Transportation puts significant pressure on land use and poses a great challenge to urban sustainability in developing countries. This study examines the influence of Land use structure on Intra-urban transportation in the developing city of cities in the West African sub-region – using Enugu city as a case study. The study uses a descriptive research method. A survey was carried out in six districts within the Enugu metropolis based on a stratified, purposive sampling technique. Questionnaires were used as data collection instruments; 400 respondents participated in the study employing Yamane equation. Furthermore, a twelve-hour (7 am to 7 pm) traffic count was conducted to assess traffic volume. The study finding revealed that Transportation within the urban areas is significantly impacted by Land-use structure, city morphology, neighbourhood characteristics in terms of population and residential density of the city. The hypothesis suggests no significant difference between the various land uses across the Enugu metropolis ($p = 0.129$). It was also discovered that an average of 122,431 Passenger Car Units (PCU) constantly ply the metropolis roads to service a total population of 564,725 daily, indicated a high rate of car dependency. The study surmises that land use generates vehicular traffic, which impacts the socio-economic environment and the effectiveness of the transportation system. The significance of this study is that the findings contribute to the existing knowledge base that would advance strategic policy formation towards acceleration of the uptake of sustainable urban transportation systems in the region.

Keywords: Transportation; Morphology; Land Use; Intra-urban; Enugu Metropolis.

1. Introduction

Globally, activities within an urban area tend to define a city and justify the concentration of people in them. Such activities are distinctively urban and may include manufacturing, trading and finance, Transportation and tertiary activities. All these combine to generate the spatial configuration of the city because their requirements are sometimes functionally differentiated and spatially segregated [1-3]. The spatial segregation of urban land use types creates a spatial imbalance, necessitating spatial interaction for functional interrelationships [4]. An outcome of this is that urban centers generate and attract many trips daily [5]. Thus, Transportation is an integral part of the functioning of any society. This is because transportation exhibits a very close relationship with life style, the range and location of the various activities, and the goods and services available for consumption [6, 7]. Its efficiency contributes mainly to productivity, economic growth and perhaps the quality of life [8]; without it, there would be no life in the city.

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On the other hand, human movements, which are made possible by transportation, are fundamental in the creation, development and growth of cities [4]. As a result, in modern societies, the importance of transportation mobility cannot be overemphasized. Individuals can participate in events, earn a living, meet their fundamental needs, relax and play. They may also form and maintain social networks due to the availability of transport mobility [9]. Mobility is equally crucial for economic development, exchange of knowledge, ideas, experience, and culture. It is, therefore, not wrong to say that urban traffic sustains urban activities. According to Rodrigue et al. [10], urban transportation is divided into three basic categories: collective transportation, individual transportation, and freight transportation. The purpose of collective transportation (public transportation) is to enable publicly accessible movement across certain areas of a community. It has to deal with moving large group of individuals and attaining economies of scale. Individual transportation encompasses any mode of movement that is the result of a personal choice and means such as the automobile, walking, cycling and motorcycle. Freight Transportation is characterized by delivery trucks moving between individual distribution centres, warehouses and retail activities. These include, seaports, rail yards, distribution centres, and airports [10].

Several studies suggest that, in general, people tend to travel in order to obtain access to a variety of goods, services, facilities and people that may not be available at the origin of their journeys [1, 5, 8, 11-14]. Thus, intra-urban travel or mobility is an essential part of human life, especially in cities. Little wonder, it is perceived as a fundamental human right, especially in large cities in developed economies [15]. However, this vital facet of the urban structure poses a significant challenge in most urban centres. In sub-Saharan Africa, especially Nigeria, the pace of urbanisation owing to Transportation has been theatrical, showing astonishingly high rates of 5-10 per cent per annum [11, 12]. Consequently, there has been a rapid expansion of Nigerian cities' areal extent, which is now tenfold their initial growth point [13]. A critical aspect of this is that city growth and expansion in Nigeria have been largely uncontrolled [9] and are currently expanding to a point where it threatens to smother the transportation system that prepared and promoted its growth [16].

For the past three decades, the colonial city of Enugu has also been experiencing rapid population growth and expansion of its environment due to the influx of migrants from rural areas [17]. This population growth is also accompanied by a substantial expansion of the city's boundaries and much higher industrial, economic, commercial and social activities. These have resulted in the growth and extension of low-income unplanned settlements on the city outskirts [18], and workers from these areas are putting further strain on the already inefficient public transportation services. With the current expansion rate, it is estimated that the population of Enugu will continue to grow unabated [17]. The rising demand for intra urban mobility has always superseded its supply, and efforts to provide adequate urban transport infrastructure has been extempore and unsustainable. The city is gradually changing and metamorphosing into a chaotic state where confusion and frustration regarding urban mobility will become the norm. More concerning is that the dominant mode of intra-city mobility is usually by road (90%), and automobiles have the largest modal share. With no alternative means of transport, the city is invariably perceived to have almost reached a point of saturation in terms of immobility. This is evidenced by the difficulty in accessing the city centre and other facilities during peak hours.

Hence, this situation requires an urgent transportation plan that would adequately address the challenges of intra-urban movement in Enugu [19]. However, there cannot be any meaningful transportation planning if policymakers and transportation experts do not appreciate the crucial relationship between transportation, commuter life style and the range and location of activities within the city [6, 20]. Therefore, this study examines the influence of Land use structure on Intra-urban Transportation in West African Sub-region, using Enugu metropolis in Nigeria as a case study to proffer solution to traffic problems experienced in the study area. The following objectives were used; (a) to examine the land use structure in Enugu metropolis, (b) to determine the pattern of intra-urban traffic in the city, (c) to highlight the influence of Land use Structure on Intra-urban travel

2. Context of the Study

Geographically, Enugu state is located in the south-east of Nigeria. The colonial city of Enugu has been the capital of Enugu state, situated between 06°21'N and 06°30'N latitude and between 07°26'E and 07°37'E longitude [21]. It is approximate 230km to the West African Atlantic coast (see Figure 1).

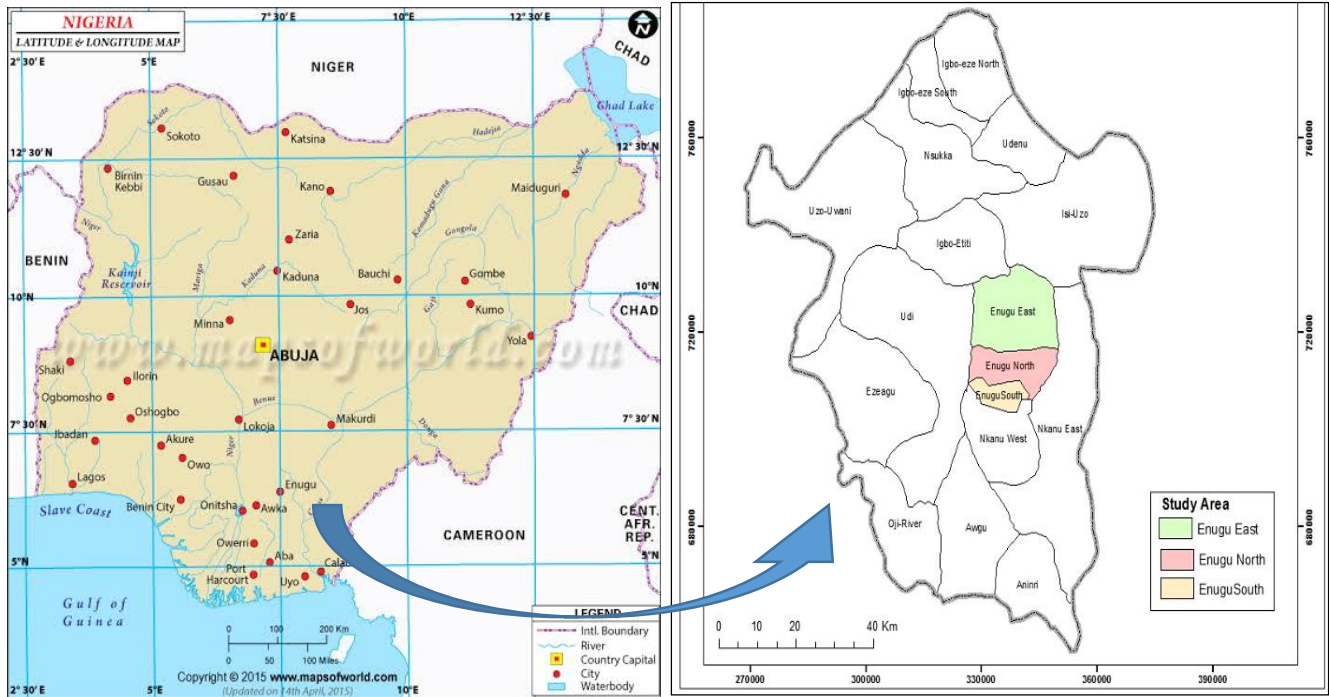


Figure 1. Map of Nigeria Showing Enugu State; Map of Enugu State Showing the study area

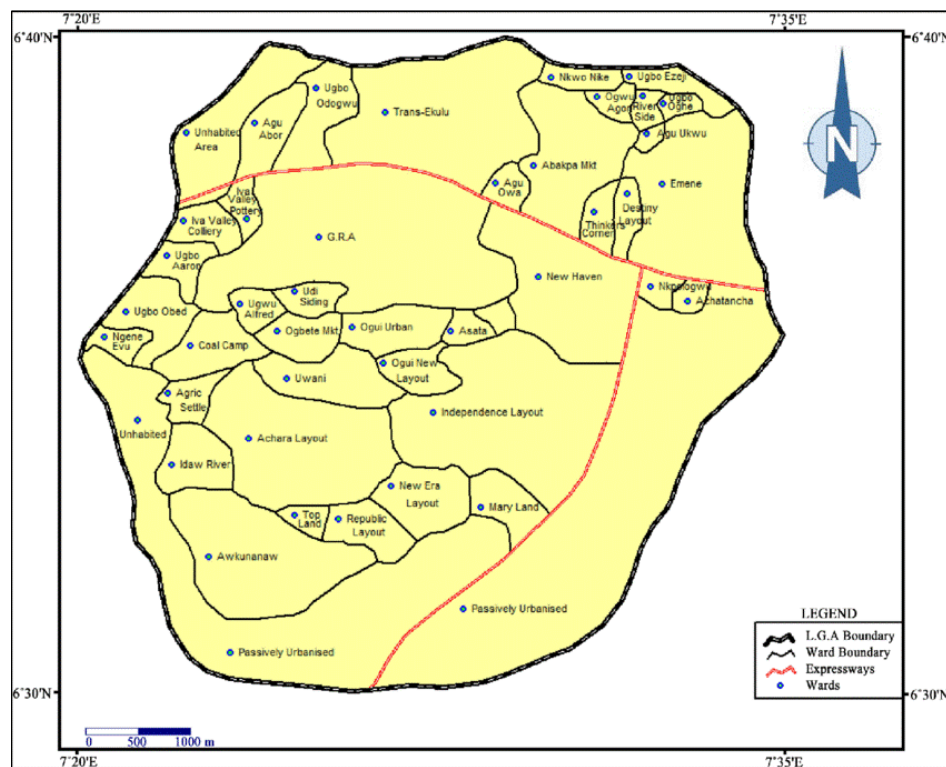


Figure 2. Map of Enugu Metropolis (Study Area) showing the Neighbourhoods

Enugu metropolis consists of three Local Governments areas: Enugu East, Enugu South, and Enugu North Local Governments areas with several residential neighbourhoods (See Figure 2). 95% of the population are from the Igbo ethnic group. Although rapidly budding and witnessing vast growth in the size of built-up areas, it is categorised as a medium-sized city; immigrants surge with rise in transportation and commercial activities [22]. According to the 2006 Nigerian head count [23], it ranks 9th among the most populous cities and covers a total area of 215m² (556 km²) having a density of 3,400/mi² (1,300/km²). The city's population is reported in the demographic data of Nigeria from 1952 to 2006 and projected for 2021. It recorded a population of 62,764 in 1952; 462,514 in 1991; 722,664 in 2006 and the projected population of Enugu in 2021 is 1,156,980 with Abakpa and Maryland (neighbourhoods) having the highest and lowest population figures respectively.

2.1. Enugu Urban Structure and Existing Land Use Development

The land use structure of Enugu urban up to 1979 though outdated is shown in Table 1;

Table 1. Land use configuration

Land uses	Percentage
Residential	74.9
Commercial	5.9
Residential/Commercial	15.6
Industrial	0.6
Public	3.0
Total	100

The table reveals a very high percentage for residential activities when compared with other land uses. However, anecdotal evidence and observations within the Metropolis have shown continuous changes and shrinkage of residential land use to various other uses, especially to commercial, institutional, and transport land uses, evident in the wide spread of commercial activities along major roads and streets of the Metropolis. Economic theory suggests that as economic activities expand in the city, other areas have to be absorbed to accommodate the expanding economic activities. Since there is no additional space for expansion within the built-up areas to accommodate the changing trend, the burden now falls on the residential land use [24, 25]. Presently, the predominant land uses in Enugu city are residential, commercial, industrial, institutional, public and Transportation land uses. All these land uses are interconnected by the transportation land use akin to the city's blood artery. The various land uses are discussed below:

- i. **Commercial Land Use:** This occupies 5.7 per cent of the total land area. Enugu metropolis originally has three planned markets where commercial activities primarily take place. These include Ogbete primary market, Newmarket and Timber market. Apart from these markets, other commercial activities in the Enugu metropolis include informal street trading along pedestrian walkways, popular bus stops and frontages of some residential buildings organically sprung up. The secretariat in the Government Reserved Area (GRA), Ogbete main market, Okpara, Chime, Ogui and Zik avenues are the major commercial uses and therefore form the Central Business District (CBD).
- ii. **Industrial Land Use:** The Metropolis's hydrogeology has affected industrial land use due to the inadequate supply of potable water for industrial activities. Industrial land use only occupies 3.8 percent of the total land area in Enugu city. Some of the major industries are Innoson plastics, Ama brewery, Anambra Mercedes Manufacturing Company (ANAMCO), Emenite Ltd, Alo Aluminium, Intercolor industries ltd, Juhel Nigeria limited, Nemel pharmaceuticals, Vee tek pipes ltd, etc.
- iii. **Public And Institutional Land Use:** This occupies 27.1 percent of the total land area in Enugu. One prominent place for public use in Enugu is the Nnamdi Azikiwe Stadium. In contrast, pivotal institutional use in the city includes the University of Nigeria, Enugu Campus, the Institute of Management and Technology (IMT), Enugu State University of Science and Technology, Army Barracks, Air-force Base etc.
- iv. **Residential Land Use:** The residential land use in Enugu city occupies 54.3 percent of the total area. Enugu metropolis has about 19 neighbourhoods that are broadly categorised into low, medium and high-density residential areas. Most of the residential areas in the city, such as Ogbete, New haven, Achara layout, Uwani, Abakpa, etc. were planned and built according to the grid-iron pattern. However, residential areas are stretching out to the city's periphery due to population increase and shortage of housing supply.
- v. **Transportation Land use and Facilities:** Enugu is located on the narrow-gauge eastern line railway linked to Port Harcourt's city. The dysfunctional Enugu train station is located beside the stadium on Ogui Street, which was the city's effective means of Transportation. The most used traffic route for entrance and exit of the city is the Enugu-Ogbete parking lot (Old Park). The city's recent transportation studies reveal that the main modes for intra-urban Transportation are private cars, coal city shuttles, buses, mini-buses, taxi/cabs, and tricycles (*keke NAPEP*). According to Echendu et al. [16], high reliance on private cars and poorly developed alternative transportation modes in the Metropolis of Enugu have recently been observed to impact intra-city mobility in the Metropolis negatively. This explains the emergence of the, informal transport services (such as the use of tricycles) which is becoming a dominant mode for intra-city travel in Enugu metropolis, also heightened by the fact that the state government banned commercial motorcycles (popularly called "okada") - which once served as a public means of Transportation in the city in 2012 on public roads.

In order to ensure the efficient movement of people and eradicate poverty in Enugu, taxis under the "coal city cabs" scheme were introduced in 2009. The state government provided 200 registered Nissan Sunny taxis in collaboration with the "Umunichimere" pro-credit and the micro-finance bank that provided 200 registered Suzuki taxis. These registered taxis were given out on loan to unemployed citizens in the city who automatically became owners of the vehicles after total payments had been made. Registered taxis are differentiated from the unregistered ones, which are popularly known as "kabu kabu", with the yellow colours of the registered vehicles. In addition, over 20 buses with 67 seated commuters were introduced as coal city shuttle buses to run as public transport in Enugu metropolis. Also, the main airport in the state is the Akanu Ibiam International airport which can be accessed by buses and taxis from different parts of the state.

2.2. Traffic Flow Theory

The nexus between transportation, land-uses and travel patterns generates various transport problems in cities, with the most visible manifestation as traffic congestion [26]. As a result, traffic congestion has become a major challenge for city managers within urban areas, with traffic flow superseding its handling capacity [27]. Traffic flow theory is an instrument that assists transportation planners and traffic engineers in understanding and expressing traffic flow features. It deals with the dynamic properties of traffic on the road sections. At any given time, millions of vehicles are on the road, interacting with one another and influencing traffic conditions. Traffic flow theory aims at evolving optimal transport network with efficient movement of traffic and minimal traffic congestion issues. According to Abdel-Aty et al. [28], traffic flow can be classified into two types: uninterrupted traffic flow and interrupted flow.

- i. **Uninterrupted Flow**; it is a type of flow regulated by vehicle-to-vehicle interaction and the interaction between vehicles and the roadway. Vehicles travelling on inter-state highway are part of a continuous flow. In contrast, there are interruptions in traffic flow on most highways in the Enugu metropolis [29]. Using the Abakpa expressway as an example, there is a traffic flow interaction usually caused by obstructions (potholes, parked vehicles) or by the police/federal road safety corps personnel. However, relevant to this study is the interrupted flow, which is discussed in the following sub-section.
- ii. **Interrupted Flow**; this form of flow is controlled by external factors such as traffic lights, etc. Vehicle-vehicle interactions play a supplementary function in defining traffic flow under interrupted flow conditions. Vehicles travelling on intra-urban routes, on the other hand, contribute to the interrupted flow. The movement of automobiles to and from locations like Ogui layout, Abakpa, Gariki, Uwani and Trans-ekulu in Enugu metropolis is an example of this flow [29].

According to Ali (2010) [29], traffic lights, wardens, speed breakers and other traffic calming mechanism, depending on the location, impede the movements of vehicles. The interruption in the movement of these vehicles leads to congestion most times in the Enugu metropolis. Taking Ogui layout and New Haven, for example, the movement of vehicles is usually interrupted by traffic lights at major intersections. However, the movement continues after an interval, and this process continues. The traffic flow theory helps to explain the characteristics of the traffic stream in the Enugu metropolis and hence, predict the consequences of alternative designs. On the other hand, the parameters help to explain the characteristics of traffic congestion that is experienced in the Enugu metropolis.

2.3. Land Use–Traffic Models

The evolution of land-use/traffic planning processes over the last few decades, have grown to become the urban planning vehicle to tackle operational needs in policy and planning decisions. Metropolitan cities continue to plan to develop their urbanized areas utilizing modifications of these planning and modeling techniques. However according to Anjomani [30], there has been tiny rigorous and comprehensive implementation of such models in the land-use/transportation planning process (without exemption of perhaps some of the largest metropolises). As early as the mid-nineteenth century, the need for travel demand models was recognized by urban transportation experts, with the macroeconomic modeling of people and commodity spatial flow [31]. To estimate spatial movements and flows, transportation planners have used aggregate approaches such as entropy-based models and gravity-based models for nearly a century [32]. A chronological procedure of estimating travel demand called the four-step model based on aggregated approaches was developed in mid-twentieth century. Until today some metropolitan planning organizations globally still use a relatively disaggregated version of the 4-step model.

Sequel to the development the four-step model of travel demand, the complex interactions between the entire urban structure and the configuration of transportation network was recognized by urban planners. The transport system is at the core, influenced by the land-use structure and the peoples travel needs, businesses and regulated by the government plans and controls [32]. Changes in transportation supply, in turn, influence the population's residential and work location preferences, as well as business site decisions, thereby altering land-use configuration. Furthermore, demographic and firmographic phenomena unrelated to the transportation system influence land-use layout and hence indirectly influence transportation demand [33]. The environment, in the form of emissions and energy consumption

from transportation and other activities conducted by individuals and companies, is the final piece of this puzzle. The environmental link has long been thought to be external to the land use-transport system, and only recently has the relevance of internalizing environmental impacts been recognized [32].

The development of land-use and transport demand models, as previously explained, can be divided into three major threads. One strand tracks the evolution of travel demand models from early 4-step models to advanced activity-based travel demand models. The second aspect is based on practical integrated land use-transport models, with the 4-step model serving as the primary transport component. Finally, the third strand involves advanced development of "next-generation LU-T models that disaggregate and utilizing the activity-based method within the transport component" [31].

2.4. Traffic Model (Lowry's Model of Metropolis)

According to Mahmud and Town [34], the basis for traffic simulation are traffic models. A traffic model is a mathematical representation of real time traffic, most commonly but not exclusively road traffic. Theoretical foundations such as network theory and some physics theories, such as the model of kinematic waves are heavily utilized in traffic modeling. The traffic flow that is, the movement of automobile units per time and travel medium capacity, is the intriguing variable being measured and modeled. Khan and Gulliver [35] gave the main types of traffic models as macroscopic, mesoscopic and microscopic. Macroscopic models deal with the aggregate behaviour of traffic flow while microscopic models concern the interaction of individual vehicles. Mesoscopic models share the properties of macroscopic and microscopic traffic models.

The development of integrated land-use/transportation models has its roots in Lowry's Model of Metropolis 1964. It was the first attempt to implement the urban land-use transport feedback cycle in an operational model. The Lowry model essentially consists of a residential location model and a service and retail employment location model nested into each other [36]. The model is considered the first transportation/land use model because it links two spatial interaction components. The first calculates spatial interactions between basic employment activities and zones of residence, while the second calculates spatial interactions between service employment activities and residence zones [37]. Because it has been widely used and has made two key contributions into urban modeling research, the Lowry model has attracted more interest than any other single urban model. First, it included forecasting and an allocation method inside its structure, and second, it linked three components of the urban system within a single general conceptual model. The model takes three important components of a city, namely population, employment, and the means of transportation between them, i.e., the transport network as represented by journey times, and describes how these interactions determine urban change by allocating population and employment across the city's various zones [38-40].

3. Research Methodology

The research methodology flow chart is depicted graphically in Figure 3. It shows that the research process can be divided into six major stages, beginning with perceived problem and culminating with a conclusion and recommendations. A survey research design was employed for the study, with both primary and secondary data sources used in data collection. The study area, was the Enugu metropolis, and the sample population is the eighteen neighbourhoods that make up the study area. Three study groups for investigation were drawn from the different residential densities, namely high, medium and low residential density areas categorised into three strata by the researcher. Using stratified- sampling technique, six neighbourhood in the Metropolis was chosen for study in the ratio 1:2:3 for low, medium and high residential neighbourhood respectively to ensure that the densities were adequately represented. From the three strata, a random sample selection of neighbourhood was made. Strata one represented the low-density neighbourhoods from which reserved government area (GRA) was randomly selected without replacement. Strata two represented the medium density neighbourhoods from which New Haven and Achara layout were randomly selected, while strata three represented the high-density neighbourhoods from which Abakpa, Ogui and Ogbete were randomly selected. The population of residents that make up the randomly selected neighbourhoods is 564,725 and was derived from the projected last official Nigerian national population census figure of 2006 to 2021 using the Thomas Malthus exponential model at an annual growth rate of 2.8 per cent. This is illustrated in Table 2;

The instrument for data collection was a two-sectioned questionnaire designed in the English language because most residents and commuters in the study area understand English. Section "A" of the questionnaire contained socio-demographic information, while Section B contained 5 items eliciting information on Land use Structure and Intra-urban Traffic in Enugu Urban. Using Yamane [41] model, the sample size adequate for the study was determined as follows;

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where: n = Sample size; N = the whole population under study (564,725); and e = the level of precision, i.e., 0.05.

Table 2. Selected Sample Neighbourhoods and their Population

Neighbourhoods	Density	1991 Population Figure	2006 Population Figure	2021 Projected Population
Abakpa	High	90,619	126,232	207,497
Ogbete	High	25,994	36,209	59,520
Ogui	High	41,237	62,339	94,423
New haven	Medium	18,753	26,123	42,940
Achara	Medium	50,427	76,306	115,466
GRA	low	19,600	29,658	44,879
Total		198,377	276,337	564,725

Thus, 400 questionnaires were distributed by the researchers by hand to members of the household aged 18 and above. The formula that was used for proportionate allocation strategy to get the sample size for each of the neighbourhoods using their various household sizes as stated below:

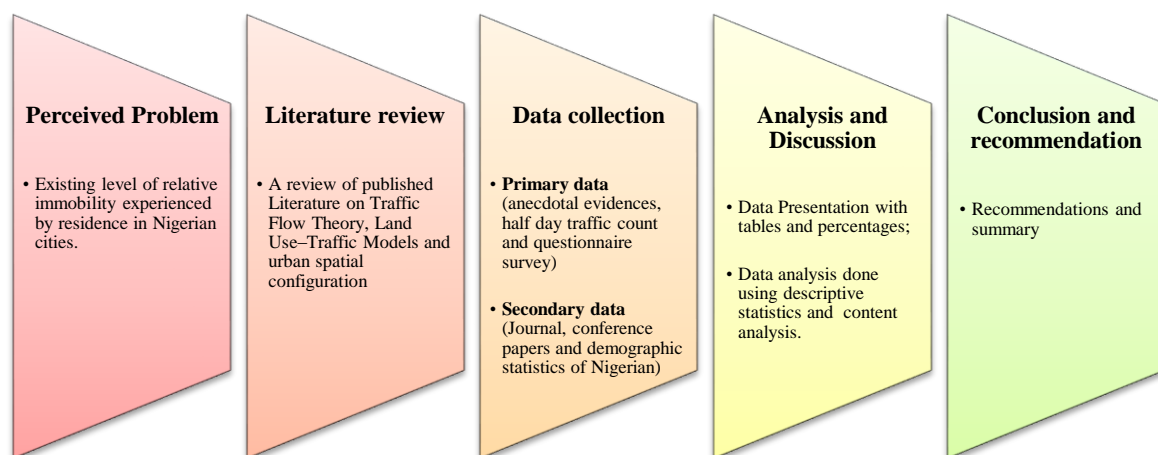
$$\begin{aligned}
 &\text{neighbourhood's sample size} \\
 &= \text{percentage of neighbourhood's household population} \\
 &\times \text{the total sample size for the study}
 \end{aligned}
 \tag{1}$$

Details are shown in Table 3.

Table 3. The Sampled Neighbourhoods and Sample Sizes

Neighbourhoods	2021 Projected Population	Household Population	%	Sample Size
Abakpa	207,497	34,583	36	144
Ogbete	59,520	9,920	11	44
Ogui	94,423	15,737	17	68
New haven	42,940	7,157	8	32
Achara	115,466	19,244	20	80
GRA	44,879	7,480	8	32
Total	564,725	94,121	100	400

Furthermore, a twelve hour (7 am-7 pm) traffic census of the automobile was carried out by the researcher in the various selected neighbourhood during the day time period to determine the traffic flow and volume of the automobile with the modal split of the studied areas. The secondary data sources include relevant books, conference papers, journal articles, and statistics of Nigerian 2006 Population Census Result for Enugu State. Analysis of data was based on descriptive statistics and thematic content analysis. In addition, Analysis of Variance (ANOVA) was used in testing the hypothesis. It was used to determine any significant difference between the various land uses across the Enugu metropolis. The response rate of the respondents achieved was 95% and with 380 correctly filled and returned by hand.

**Figure 3. Research methodology flowchart**

4. Results and Analysis

4.1. Personal Data and Socio-economic Characteristics of the Respondents

Table 4 shows the socio-demographic characteristics of the respondents. More than half (51.3%) were males, while their mean age was 33.4 (\pm 8.6) years. More than half (59.6%) were within the ages of 21 – 40 years, while 52.4% were singles. Also, their primary occupation was business (26.3%) and civil service (22.6%), while their average monthly income was 78.30 (\pm 33.87) US dollars.

Table 4. Socio-demographic characteristics of respondents (n = 380)

Characteristics	Frequency	Percent (%)
Gender		
Male	195	51.3
Female	185	48.7
Age Groups (years)		
20 years and below	54	14.2
21 – 40 years	227	59.6
31 – 60 years	97	25.5
> 60 years	2	0.5
Mean \pm SD (years)	33.4 \pm 8.6	
Marital Status		
Single	199	52.4
Married	163	42.9
Widowed/Divorced/separated	18	4.7
Occupation		
Civil servant	86	22.6
Business person/ Self-employed/ Trader	100	26.3
Private employed	63	16.6
Unemployed	35	9.2
Student	96	25.3
Monthly income (\$)		
Below \$ 24.30	24	6.3
\$ 24.30 - \$ 48.60	68	17.9
\$ 48.60 - \$ 72.90	91	23.9
\$ 72.90 - \$ 97.20	63	16.6
\$ 97.20 - \$ 121.50	39	10.3
Above \$ 121.50	95	25.0
Mean \pm SD (income)	78.30 \pm 33.87	

4.2. Land use Structure and Intra-Urban Traffic in Enugu Urban

The data in Tables 5 showed the relationship between land use structure and intra-urban traffic in Enugu. The respondents indicated that the land-use configuration has an impact on the transport system. The neighbourhood characteristics (population, residential density, etc.) tend to affect intra-urban travel; whilst improvement in road transportation facilities results in increased demand for land. Changes in transport supply is reported to influence location choices of the population and the relationship between accessibility and the value of property. The mean score of the factors mentioned above was more significant than 2.5

Table 5. Relationship between land use structure and Intra-urban traffic in Enugu urban

Proxies	SA (5)	A (4)	I (3)	DA (2)	SD (1)	Weighted mean	Perception
Transport system is influenced by land use configuration	116	130	30	43	61	3.5	Agreed
Neighbourhood characteristics (population, residential density, etc.) affect intra-urban travel	95	117	23	60	85	3.2	Agreed
Improvement in road transportation facilities results in increased demand for land	120	135	21	44	60	3.6	Agreed
Changes in transport supply influence location choices of the population	89	134	31	71	55	3.3	Agreed
There is a relationship between accessibility and value of properties.	170	100	26	39	45	3.8	Agreed

4.3. Result of Automobile Traffic Census in the Six Selected Neighborhood

Table 6 shows the volume of traffic at Ogbete on a typical day under ideal traffic condition was 28, 971 Passenger Car unit (PCU). Origin trips that were made in the morning, between 7am – 9am, comprised 11% of the total daily traffic while the destination trip, between 4pm – 6pm, comprised 12% of the total daily traffic. Moreover, the peak period was between 3pm and 4pm which showed that this was the period when most commuting occurs in Enugu metropolis. In addition, cars and buses were the predominant mode (71 and 18%) while bicycles were the least (0.03%). These information is expressed graphically as shown below.

Table 6. Hourly traffic flow of different vehicle classification along Ogbete Road

Time Interval	Cars	Tricycle	Articulated Vehicles	Buses	Lorries	Taxi	Bicycles	Total
7am-8am	684	9	4	206	5	125	0	1163 (3%)
8am - 9am	1283	31	8	609	5	231	1	2877 (8%)
9am-10am	1283	22	8	553	18	184	0	3038 (9%)
10am-11am	1449	41	7	537	8	179	0	2941 (8%)
11am-12pm	998	42	3	500	8	290	0	2537 (7%)
12pm-1pm	3497	27	1	540	20	233	0	4786 (13%)
1pm-2pm	2141	40	3	608	28	282	0	3557 (10%)
2pm-3pm	3053	45	1	355	21	344	0	4301 (12%)
3pm-4pm	3763	34	1	115	19	242	1	4849 (14%)
4pm-5pm	868	36	4	346	32	150	1	2027 (6%)
5pm-6pm	723	44	12	357	60	188	4	1989 (6%)
6pm-7pm	511	39	4	354	45	148	2	1670 (5%)
Total	20556 (71%)	410 (1.4%)	56 (0.2%)	5080 (18%)	263 (0.9%)	2597 (9%)	9 (0.03%)	28971 PCU

Figure 5 shows the peak hours for different automobiles vary significantly, but cars still maintain afternoon hours of 3pm-4pm as peak hour period, emphasising the peak commuting period in Enugu metropolis. In contrast, the morning hours of 7am-8am has the least automobile traffic of 1163 Passenger Car unit.

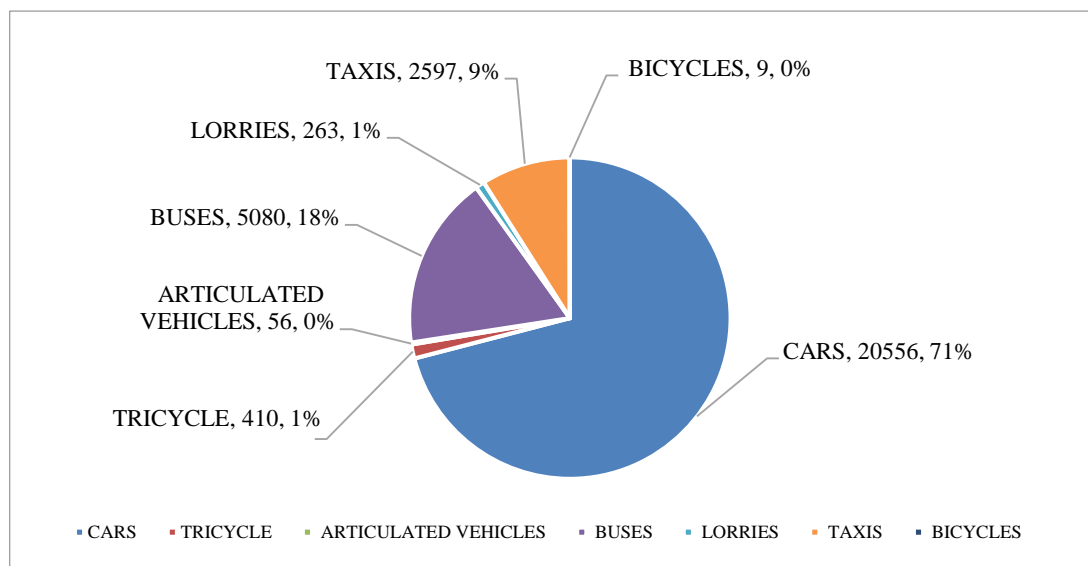


Figure 4. Modal Split of commuters along Ogbete

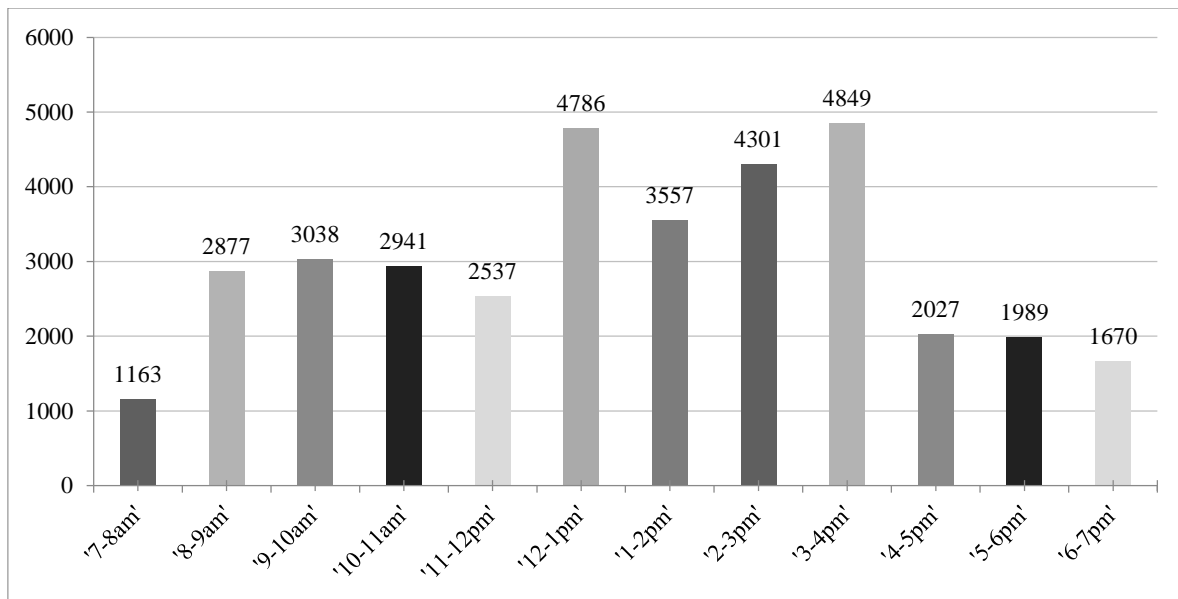


Figure 5. Hourly Flow of Traffic along Ogbete

Table 7 shows that the volume of traffic along Ogui road on a typical day under ideal traffic condition was 34,634 Passenger Car Units (PCU). Origin trips made in the morning, between 7am – 9 am, comprised 12% of the total daily traffic while the destination trip, between 4pm – 6pm, comprised 10% of the total daily traffic. This result may be explained by the fact that perhaps some commuters that used Ogui road in the morning possibly used alternative route to avoid traffic delay in the evening considering its proximity to the Central Business District. The peak period was between 12pm - 1pm and between 3pm to 4pm. Again, this can be adduced to the fact that this was when most commuters in Enugu metropolis make trips to and from the Central Business District. The Modal Split of commuters along Ogui Road shown below revealed that cars were the predominant mode (71%) while bicycles were the least (0.05%).

Table 7. Hourly Traffic flow of different vehicle classification along Ogui road

Time Interval	Cars	Tricycle	Articulated Vehicles	Buses	Lorries	Taxi	Bicycles	Total
7am-8am	811	21	5	247	6	150	2	1,242 (4%)
8am - 9am	1550	47	10	731	6	277	3	2,624 (8%)
9am-10am	1520	26	10	664	22	221	0	2,463 (7%)
10am-11am	1739	49	8	644	10	215	0	2,665 (8%)
11am-12pm	1198	50	4	600	10	348	0	2,210 (6%)
12pm-1pm	4196	32	1	648	24	280	2	5,183 (15%)
1pm-2pm	2579	48	4	730	34	338	0	3,733 (11%)
2pm-3pm	3674	54	1	426	25	413	0	4,593 (13%)
3pm-4pm	4536	41	1	138	23	290	1	5,030 (15%)
4pm-5pm	1142	63	5	415	38	180	1	1,844 (5%)
5pm-6pm	898	60	14	428	72	226	5	1,703 (5%)
6pm-7pm	633	47	5	425	54	178	2	1,344 (4%)
Total	24,476 (71%)	538 (2%)	68 (0.2%)	6096 (18%)	324 (0.9%)	3116 (9%)	16 (0.05%)	34,634 PCU

Figure 7 indicates peak hour traffic at period of 12pm-1pm emphasising when most inhabitants of Enugu metropolis make trips to and from the Central Business District. Furthermore, the morning hours of 7am-8am has the least automobile traffic of 1242 Passenger Car unit.

Table 8 shows that the volume of traffic along Abakpa road on a typical day under normal traffic condition was 17,214 Passenger Car Units (PCU). Origin trips made in the morning, between 7am – 9am, comprised 11% of the total daily traffic while the destination trips, between 4pm – 6pm, consists of 10% of the total daily traffic. However, the peak period was between 12 pm to 1pm and between 3pm to 4pm. The data indicated that some commuters (especially those within the schooling age) in the Enugu metropolis commuted to and from school, considering the number of educational facilities along this area. The modal split presented below revealed that cars were the predominant mode (71%) while bicycles were the least (0.05%).

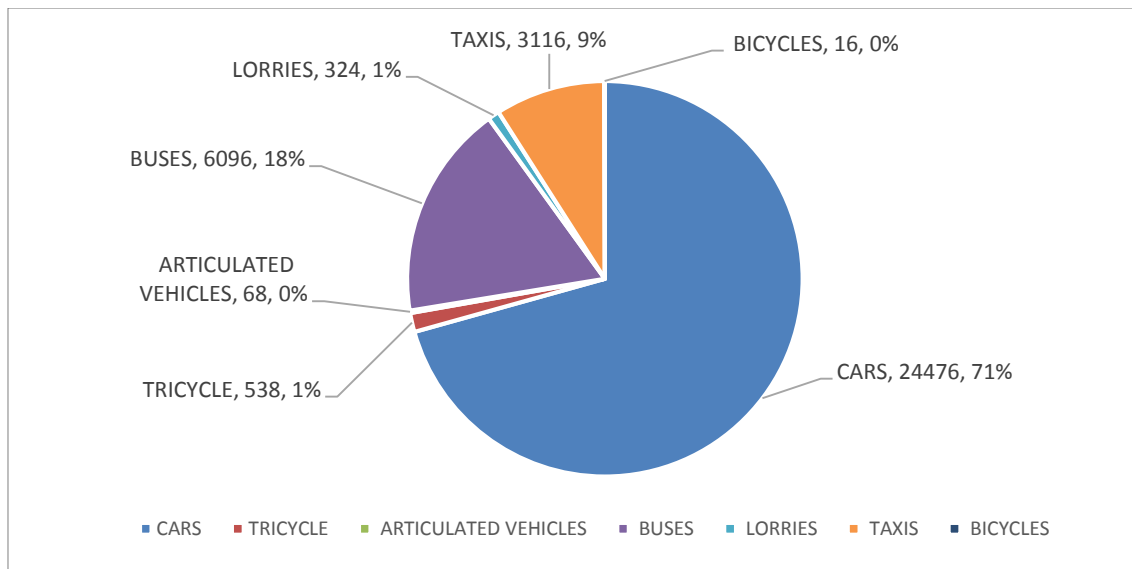


Figure 6. Modal Split of commuters along Ogui Road

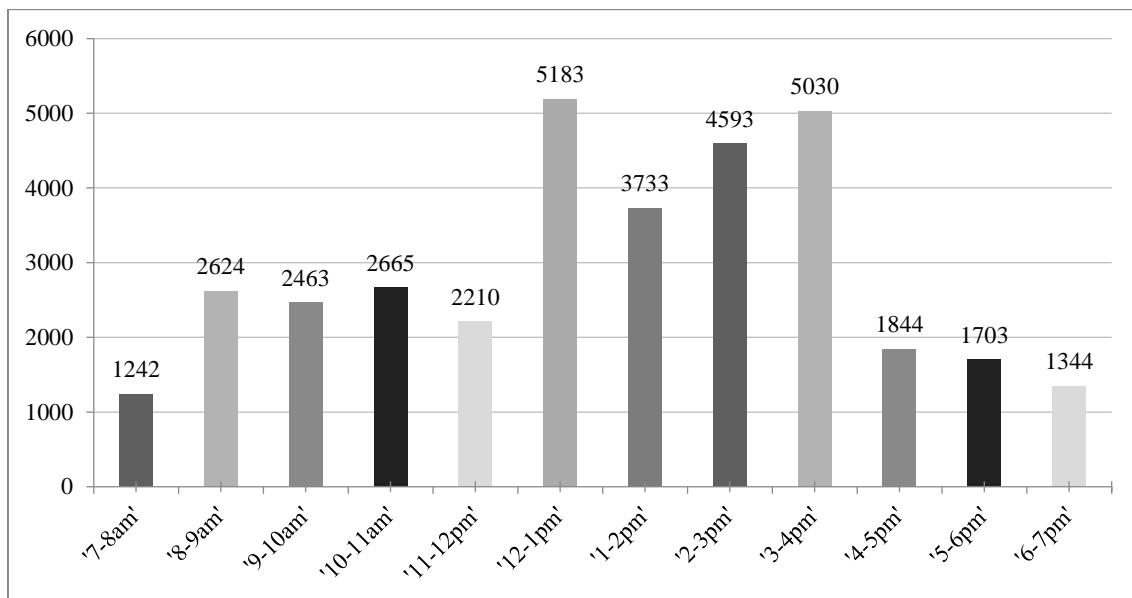


Figure 7. Hourly Flow of Traffic along Ogui Road

Table 8. Hourly Traffic flow of different vehicle classification along Abakpa Road

Time Interval	Cars	Tricycle	Articulated Vehicles	Buses	Lorries	Taxi	Bicycles	Total
7am-8am	410	5	3	124	3	75	0	620 (4%)
8am - 9am	770	19	5	365	3	139	1	1302 (7%)
9am-10am	770	13	5	332	11	110	0	1241 (7%)
10am-11am	869	25	4	322	5	107	0	1332 (7%)
11am-12pm	600	25	2	300	5	174	0	1106 (6%)
12pm-1pm	2098	16	1	324	12	140	0	2591 (15%)
1pm-2pm	1285	24	2	365	17	169	0	1862 (11%)
2pm-3pm	1832	27	1	213	13	206	0	2292 (13%)
3pm-4pm	2258	20	1	69	11	145	1	2505 (15%)
4pm-5pm	521	22	3	208	19	90	1	864 (5%)
5pm-6pm	434	27	7	214	36	113	4	835 (5%)
6pm-7pm	307	24	3	212	27	89	2	66 (4%)
Total	12,154 (71%)	247 (1.4%)	37 (0.2%)	3048 (18%)	162 (0.9%)	1557 (9%)	9 (0.05%)	17,214 PCU

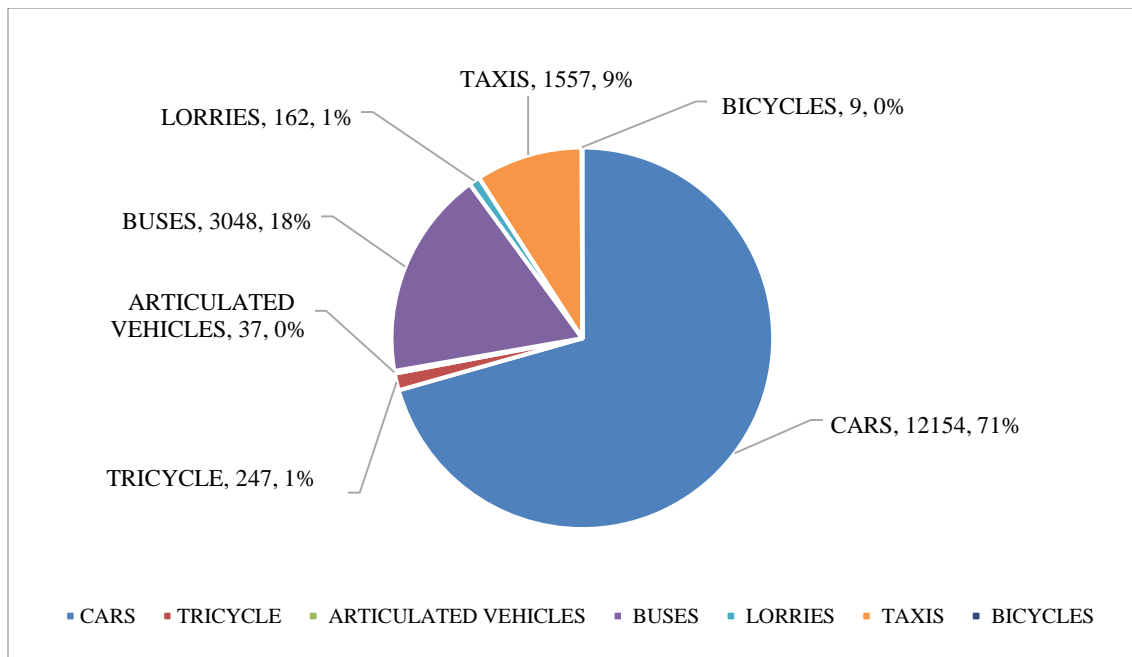


Figure 8. Modal Split of Commuters along Abakpa Road

The Figure 9 revealed the peak hour traffic to be between the hours of 12pm-1pm. This data showed that some commuters (especially those within the schooling age) in the Enugu metropolis commute from school during this time period. Enugu metropolis has a large number of schools and residential households in the neighbourhood. The evening hours of 6pm – 7pm appears to have the least automobile traffic of 66 Passenger Car unit.

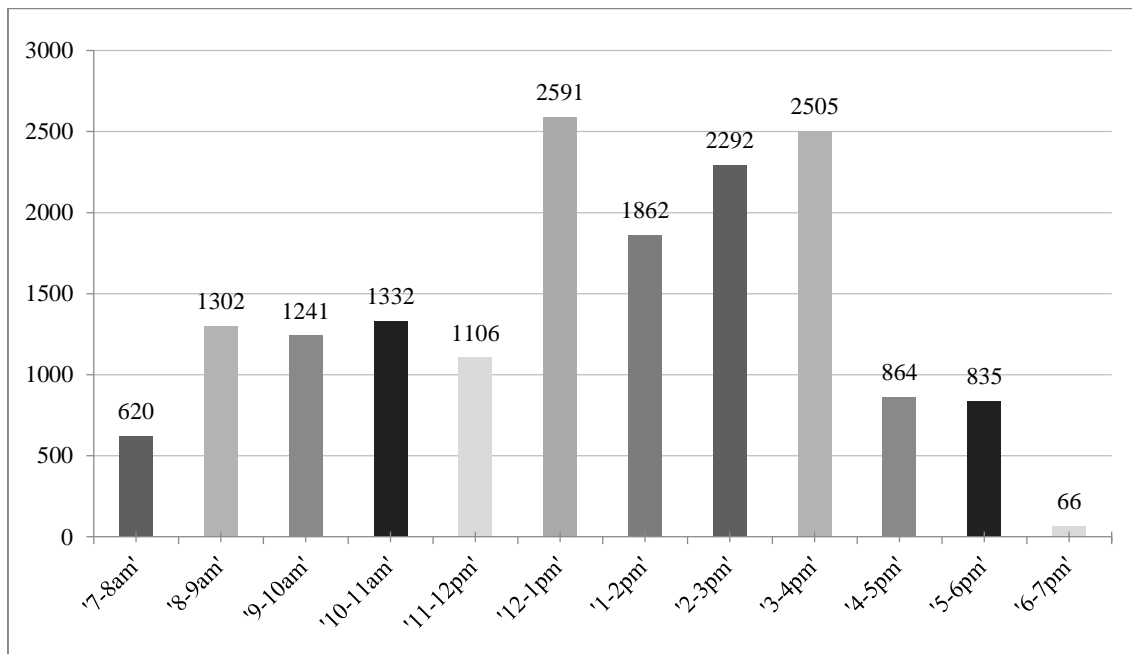
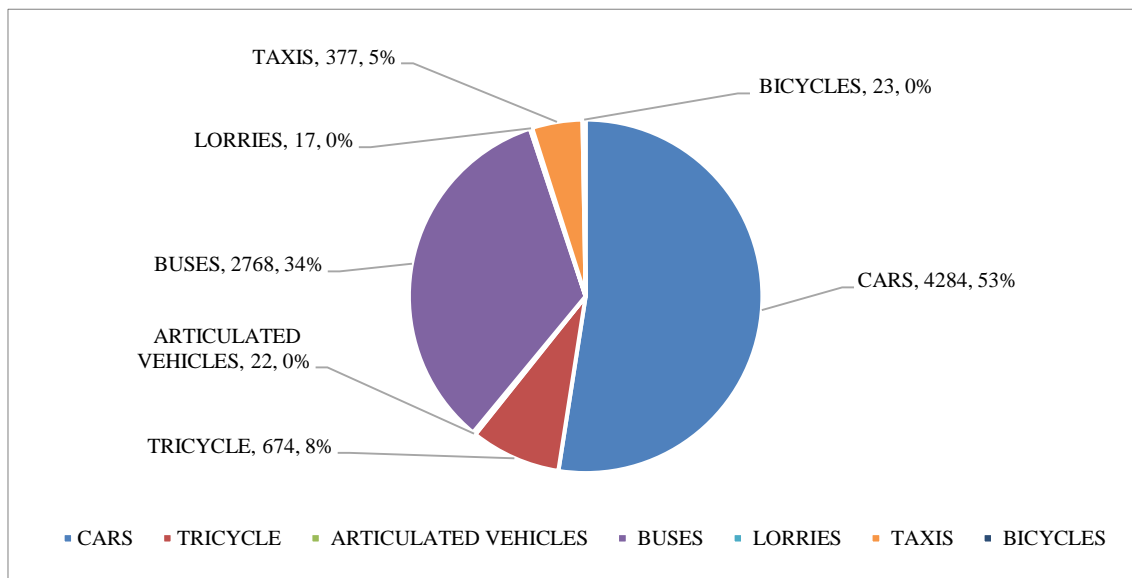
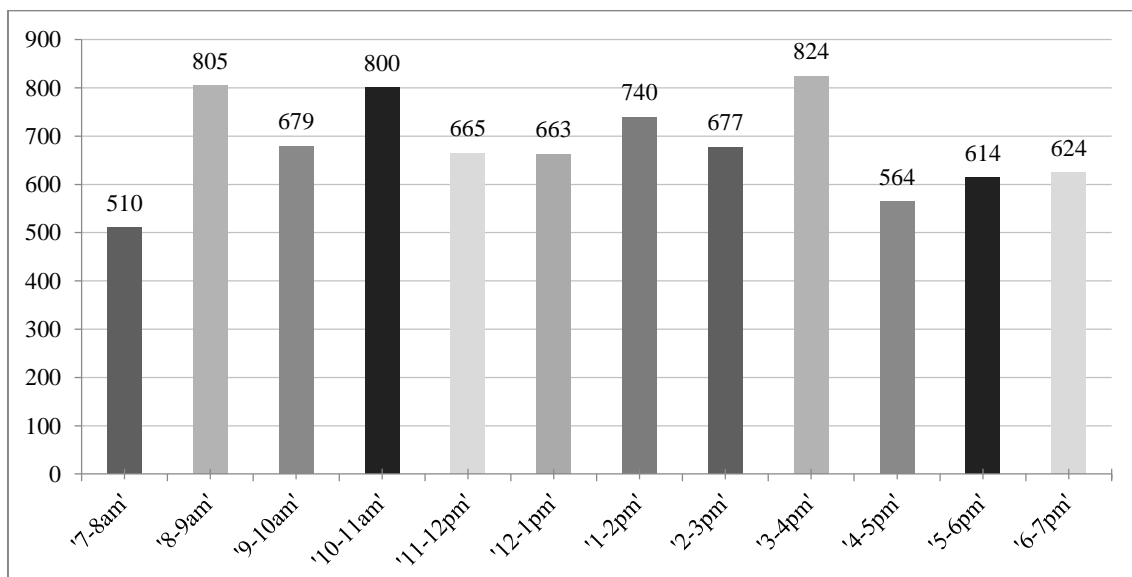


Figure 9. Hourly flow of traffic along Abakpa road

Table 9 revealed that the traffic volume along New Haven road on a typical day under normal traffic condition was 8,165 Passenger Car Units (PCU). Origin trips made in the morning, between 7am – 9am, comprised 14% of the total daily traffic, while the destination trips, between 4pm – 6pm, comprised 15% of the total daily traffic. This data shows the time of the day when most people commuters in the Enugu metropolis returned from work. The peak period was between 8am to 9am and between 3pm to 4pm. This could be adduced as evidence that this was the period when most commuters in Enugu metropolis go for or returned from their daily itinerary within city. The modal split shown in Figure 10 highlighted cars and buses as the predominant mode (52 and 34%) while Lorries, articulated vehicles and bicycles were the least (0.2, 0.3 and 0.3%) respectively.

Table 9. Hourly traffic flow of different vehicle classification along New Haven road

Time Interval	Cars	Tricycle	Articulated Vehicles	Buses	Lorries	Taxi	Bicycles	Total
7am - 8am	291	34	-	149	-	33	3	510 (6%)
8am - 9am	381	67	-	331	-	24	2	805 (10%)
9am - 10am	312	69	3	271	1	21	2	679 (8%)
10am - 11am	388	70	5	294	-	40	3	800 (10%)
11am - 12pm	301	72	-	269	-	22	1	665 (8%)
12pm - 1pm	293	95	6	235	1	31	2	663 (8%)
1pm - 2pm	377	46	4	273	2	36	2	740 (9%)
2pm - 3pm	376	34	2	235	3	25	2	677 (8%)
3pm - 4pm	458	54	-	276	4	28	4	824 (10%)
4pm - 5pm	306	58	2	160	2	34	2	564 (7%)
5pm - 6pm	400	40	-	130	4	40	-	614 (8%)
6pm - 7pm	401	35	-	145	-	43	-	624 (8%)
Total	4284 (52%)	674 (8%)	22 (0.3%)	2768 (34%)	17 (0.2%)	377 (5%)	23 (0.3%)	8165 PCU

**Figure 10. Modal Split of Commuters along New Haven Road****Figure 11. Hourly flow of traffic along New Haven road**

The traffic peak period was between 3pm-4pm and 8am-9am. This could be related to the fact that this was the period of time when the residents in the area go to work and or returned from their daily programme been a zone of medium density. The morning hours of 7am-8am has the least automobile traffic in the area of 510 Passenger Car unit.

Table 10 revealed that the volume of traffic along Achara layout on a typical day under ideal traffic condition was 22,178 Passenger Car Units (PCU). Origin trips that were made in the morning, between 7am – 9am, comprised 18% of the total daily traffic while the destination trips, between 4pm – 6pm, comprised 14% of the total daily traffic. This data also shows that this was the period of the day when most residents in Enugu metropolis commute to and fro work. The difference between origin trips and destination trips could be attributed to the fact that, most commuters in the neighbourhood go out to conduct daily activities and return using different route to avoid traffic congestion. The peak period was between 8am - 9pm as well as between 9am – 10am. Also, the modal split shown below reveals that tricycles and commercial buses were the predominant mode (39% and 32%) while bicycles were the least (0%). Thus, auto-dependency on commercial transport mode is high when compared with other areas.

Table 10. Hourly traffic flow of different vehicle classification along Achara Layout

Time Interval	Cars	Tricycle	Articulated vehicles	Buses	Lorries	Taxi	Bicycles	Total
7am - 8am	275	480	3	592	15	68	2	1445 (7%)
8am - 9am	498	960	4	766	25	127	1	2371 (11%)
9am - 10am	489	1085	4	617	31	134	-	2360 (11%)
10am - 11am	596	825	1	544	27	74	-	2067 (9%)
11am - 12pm	673	899	3	554	36	78	-	2241 (10%)
12pm - 1pm	432	654	4	493	33	70	-	1686 (8%)
1pm - 2pm	406	618	2	498	14	48	-	1586 (7%)
2pm - 3pm	428	665	4	564	27	103	1	1792 (8%)
3pm - 4pm	492	637	2	673	16	171	1	1892 (9%)
4pm - 5pm	373	527	6	632	17	77	4	1636 (7%)
5pm - 6pm	317	662	2	559	16	69	1	1666 (7%)
6pm - 7pm	267	557	2	530	10	70	-	1436 (6%)
Total	5256 (24%)	8569 (39%)	37 (0%)	7050 (32%)	267 (1%)	969 (4%)	10 (0%)	22178 PCU

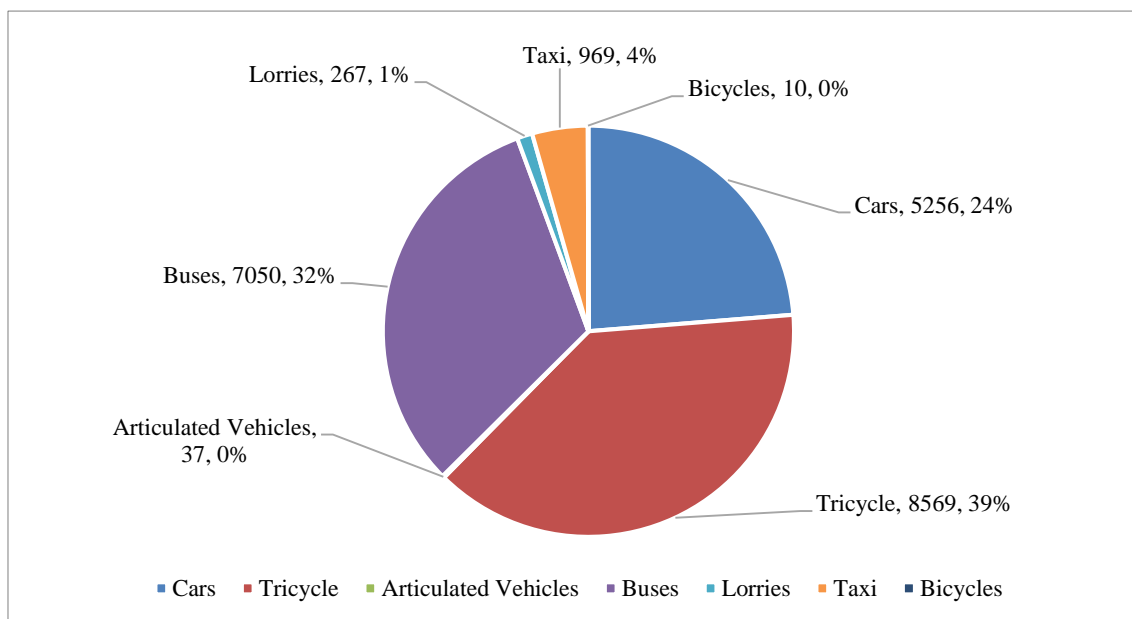


Figure 12. Modal Split of commuters along Achara Layout

Figure 13 indicates the peak hour traffic at period of 8am-9am. This data showed that most residents in the area are working-class citizens and leave home mostly in the early hours of the morning. The evening hours of 6pm-7pm shows the least automobile traffic of 1436 Passenger Car unit.

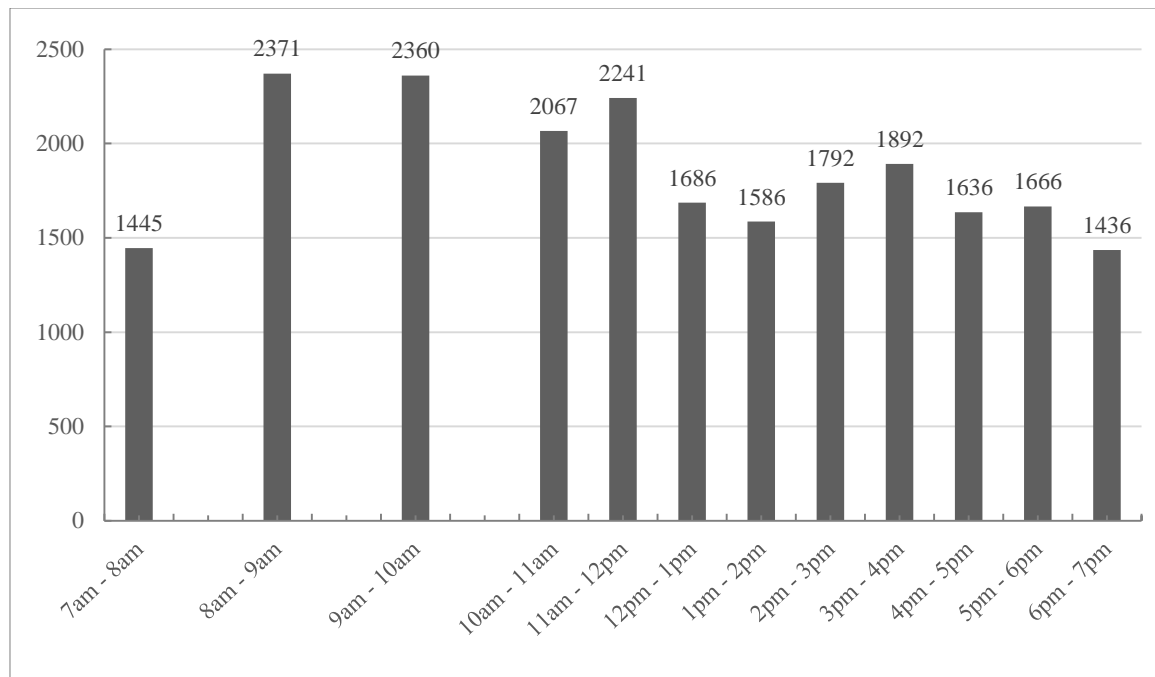


Figure 13. Hourly flow of traffic along Achara Layout

Table 11 revealed that the volume of traffic along GRA road on a typical day under ideal traffic condition was 11,269 Passenger Car Units (PCU). Origin trips that were made in the morning, between 7am – 9am, comprised 14% of the total daily traffic while the destination trips, between 4pm – 6pm, comprised 15% of the total daily traffic. This data also shows that this was the period of the day when most inhabitants in Enugu metropolis commute from work. The peak period was between 10am to 11pm as well as between 3pm to 4pm. This is likened to the fact that, this was the period of time when most commuters in Enugu metropolis go to or returned from their daily schedule within the Metropolis. The modal split diagram, indicates that cars and buses were the predominant mode (56 and 31%) while Lorries, articulated vehicles and bicycles were the least (0.2, 0.2 and 0.4% respectively).

Table 11. Hourly Traffic Flow of Different Vehicle Classification along GRA Road

Time Interval	Cars	Tricycle	Articulated Vehicles	Buses	Lorries	Taxi	Bicycles	Total
7am - 8am	410	48	0	194	0	43	5	700 (6%)
8am - 9am	512	94	0	410	0	31	3	1050 (8%)
9am - 10am	468	101	3	343	1	27	3	946 (8%)
10am - 11am	580	98	6	365	0	52	5	1106 (10%)
11am - 12pm	425	101	0	320	0	29	5	880 (8%)
12pm - 1pm	440	133	7	316	1	53	3	953 (9%)
1pm - 2pm	566	64	4	321	2	47	3	1007 (9%)
2pm - 3pm	500	48	2	311	4	33	3	901 (8%)
3pm - 4pm	687	76	0	324	5	36	6	1134 (10%)
4pm - 5pm	478	81	2	200	2	44	7	814 (7%)
5pm - 6pm	600	56	0	169	5	52	0	882 (8%)
6pm - 7pm	602	49	0	189	0	56	0	896 (8%)
Total	6268 (56%)	949 (8%)	24 (0.2%)	3462 (31%)	20 (0.2%)	503 (5%)	43 (0.4%)	11269 PCU

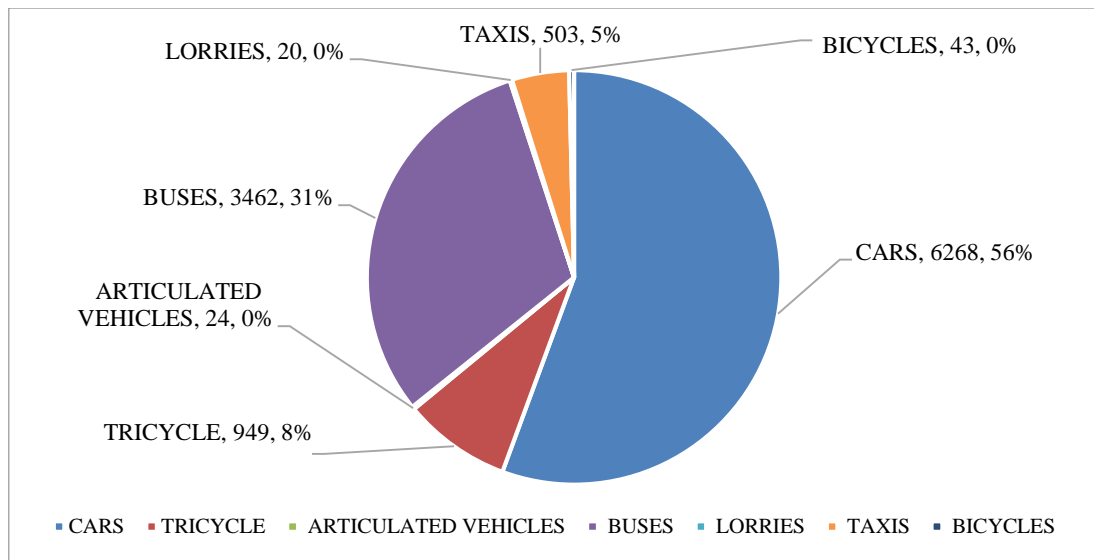


Figure 14. Modal Split of commuters along GRA Road

Figure 15 indicates peak hour traffic at 10am - 11pm and between 3pm-4pm, signifying when most Enugu inhabitants commute to and fro work with automobile. The morning hours of 7am-8am has the least automobile traffic of 700 Passenger Car unit.

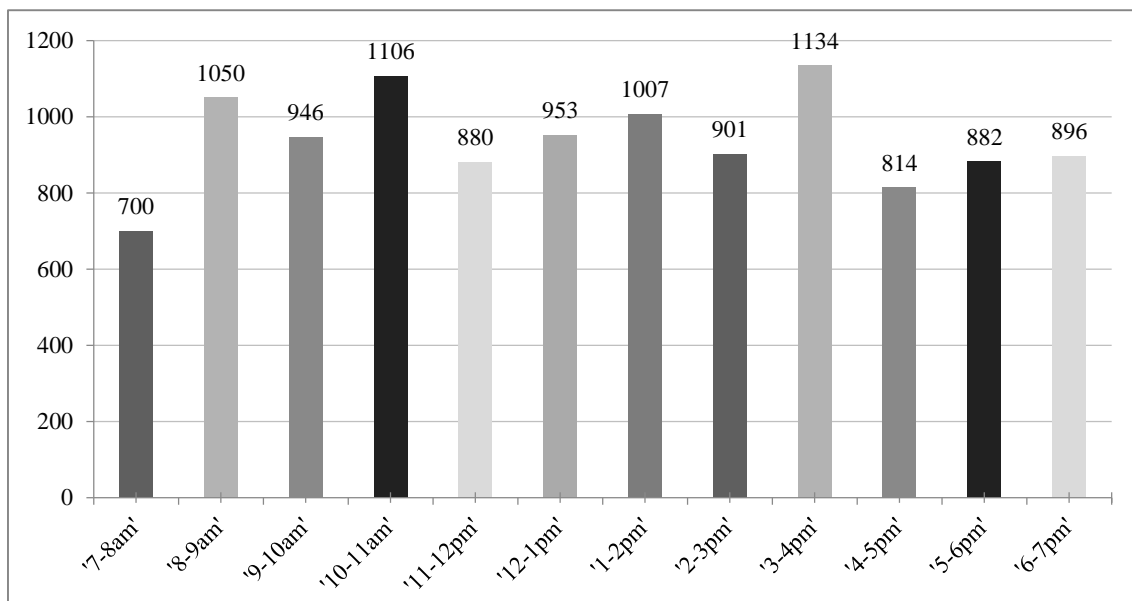


Figure 15. Hourly Flow of Traffic along GRA road

4.4. Hypothesis

H_0 : There is no significant difference between the various land uses across Enugu metropolis.

4.4.1. Result for Hypothesis

The result of the hypothesis suggests that there was no significant difference between the various land uses across the Enugu metropolis ($p = 0.129$). Therefore the null hypothesis was accepted (see Table 12).

Table 12. ANOVA result for Hypothesis 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3097.067	5	619.413	1.918	.129
Within Groups	7751.600	24	322.983		
Total	10848.667	29			

5. Discussion

5.1. The Land Use Structure in the Enugu Metropolis

The study's findings revealed that the transportation system in Enugu urban area is influenced or affected by the city's land use structure or configuration. The neighbourhood characteristics (population and residential density) of districts in Enugu urban affect intra-urban travel. From the results, it can be deduced that the activity to which lands in Enugu urban are put into and the arrangement of the land use influences the transportation system that is peculiar in a given location. Examples of this finding abound in places like Ogbete and Abakpa where traffic gridlock is experienced most times of the day due to the location being designated for commercial land uses (markets and shops) unlike other areas like New Haven and GRA. This corroborated the earlier work of Holguin-Veras et al., [42] whose study emphasizes on the expansion of the commercial sector of the city of Cali, Colombia, in the previous years that resulted in automobile inefficiencies and congestion problems hindering the city from becoming one of the largest logistical and manufacturing centres in the country due to failure to implement the minimal land-use plan. This finding is consistent with the study of Hanson and Hanson [38] who posits that land use structure influences the travel pattern of commuters. It also agrees with research of Austin and Bysveen [43], who discovered a significant relationship between the travel behaviour of commuters and the land use structure. Furthermore, it supports the studies of [39, 44]. Their works revealed that the structure and form of the city has a relationship with the transportation pattern of the city.

Subsequently, the findings from the study shows that improvement in road transportation facilities results to increased demand for land. This supports previous studies of [45-47] which suggested that transportation improvement and accessibility to an area positively affect the value of nearby land. This is also evident in almost all the neighbourhoods in Enugu urban where there has been an increased demand for land and also incongruent land use change mainly as a result of the recent improvements in road facilities in Enugu urban. A typical example is college road, where many residential properties have been changed to accommodate commercial uses. The same can be said of New layout where most residential houses are currently rehabilitated to serve the demand for better housing by teeming urban population and gentrification within the city centre. This result however contrast with the submission of Li et al., [48] who believed that the more significant the position of the core node, the more crucial it is to improve traffic conditions in the surrounding area to enable urban development. It is also worthy of note that city Planners are sometimes oblivious of the fact that the development and expansion of roads to improve ease of access or reduce congestion and increase traffic speed would promote increased use of automobile and invariably auto-dependency [12, 49]. It is reflected in the increasing high number of Passenger Car Units (PCU) plying major streets with good roads network. This supports the assertion of Bandara, [50] who stated that, because of the annually average 2-3% growth rate of Sri Lanka city road network, traffic flow rate that is demanded increased by 10% annually.

Again, the neighbourhood characteristics such as population and residential density of the studied areas in Enugu urban affect intra-urban travel. The neighbourhood 2021 Projected Population for the high density areas of Abakpa, Ogbete and Ogui are 207,497; 59,520 and 94,423 with total Passenger Car Units (PCU) travel of 17,214; 28,971 and 34,634 respectively. These figures are significantly high when compared with medium and low densities residential areas of the studied areas like New Haven and GRA (population 42,940 and 44,879; Passenger Car Units (PCU) travel of 8,165 and 11,269 respectively) but with the exception of Achara Layout having a large population of 115,466 and total Passenger Car Units (PCU) travel of 22,178 that is almost equal to the high densities areas. These findings indicate that although residential density affects intra urban travel, population has a more significant influence on intra urban travel within a city. It corroborates the findings Lee et al., [51] on two cities, London and Seoul. Their research clearly demonstrates the necessity for a more coordinated and comprehensive strategy to urban transportation infrastructure development that considers the social effects of multi-scale spatial shifts and population growth influence.

Furthermore, the study's findings revealed that changes in transportation supply invariably influences the population's location choices. It also showed that accessibility through transportation supply also influences the value of properties. From this finding, it can be deduced that the land use structure influences transportation supply; Transportation also influences land use structure or the location choices of the population. This finding can be buttressed with most commuters in Enugu choosing to reside in the Metropolis such as New layout, Ogui, New haven, etc where there are good road networks. Also, the value of properties in such areas remains relatively higher unlike other places at the periphery of Enugu urban like Abakpa. From these findings, it can be inferred that there is a relationship between transportation supply and land use structure in Enugu urban. These findings can be supported with the studies of [52-55], who all revealed that the residential densities of commuters affect their travel demand. This was also corroborated by Ogunjomo [56] whose findings revealed that trip frequencies are influenced by land use structure. However, the finding disagrees with that of Olayemi [57], whose work could not show any variation in travel pattern across residential densities.

5.2. Pattern of Intra-Urban Traffic in Enugu Urban

The findings from the traffic census of the study revealed that a total of 122,431 Passenger Car Units (PCU) constantly ply the roads of the study areas to service a total population of 564,725 daily between the hours of 7am-7pm and the major travel mode for their journey was private cars, (72,994) buses (27,504) and tricycles (11,387). This results may be attributed to the fact that the private cars tend to provide better comfort and the convenience of travel; private cars also enable the ease of circumventing traffic-congested areas. For commercial buses, these modes are the most readily available for public Transportation in Enugu urban. The use of tricycle could also be traced to the flexibility that the mode provides when compared to other modes. This agrees with the research of [16, 27] who attributed dominant travel modes of a city to be under the influence of infrastructures and facilities which are fragments of availability factors. The above findings disagree with the work of Ali [29] who observed that buses are the most dominant mode of motorised transport in third world cities such as Enugu. However, the modal split reinforces the obviously, over auto-dependency among commuters in Enugu metropolis compared to the use of public transport modes. This submission is in line with the previous studies of Okeke et al. [12] who assert that the rising dominance of automobile dependence is well revealed by their imprints on the urban land use patterns as open spaces and informal playground been converted to access road or parking lots for automobile.

The study also revealed the peak traffic hours as the morning periods between 8am-10am and the afternoon period between 3pm-4pm, indicating that the major trips made by commuters in Enugu urban are commercial, work and school trips. This finding summarises the basic activities in Enugu urban namely commercial institutions, public institutions and educational institutions. This finding can be compared to developing city of Sri Lanka where [50] noted also the rush hour to be two or three hour peak period with traffic congestion recurring at mornings, midday and midevening.

6. Conclusions and Recommendation

Intra-urban mobility represents the expression of an individual's travel behaviour within the urban centre. Thus, ascertaining the nexus between intracity mobility and land use structure is pivotal to transportation planning. This study was aimed to ascertain the influence of Land use Structure on Intra-urban transportation in Enugu urban and it demonstrated that transportation systems and land use are interdependent. The findings of this research have identified that;

- The transportation system in Enugu urban is influenced or affected by the land use structure and neighbourhood characteristics (mean score was above 2.5 on a 5-point likert scale);
- That improvement in road transportation facilities results to increased demand for land;
- changes in transportation supply invariably influences the location choices of the population and also accessibility through transportation supply also influences the value of properties;
- Enugu metropolis is automobile dependent with the dominant mode of city transportation as private cars and least been bicycle;
- The significant trips made by commuters in Enugu urban are commercial, work and school trips with peak hour traffic of at morning periods between 8am-10am and noon between 3pm-4pm.

Recent experiences suggest that a wider range of public transportation modes is required. Public transportation networks, especially in densely populated urban areas, are the most efficient means of moving large number of people. In addition to the well-being of its users, public transportation is critical to cities productivity, which has a direct impact on national economies. The study therefore recommends that;

- Through Public and private partnership (PPP) Non-motorised mode of Transportation be reintroduced with a redesign of the traffic and transportation infrastructure to accommodate and sustain these mobility nodes;
- The introduction of 'Park and Ride' facilities in the Central Business district to decongest the city centre and provide for a clean and sustainable city for all users;
- Introduction of carpooling strategy in urban centre to reduce the volume of traffic and increase vehicle occupancy;
- Implement an urban land use policy that seek to decentralise activities and human settlement with dense urban villages. Transportation system planning should begin by prioritising pedestrians and cyclists (Pro-Poor design strategy);
- Enugu state government should embark on aggressive road rehabilitation and improvement (where necessary) in Metropolis to enhance access to other city regions.

7. Declarations

7.1. Author Contributions

Conceptualization, F.O.O. and I.F.E.; methodology, F.O.O. and I.F.E.; Performed the experiments, I.F.E.; formal analysis, L.G. and F.O.O.; data curation, L.G. and F.O.O.; writing—original draft preparation, F.O.O. and I.F.E.; writing—review and editing, L.G. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Conflicts of Interest

The authors declare no conflict of interest.

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