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DOCTOR OF PHILOSOPHY
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SPATIAL ANALYSIS OF GASOLINE CONSUMPTION IN NIGERIA

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BY

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ABSTRACT

Automobile accounts for the rise in traffic volume and energy consumption in the Nigeria transport sector. Land use planning and land use design are increasingly powerful tools influencing travel behaviour and gasoline consumption. However, only modest empirical evidence of this relationship exists. This study examined the spatio-temporal pattern of gasoline consumption in Nigeria. It also investigated the relationship between gasoline consumption and urban land use in terms of location of employment, shopping and service centres with particular reference to Ibadan metropolis.

Secondary data on gasoline consumption and the explanatory variables such as per capita income and vehicle registration in the 36 States for the period 1971-2005 were collected from various government publications. Survey was conducted on 1451 households selected through systematic random sampling technique to obtain information on household intra-urban travel and socio-economic characteristics. The analysis was based on 640 vehicle owners that consumed gasoline directly for intra-urban travel. Descriptive analysis was used to explain the spatio-temporal pattern of gasoline consumption in Nigeria. Multiple correlation and regression analysis were employed to explain the determinants of the pattern of gasoline consumption, relationships between household gasoline consumption and land use variables, socio-economic and trip characteristics.

There were substantial differences in the spatial distribution of gasoline consumption among the states. Lagos State had the highest consumption level with 25.0%, followed by Oyo (6.5%), Ogun (5.4%), Kaduna (5.0%),and Edo (3.9%) States. Gasoline consumption increased from 427,937.7 litres in 1971 to 5,219,957 litres in 1983 and 8,725,938 litres in 2003.The spatial pattern was significantly explained by new registration of vehicles ($p<0.01$), number of industries ($p<0.02$) and per capita income ($p<0.04$) ($R^2=0.958$). Within Ibadan metropolis, gasoline consumption for work trips was dominated by Ibadan North (21.4%),North West (15.7%) and North East (12.1%); for school trips, Ibadan North (27.2%), North West (13.3%) and South East (12.6%); for shopping trips, Ibadan North (26.9), Ido (14.9%) and Akinyele (14.3%); for service trips, Ibadan North (22.7%), North West (14.2%) and Ido (14.2%). Number of industries ($p<0.03$) and recreational facilities ($p<0.01$) significantly explained the variation in gasoline consumption ($R^2 =0.811$). Number of buses, gender and educational level account for the variation in gasoline consumption for work trips; number of cars and age of household head account for school trips; annual income, number of cars, household size and number of relatives account for shopping trips while annual income, number of cars and gender of household head account for service trips. Regression analysis results showed that land use variables explain 81% of the variation in gasoline consumption for intra-urban travel while socio-economic variables accounts for only 17%. Gasoline consumption is determined by number of trips, travel time, distance and use of vehicles for work, school, shopping and service trips.

Urban spatial activities influenced travel and gasoline consumption. Therefore, there is a need to incorporate transport planning into urban planning to reduce energy consumption arising from travel and encourage the use of non-vehicular means of travel.

Keywords: Gasoline consumption, Urban structure, Intra-urban travel, Urban land-use, Spatial analysis.

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CERTIFICATION

I certify that this work was carried out by Miss Yingigba Chioma Jaja in the Department of Geography, University of Ibadan.

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TABLE OF CONTENTS

CHAPTER THREE

THEORETICAL/ CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

CHAPTER FOUR

SPATIAL AND TEMPORAL PATTERN OF GASOLINE CONSUMPTION IN NIGERIA

CHAPTER FIVE

DETERMINANTS OF HOUSEHOLD GASOLINE CONSUMPTION

CHAPTER SIX

SUMMARY AND CONCLUSION

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Managing the demand for energy in all sectors is key to sustainable development. Given current trends, it is especially important in the transport and urban development sector. Breakdown of energy consumption among various modes of transport show that highway traffic is by far the single largest consumer of transportation energy (IEO, 1995). This is because the principal means of transporting people and goods are at present private cars and commercial road vehicles. World gasoline consumption increased from 902,270.7 million litres in 1990 to 1,059,119.1 million litres in 2001. In terms of regional consumption, North America, Europe and Asia dominated gasoline consumption in 1990, 2000 and 2001. Within these regions, countries with the highest volume of gasoline consumption are the United States, France, Italy, United Kingdom and Japan. Regions with low gasoline consumption are the Middle East, Africa, Central America and Caribbean and South America (IEA,2003). In Nigeria, in particular, gasoline consumption increased from 4,501,511 litres in 1990 to 6,373,253 and 8,644,263 litres in 2000 and 2005 respectively (NNPC,2005).

The high demand for gasoline in developed countries is associated with the high per capita motorization level (number of vehicles per person). The automobile is responsible for nearly 90 percent of the energy consumed for travel in the US, about 80% in Western Europe and nearly 60% in Japan. There are approximately 745 million vehicles in the world. If the current urbanization, land development and economic development trends continue, the world will have over a billion cars in addition to millions of trucks, buses and motorcycles by 2014 (IIEC.1999). Given current urbanization and economic growth trends in the developing world, more people and more goods will be making more trips in urban areas, often over longer distances, that is, an increase in the demand for mobility or vehicles miles travelled (VMT). Current trends also suggest that the developing countries will eventually be the world's biggest consumers of, and investors in, motor vehicles, transport energy and urban infrastructure. Projections reflect that the developing world will be home to approximately 50 percent of the world's motor vehicles by 2030 and it will have the highest rate of growth in vehicle mile travelled (IIEC,1999). For example, in China, the annual rate of growth in the motor vehicle population as at 1999 was 20%. The average annual growth rate throughout the developing world was 16%. By contrast, the U.S.A. and other developed countries had an average annual rate of growth in motor vehicle population of 2% (IIEC, 1999).

For the rapidly growing developing world cities, land use may have a particularly important role to play, since a population growth rate of just 2.5% per year- still common in many developing cities-means that an urban area will double its population in less than 30 years. Such growth rate will essentially lock in urban areas and their underlying travel behaviours for generations. Moreover, the massive urban sprawl typical of developing countries caused by urban poverty and the sprawling costs of central city land have resulted in the construction in peri-urban areas of low income housing by the urban poor who cannot afford the formal housing market of the city. The problem, therefore, is to explain the interaction between urban form/land use and travel pattern with a view to determining the relationship between gasoline consumption, urban land use characteristics and trip characteristics. This dissertation therefore, seeks to provide answers to the following questions:

1.2 Research Questions

1. How is gasoline consumption distributed over time and space?
2. What is the relationship between gasoline consumption and urban form?
3. What is the relationship between gasoline consumption and socio-economic characteristics of households?
4. What is the relationship between gasoline consumption and travel characteristics of households?
5. What role, if any, does increase in price of gasoline play in determining automobile use and gasoline consumption?

In answering these questions, the thesis looks at the spatio-temporal pattern of gasoline consumption in Nigeria. The objective is to determine the relationship between regional characteristics of each state such as population size and gasoline consumption. In addition, the city scale analysis examines the relationship between urban form, socio-economic and trip characteristics of urban households and their gasoline consumption using Ibadan metropolis as a case study.

1.3 Rationale for study

One of the products of increased energy consumption in the transportation sector is the proliferation of studies on the demand for fuel in the sector and measures of reducing energy consumption. Over the past two decades a growing body of research has aimed at improving our understanding of the influence of land use on travel behaviour. The great majority of this work focuses on industrialized world cities especially the United States. According to Geltner (1985), compared with the attention devoted to energy use in buildings and on industry, relatively little has been devoted to urban transportation in developing countries.

Research on urban transport in Nigeria focuses on issues relating to road traffic problems, road traffic accidents, urban mass transit, transportation problems and travel demands, transportation development/policy, urban land use, transportation mode, pattern of road and parking development, urban transportation planning, transportation investment, journey to work and transit cost and location of industries. Adesina (1974) studied intra-urban mobility in the old core region of Ibadan. Ojo's (1990) work, for instance, dealt with the schedule of activities which households undertake in a city and also investigated the variations of these over space. In a related fashion, Obateru (1981) and Afolabi (1988) examined the recreational behaviour of urban residents, the first concentrating on the movement patterns while the latter defined spheres of influence for various types of activities. Adeniji-Soji(1994) examined patterns of telecommunication and the trade off between these and patterns of intra-city travel. Banjo (1994) examined the role of regulatory instruments in the attempt by African cities to meet present and future transport needs.

Studies on accessibility have been from one or two perspectives. These perspectives are access to facilities (Ikporukpo, 1987) and access to transport modes. The focus has been on rural or urban accessibility problems. Aloba (1986), Ikporukpo (1988, 1990) and Filani (1993) are examples of works on the accessibility problems of rural areas, while Bolade (1986) Ogunsanya (1986) and Adeniyi (1983, 1987) are examples of works on urban accessibility issues. One of the earliest works on enviromental issues in transportation is that by Oluwande (1977), who examined the public health hazard of various levels of dust and smoke pollution consequent on transportation in Ibadan. Onakomaiya (1981) analyzed the pattern of accidents in Nigeria and Jegede (1988) analyzed the spatio-temporal dynamics of road accidents in Oyo state.

In Nigeria, works on the petroleum industry have tended to concentrate on the effects of petroleum on the economy and activities related to the exploitation of the resource. The literature on the petroleum economy ranges from studies which consider both the impact and the exploitation of oil to those dealing with only aspects of the oil economy. Among the studies dealing with the impact of oil are those of Schatzl (1969) and Pearson (1970). Schatzl's work deals with the emergence of Nigeria as a major oil producing country. The work considered such aspects as the production and marketing of crude oil, legislature on the industry and the general effects of oil on the economy. Pearson (1970) further introduced the issue of the political and policy implications of Nigeria's oil riches.

The study of the impact of oil as a resource has attracted most attention. Sokunbi (1962), Robinson (1964) and Ikoku (1972) though interested respectively in the economics of production and distribution of crude oil and the policy implications of the dominance of foreign oil companies in Nigeria, discussed in part the economic importance of petroleum to Nigeria.

Studies on gasoline consumption have been carried out by several researchers. Ikporukpo (1978) analysed the supply and consumption pattern of gasoline in Nigeria and also evaluated the efficiency in the organization of the gasoline distribution system. Adegbulugbe et al (1986) analyzed the demand for gasoline using economic models of pooled cross-section and time series. Adenikinju (1995) examined the impact of an efficient energy pricing policy on the macro economy. Demand for coal, natural gas, petroleum and electricity in response to changes in price was the central focus of the study.

Although the ideas and models utilized by the various authors vary, the studies make use of aggregate data. Aggregate studies use spatially defined averages for all variables. Observations are usually for cities or metropolitan areas and for zones or neighbourhoods within cities. Studies on gasoline consumption in Nigeria provide little concrete evidence for local areas, offer little actual evidence for local policy making and do not account for the influence of land use on household gasoline consumption for intra-urban travel. Steiner (1994) and Handy (1990) noted that by masking within area variations in both urban form and travel behaviour, aggregate studies are generally not capable of uncovering true relationships between land use and gasoline consumption. Compared with previous studies on gasoline consumption in Nigeria, this study examines the contribution of land use and household socio-economic characteristics to household gasoline consumption for urban travel.

It has become clear that the amount of oil available in the world is limited. Also, the negative impacts of transportation such as pollution, congestion and accidents are now widely recognized in both the industrialized and developing countries. Although improved vehicle and system technologies will help ameliorate some negative impacts of transportation, a group of analysts have been focusing increasingly on the potential contribution of land use strategies particularly those characterized as neo traditional development, the 'new urbanism', 'new community design' or more generally 'smart growth'. Such strategies aim to create denser cities, reduce average trip length, improve service levels and reduce unit operating costs for public transport and create better conditions for non-motorized travel modes such as biking and walking. Over the past two decades, a growing body of research has aimed at improving our understanding of the influence of land use on travel behaviour. The role of land use planning in contributing to reduced transport energy consumption remains inconclusive. The debate about the influence of land use measures on travel behaviour and gasoline consumption continues evolving around questions such as which aspect of land use measures are most relevant to travel behaviour? How important are urban form characteristics vis-à-vis other factors known to affect the amount of travel and gasoline consumption . Some authors contend that certain land use variables, for example, density, are strongly associated with energy consumption on travel (e.g. Newman and Kenworthy, 1989) while some authors suggest that land use factors are, at most, only a small part of the picture, and that other factors such as income are more important in influencing the variation in travel (e.g. Gordon et al, 1997).

Most of the research on the influence of land use on travel behaviour and gasoline consumption focus on industrialized world cities especially the United States. Very few empirical work on the links between urban form and transportation in the developing world exists. Ingram (1998) reports on a 1982 analyses in Bogota (Columbia) indicating that workplace decentralization played a role in maintaining a constant average distance from home to work despite a 40% increase in the city's population. In an update to Newman and Kenworthy(1989), Kenworthy and Laube(1999) include certain Asian developing country cities (Jakarta, Bangkok, Kuala Lumpur, Surabaya, Manila) within an international framework linking increased urban density to reduced car use, increased transit use, and lower total urban transportation operating costs. As mentioned above, broad international comparisons of this type provide little evidence on the relationship between land use and household gasoline consumption.

Although some analysts are pessimistic about the likely success of using land use measures to affect transport demand in developing countries (Ingram, 1998), the World Bank (2002) in its urban transport strategy identifies the need for a policy emphasis on instruments (including land use mix and public transport service levels) that influence travel choices in ways that meet individual preferences. Such a policy emphasis implies the need for a better understanding of the relationship between urban land use, travel behaviour and energy consumption. To help improve our understanding of this relationship, this study, therefore, examines the potential for land use strategies to affect transport system performance in a city in a developing country. The research aims to extend existing theory by assessing the relationship between wide range land use variables and travel behaviour and to determine the relative contribution of urban structure and socio- economic variables to travel behaviour and energy consumption.

1.4 Aim and objectives

The aim of this study is to explain the relative importance of urban land use patterns and household characteristics in explaining intra-urban travel pattern, vehicle use and energy consumption. The study also examines the spatio-temporal changes in gasoline consumption within the last three decades. Objectives of doing these are to

(i) determine the spatio-temporal pattern of gasoline consumption in Nigeria.

(ii) identify the relationship between gasoline consumption and location of employment, shopping, service centers and public transit.

(iii) identify the relationship between gasoline consumption and trip characteristics of households in Ibadan metropolis.

(iv) investigate the relationship between gasoline consumption and socio-economic characteristics of households in Ibadan metropolis, and

(v) identify the impact of rising prices of gasoline on travel pattern and behaviour of households in Ibadan metropolis.

With these objectives, the study hopes to contribute to an understanding of the factors that govern gasoline consumption at the metropolitan level, using Ibadan as a case study. The study will show the spatio- temporal growth and changes in gasoline consumption in the country compared with Ikporukpo's 1978 study. The study will also assist in gaining insight into the complexity of gasoline consumption for intra-urban travel and their underlying factors in relation to socio-economic characteristics of urban residents and spatial features of the city.

1.5 Hypotheses

A number of hypotheses were formulated to shed light on the relationship between gasoline consumption, trip and socio-economic characteristics of households on one hand and between gasoline consumption and urban form measures on the other. Such hypotheses which were postulated for testing include the following:

1. there has been a significant change in the spatio-temporal pattern of gasoline consumption in the last three decades.
2. location of jobs, shopping, service centers, and availability of public transit have a significant impact on household gasoline consumption.
3. gasoline consumption is significantly related to households' trip length and travel costs.
4. socio-economic characteristics of households and vehicle ownership significantly affect gasoline consumption.
5. households respond to increase in price of gasoline mostly by combining shopping trips, reducing the number of trips, shifting to fuel efficient car and using public transit.

1.6 Research Methodology

1.6.1 Research Design

The study was undertaken at three levels, namely, national, state and urban center levels. At the national and state levels, the interest was centered mainly on the analysis of the spatial and temporal pattern of gasoline consumption in Nigeria. Ibadan metropolis was then used as a case study area in the analysis of household gasoline consumption for intra-urban travel. Major data sets were collected on the factors that determine gasoline consumption in the thirty-six states, household day-to-day movement for various activities within Ibadan and gasoline consumption, socio-economic and demographic characteristics of urban residents.

1.6.2 Types of Data and Method of Data Collection

The data for the study was collected from both primary and secondary sources. The primary data include: household gasoline consumption for intra-urban travel, socio-economic and trip characteristics that determine the level of gasoline consumption by households and impact of rising prices of gasoline on their travel pattern and behaviour.

The secondary data include domestic consumption of gasoline by states for the period 1971-2005. This was to show the general overview of gasoline consumption in the country and provide an insight into changes which have occurred since Ikporupko's study of 1978. Others are new registration of gasoline using vehicles by states, population size, per capita income, population density, distribution of employed population, length of roads in each state, motor vehicle newly registered by states and number of industrial establishments in each state. Data on these variables were collected for the period 1971 - 2005. However, due to lack of consistency in the availability of data on some of the variables for the entire period, the means of the total of each variable for the period in which data were available was used in the analysis. The sources of these data are the Annual Abstract of Statistics of the Nigerian Bureau of Statistics and the Annual Statistical Bulletin of the Nigerian National Petroleum Corporation. The secondary data used for the urban analysis include the number of industries, markets, hospitals\clinics, financial institutions, secondary, primary and nursery schools, and availability of public transit in each local government area in Ibadan. Information on these variables was obtained from the Local Government planning Offices and Oyo State Ministries of Education and Health.

Since part of the study compares existing situation with Ikporuko's work of 1978, some adjustments were made to the data collected for the states because of the geographical changes that have occurred in the country since Ikporukpo's study. In 1978, there were 19 states and Abuja(Federal Capital Territory)as 7 new states were created in 1976 and the names of some existing states were changed. Two additional states were created in 1987 and in 1991 nine states were added. By 1996, six more states were created to make a total of thirty-six states which exist today. Data for the states created over time were estimated from the data for the states from which they were created. To achieve this, the political map of Nigeria for 1963, 1967, 1976, 1987, 1991 and 1996 were digitized and overlaid to obtain the percentage proportion of the new states contained in the old state boundaries. The computed proportion was used to calculate the proportional percentage of the new boundaries contained in the old boundaries. This value was then subtracted from the old value to give the percentage of the old and new boundaries. These percentages were used to estimate values for the old and new states from the available secondary data for the period 1971-1996.For example, 50.6 percent of the areal size of the old Western Region made up Oyo state in 1967. In 1991, Oyo State was divided into two states, namely, Oyo (74.9%) and Osun (25.1%). These percentages were used to estimate values for Oyo and Osun states from the various secondary data obtained for the study. Table 1.1 shows the percentage of the areal size of new states that was derived from existing states between 1976 and 1996. The change in the areal size of each state was used to estimate the secondary data because the total distance traveled within a state is influenced by the area extent of the state and not by the population size of the state.

The primary sources of data for Ibadan are questionnaire survey, map of the eleven local government areas of the metropolis and data from the financial institutions within the city. A household is defined as persons living under the same roof and eating from the same pot. Following the works of Ogunjumo (1986), Oyesiku (1990), Dimitriou (1995) and Golob et al (2005), household is a well known key decision making unit for the general movement pattern and constitutes the major point of origin of urban travel. This survey which provided the greater proportion of information on household travel behaviour was divided into three sections (see Appendix 1). The first section collects information on household composition and socio-economic characteristics. Questions on the composition of the household were designed to identify the household size, number of adults, number of workers and students in the household. Information on household socio-economic characteristics included sex, age of the household head, marital status, level of education, income, occupation, length of stay, vehicle ownership and vehicle characteristics.

Table 1.1: Percentage proportion of new states derived from old states 1976-1996.

Old state	*Area km2*	*%*	*New State*	*Area km2*	*%*
1967			1976		
East	28802.96	100	Anambra	18677.71	64.8
Central			Imo	110125.25	35.2
North	284527.75	100	Bauchi	68719.00	24.2
Eastern					
			Bornu	120016.16	42.1
			Gongola	95792.59	33.7
Mid	37063.64	100	Bendel	37063.64	100
Western					
Benue	86513.54	100	Benue	31723.49	36.7
Plateau					
			Plateau	54790.05	63.3
North	69600.69	100	Kaduna	69600.69	100
Central					
Kano	45248.43	100	Kano	45248.43	100
Kwara	65346.31	100	Kwara	65346.31	100
Lagos	3933.65	100	Lagos	3933.65	100
North	184922.40	100	Sokoto	105047.83	56.8
Western					
			Abuja(FCT)	7471.60	4.0
			Niger	72402.96	39.2
Western	73373.99	100	Ogun	16283.53	22.2
			Ondo	19983.78	27.2
			Oyo	37106.68	50.6
Rivers	19404.75	100	Rivers	19404.74	100
South	28172.61	100	Cross Rivers	28172.61	100
Eastern					
			1989		
Cross	28172.61	100	Akwa Ibom	6798.49	24.1
Rivers					
			Cross Rivers	21374.13	75.9
Kaduna	69600.69	100	Katsina	24364.79	35.0
			Kaduna	45235.90	65.0
			1991		
Imo	10125.25	100	Abia	4766.49	47.1
			Imo	5358.76	52.9
Anambra	18677.71	100	Enugu	14040.12	75.2
			Anambra	4637.59	24.8
Bendel	37063.64	100	Delta	17256.24	46.6
			Edo	19807.40	53.4
Kano	45248.43	100	Jigawa	24654.34	54.5

			Kano	20594.09	45.5
Sokoto	105047.83	100	Kebbi	36891.48	35.1
			Sokoto	68156.35	64.9
Kwara-Benue	97069.80	100	Kogi	29332.47	30.2
			Kwara	36013.84	37.1
			Benue	31723.49	32.7
Oyo	37106.63	100	Osun	9309.95	25.1
			Oyo	27796.73	74.9
Gongola	95792.59	100	Taraba	60957.33	63.6
			Adamawa	34835.26	36.4
Bornu	120016	100	Yobe	46822.92	39.0
			Bornu	73193.16	61.0
Niger	72402.96	100	Abuja	7471.60	10.3
			Niger	72402.96	89.7
			1996		
Rivers	19404.74	100	Bayelsa	10235.76	52.7
			Rivers	9168.98	47.3
Enugu	14040.12	100	Enugu	7786.80	41.4
Abia	4766.49	100	Ebonyi	6253.32	33.3
			Abia	4766.49	25.3
Ondo	19983.78	100	Ekiti	5307.01	26.6
			Ondo	14676.77	73.4
Bauchi	68719.00	100	Gombe	18570.93	27.0
			Bauchi	50148.07	73.0
Plateau	54790.05	100	Nassarawa	26732.36	48.8
			Plateau	28057.69	51.2
Sokoto	68156.36	100	Zamfara	35448.50	52.0
			Sokoto	32707.86	48.0

Author's Analysis,2008

The second section of the questionnaire deals with the actions taken by households to reduce vehicle gasoline consumption due to increase in the price of gasoline. The third section deals with the intra-urban travel and activity patterns of residents in Ibadan metropolis. The information sought for include trip characteristics for various purposes for 7 days of the week. The choice of a full week was to enable the coverage of the totality of trips made by every member of the household both on weekdays and weekends. All the possible trips were classified into four, namely, work, school, shopping, and recreational trips. The basic questions here include, mode choice, trip purpose, frequency, length, origin and destination, vehicle occupancy, gasoline consumption, cost of travel and vehicle ownership. In collecting these information on travel activities, a travel diary was used. Respondents were requested to keep a travel diary with adults reporting for young children for the 7 days. This was combined with personal interviews at the beginning and end of the diary period. However, respondents that were unable to read were asked questions on their urban trips within the past one week to the date of survey. The immediate past week to the date of survey was chosen in order to collect information while they were still relatively fresh in their memory, thus enhancing the accuracy of the information.

In addition to questionnaire survey, the distance between the origin and destination of households trips were computed from a digital map of Ibadan using the Arcview GIS package. The coordinates of the origin and destination points were extracted from existing topographical maps. Field investigation was used to supplement government official records on the industries, financial institutions and markets in each of the local government areas in the metropolis.

1.6.3 Sampling framework and Questionnaire Administration

The administration of the questionnaire was conducted in June, 2006 by the author and several field assistants adequately trained for the purpose. A pre-test of the questionnaire was conducted on 165 randomly selected respondents (5 from each of the selected localities). This exercise helped to highlight the inherent problems in the questionnaire design and invariably some necessary amendments were made. Further training was also carried out for the field assistants and coordinators in view of the complex nature of travel activity studies. Three neighbourhoods were selected from each local government area based on their various population sizes, income groups, location vis-à-vis the city centre and traditional nature of Ibadan. In each of the neighbourhood surveyed, the number of streets were identified and a random selection made. On each street, systematic random sampling technique was employed to select each housing unit in which the target respondents reside. In case of multi-family units, one household was interviewed.

The size of the household sample interviewed depended on the total estimated year 2006 population projection for all the local government areas. The projected population was based on the growth rate of 2.8% used by the National Population Commision for 1996 projection. The 1991 population census figures were used as the base year population. Though Bruton (1975) and Neuman (1994) recommended sample sizes of between 10% and 15 for population areas of under 50,000 and over 1 000 000 respectively. 0.005% of the estimated population of selected neighbourhoods was chosen as the sample size taking cognizance of the fact that one has to visit each respondent in all the local government areas of the city and considering the fact that accuracy is very essential in travel studies. Furthermore, the cost of procuring survey materials, skilled interviewers and more importantly , the time to spend on the field such that the survey was done around the same period in all the localities were also responsible for the sample size chosen. Out of the 1451 questionnaires administered in the neighbourhoods, (table 1.2) 1327 fully completed ones were received for this study. This figure represents 91.45% rate of response. Figure 1.1 shows the distribution of questionnaires in the local government areas in the metropolis.

Table 1.2 : Distribution of Questionnaires within the Local Government Areas

LGA	Locality	1991 Population	Projected population 2006	Estimated Sample Size	Sample Size
IB NW	Eleyele	18949	28673.65	143.37	143
	Omitowoju	2032	3074.83	15.37	15
	Jericho	1130	1709.92	8.55	9
IB NE	Idi Ape	5943	8992.96	44.96	45
	Aremo	17882	27059.07	135.30	135
	Onipepeye	1092	1652.42	8.26	8
IB SE	Molete	10902	16496.92	82.48	82
	Bere	1307	1977.75	9.89	10
	Orita Challenge	5954	9009.60	45.05	45
IB N	Samonda	3550	5371.87	26.86	27
	Bodija	23779	35982.41	179.91	180
	Ojoo	1518	2297.04	11.49	11
IB SW	Popo yemoja	13101	19824.45	99.12	99
	Oluyole	5097	7712.79	38.56	39
	Idi Arere	2369	3584.77	17.92	18
Oluyole	Ifelodun	4169	6308.54	31.54	32
	Idi Ayunre	1191	1802.22	9.01	9
	CRIN	1475	2231.97	11.16	11
Ona Ara	Ogbere Ti Oya	12684	19193.45	95.97	96
	Badeku	1629	2465.01	12.33	12
	Akanran	1293	1956.57	9.78	10
Lagelu	Oyedeji	646	977.53	4.89	5
	Lalupon	6918	10468.33	52.34	52
	Apetere	1662	2514.94	12.57	13
Ido	Omo Adio	11094	16787.46	83.94	84
	Apete	3062	4633.42	23.17	23
	Ido	1003	1517.74	7.59	8
Akinyele	Moniya	12929	19564.18	97.82	98
	U.I.	3363	5088.90	25.45	25
	Bode Igbo	2241	3391.08	16.96	17
Egbeda	Egbeda	1121	1696.30	8.48	8
	Alakia	8135	12309.89	61.55	62
	Alarobo	2593	3923.73	19.62	20
Total		191813	290251.71	1451.26	1451

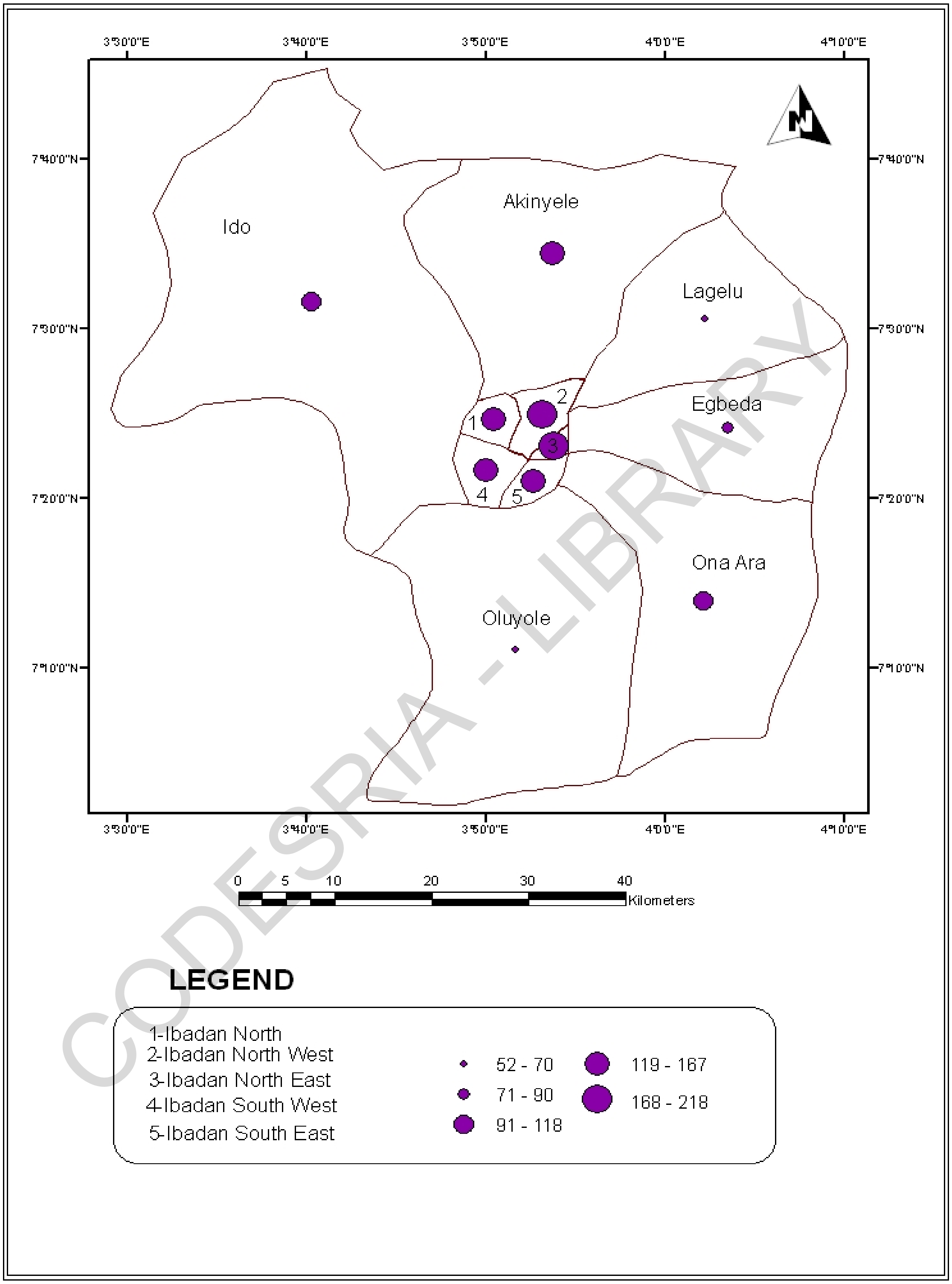


Fig. 1.1: Map showing the distribution of questionnaire within Ibadan metropolis

1.6.4 Method of Data Analysis

Various descriptive statistical methods and diagrams were used in the analysis and display of the data. The descriptive statistics include percentages while the cartographic methods include line graph, bar graph, and proportional circles.

The first hypothesis which states that there has been a significant change in the spatio-temporal pattern of gasoline consumption in Nigeria was analysed using the Analysis of Variance technique. This was to examine the variation in gasoline consumption overtime and among the thirty-six states. The least square method which provides the best linear unbiased estimator of the straight line was used to fit a straight line to the time series so that the general path of the time series data may emerge. Multiple regression analysis was employed to explain the variables that predict gasoline consumption in the states. The stepwise version of the model was used to determine the most important variables explaining the observed pattern.

Correlation and multiple regression analysis were used to determine the nature and degree of the relationship between household gasoline consumption for intra-urban travel and household social-economic characteristics, trip characteristics and land-use variables in Ibadan metropolis. The details of each of these analytical techniques are discussed in succeeding chapters where they are employed.

1.7 Plan of the thesis

The thesis is organized into six chapters. Chapter one discusses the background and research problem, the aim and objectives of the study. Also, the hypotheses, type of data, method of data collection, techniques of analysis are discussed. The physical and socio-economic setting of Ibadan metropolis are discussed in chapter two.

Chapter three focuses on the conceptual/theoretical basis of the study and a review of relevant literature. Specifically, the theories of spatial interaction, location, urban spatial structure and trip generation models are discussed. Chapter four is concerned with the spatial and temporal pattern of gasoline consumption in Nigeria, development of the oil industry and determinants of the spatial pattern of gasoline consumption in the country. In chapter five, the determinants of household gasoline consumption for intra-urban travel is examined. The relationship between gasoline consumption and household socio-economic characteristics, trip characteristics and land use variables are examined. Lastly, chapter six summarizes the major findings of the study. It also presents the implications of the study for planning and recommendations for further research.

CHAPTER TWO

PHYSICAL AND SOCIO-ECONOMIC CHARACTERISTICS OF THE STUDY AREA

2.0 Introduction

The social and economic geography of Ibadan provides a setting for the study of gasoline consumption for intra-urban travel. Therefore, an overview of the various dimensions of socio-economic geography of the study area is necessary. Of interest are the spatial organization of the population, spatial growth of the city and the various land-use types.

2.1 Location

As shown in Figure 2.1, the city of Ibadan is located approximately on longitude $3^{0}5'$ East of the Greenwich meridian and latitude $9^{0}23'$ North of the equator. It is one of the largest cities of Africa and the largest indigenous urban centre in Africa South of the Sahara. Ibadan city is connected to many cities and towns in Nigeria by a variety of transport modes. Ibadan is a nodal city. All road traffic from Lagos to the Northern states through Abeokuta and Shagamu converge on Ibadan. The railway to the northern states also passes through Ibadan which has since become a major break of bulk point for trade goods from the southwest to the north as well as from the north to the south west.

Ibadan metropolis is contemporarily the capital city of Oyo state and is made up of 11 local government areas of Akinyele, Egbeda, Ibadan North West, Ido, Lagelu, Oluyole, Ona-Ara, Ibadan North East, Ibadan South East, Ibadan South West and Ibadan North, (figure 2.2). The pre-colonial origin of the city and much of its surrounding region and the later imposition of the British culture are reflected in the city's display of a mix of old and new and of tradition and modernity.

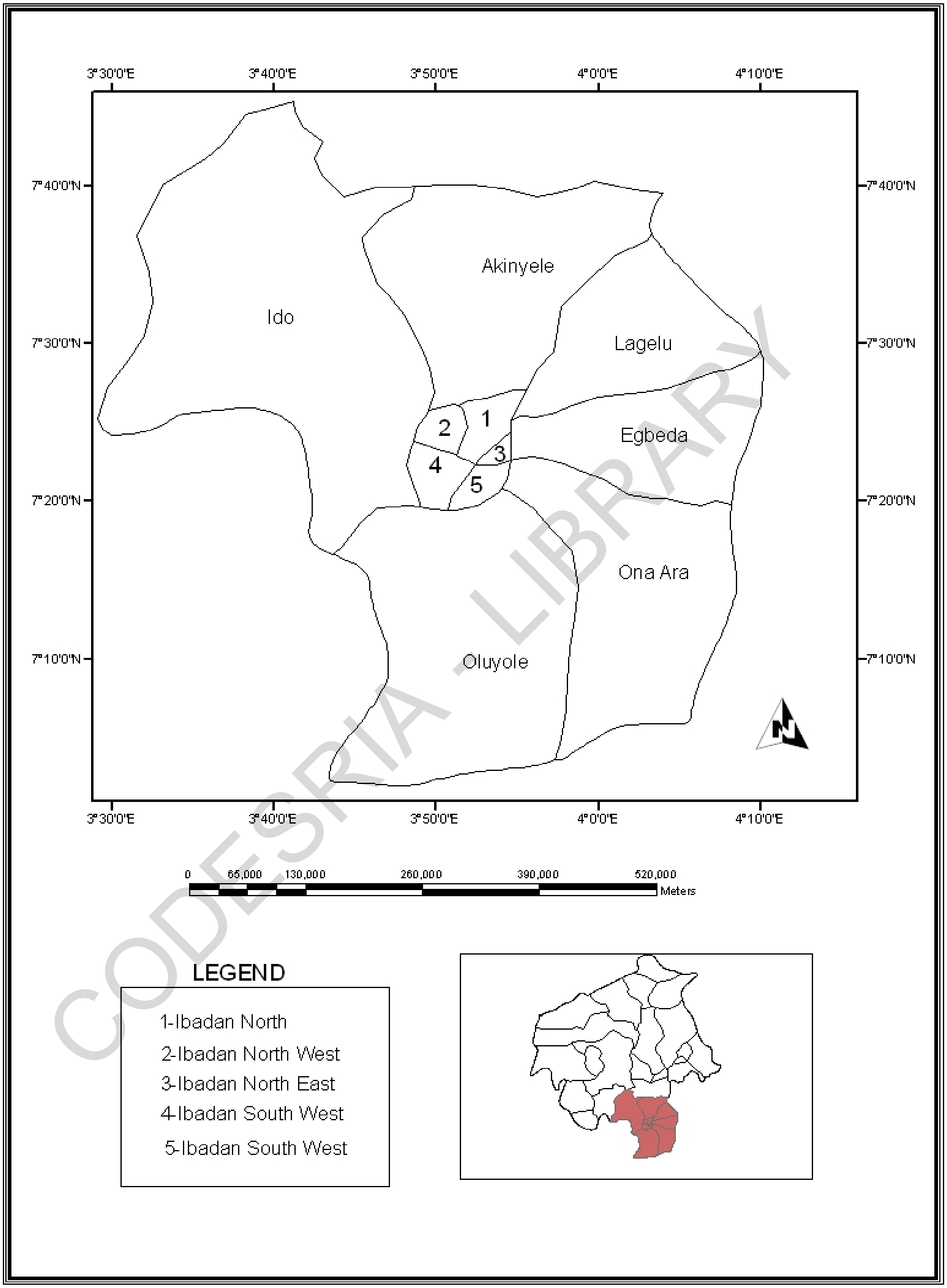


Figure 2.1: Map of Ibadan Metropolis showing the local government areas

Physically, the form and structure of the city are made up of ridges of lateritized quartztic hills running in a northwest-southeast directions. The highest and largest of the hills are along Mapo, Mokola and Aremo areasof the study area.The approximate elevation is between 160 and 275 metres above sea level. The city is drained by Ogunpa River and its tributary, Kudeti stream which flow to the southeastern wards while Ona River and its tributaries which include Alalubosa, Oshun and Yemoja streams flow to the western part of the city.

2.2 Growth Trends

The present site of Ibadan was settled in 1829, as a camp by the soldiers of the Ife, Ijebu and Oyo after they had successfully destroyed the neigbouring kingdom of Owu. Although, Ibadan started as a war camp, it grew so rapidly that within a period of a few years, it became unreasonable to break it up. Thus, the Ife and Oyo soldiers settled around the present Oja Oba and Mapo Hall while the Ijebu soldiers settled at Isale Ijebu to the south and a few of the Egba inhabitants who returned with the allies took up residence to the west in a quarter now known as Yeosa. (Mabogunje, 1968, p.188). When the first European, the Reverend David Hinderer of the church missionary society got to the city in 1851, he noted that this walled town contained about 100,000 inhabitants, many of whom were engaged in the crafts, as well as, trading in both local and imported commodities and slaves (Mabogunje, 1968).In the second half of the nineteenth century, the growth of Ibadan in depended on the size of Yorubaland which it could dominate.

Thus, by the time Nigeria formally passed into the hands of Britain, Ibadan had a tributary area covering some 50,000 square kilometers and consisting of most of Yorubaland. By 1858, a new town wall known as Odi Ibikunle had to be built while by 1890, the city contained over 200,000 people, while within the wall at least, 120,000 people were gathered.

The construction of the western railway which reached Ibadan from Lagos in 1901 greatly increased the city's trade links with the northern parts of the country. The south-north and east-west transport routes intersected at Ibadan. By 1918, European firms had established branches or depots in Ibadan, thereby boosting the commercial importance of the city. This led to the establishment of a modern business center and European reservation area.

The colonial administration established Government Reservation Areas (GRA) at the outskirts of the city to the east – (Agodi) and north-west (Jericho) whilst modern residential layouts were established outside the traditional core of the city to serve the flood of migrants. The Bodija Housing Estate was established by government in 1959 to relieve pressure on the GRAs and cater for the needs of the growing number of Nigerian professionals.

The impact of these development on the spatial growth of the city was revealed when the first comprehensive aerial photo-coverage of the city and its environs was provided in 1964. By this time, Ibadan city had spread beyond the drainage basins of Ogunpa and Kudeti to the catchment areas of River Ona to the west and River Ogbere to the east. Oyelese (1970) estimated the total area the city approximately as 103.8 sq. km. This represented approximately a 260 per cent increase in area since 1890. However, only 36.2 sq km (or 34.9% of the land area) was actually devoted to "urban land uses" consisting of residential areas, public buildings, markets, industrial and commercial areas, educational institutions and amenities and open space. This meant that as much as 67.6 sq km was devoted to non-urban uses such as farmlands, river floodplains, forest reserves, fallow lands and water bodies.

A remarkable feature of the growth of Ibadan city since the 1960s has been the disappearance of these "non-urban land uses" in the face of a rapid expansion of "urban land uses". The aerial photograph of the city covered in 1973 revealed that the urban landscape of Ibadan had completely spread over about 101.9 sq km. The former farmlands and river floodplains within the city had been built upon, and the forest reserves had become part of the recreational resource system of the city. Non-urban land uses were largely confined to the urban fringes.

The boom in the construction industry which was generated by the country's oil wealth after the civil war (1967-1970) also greatly affected the city of Ibadan. Certain sectors of the city which had appeared "depressed" for years without any marked physical developments suddenly sprang to life. These included: the eastern (Ife-Iwo Roads) northern (university-Agbowo) and south western (Felele-Challenge-Ring Road) sectors, where privately owned housing estates were established in quick succession. According to Areola, (1994), it was estimated that the city covered an area of about 130.5 sq km in 1982. Many new developments had taken place since 1973 to generate the outward growth of the city in almost all directions. These developments include:

(a) the building of the Lagos- Ibadan expressway which goes round the southern, eastern, and north eastern parts of the city:
(b) the establishment of the housing estate, the wire and cable-factory, and the NNPC oil storage depot at Owode on Abeokuta road.
© the building of the new airport and the commissioning of Ajoda New Town on Ife Road.
(d) the building of the Leyland Motor Assembly plant and the Triplex Glass Factory on Iwo road
(e) the building of the new army barracks near Ojoo to the north of the city.

These developments led to a sharp reduction in the proportion of land devoted to non-urban land uses at the fringes of the city.

Recently, Taiwo (2006) using three Landsat satellite imageries (1984, 1990 and 2006) analysed the pattern of growth of the city of Ibadan. It was observed that the area extent of the urban part of the city changed from 302.54 sq km in 1984 to 325.68 sq km in 1990 representing about 23.14 sq km increase in the urban area extent. By the year 2000,the urban area has increased to 417.92 sq km indicating about 92.24 sq km increase in the extent of urbanization in the city. The rate of growth of the urban areas shows that, in all, the city has grown by about 115.38 sq km between 1984 and 2000. The rate of urban growth between 1984 and 1990 was 3.86, while between 1990 and 2000 was 9.22. In order to understand the contribution of each local government area (LGA) to the overall growth of the city, the contribution of each LGA to the urbanization component was computed. The LGA map was overlayed on the composite urban growth map to compute each LGA share of the urban growth in the city.

Table 2.1 provides information on the contribution to urban growth by each of the LGAs in the city of Ibadan. The table shows that in Akinyele LGA 20.77 sq. km was urbanized in 1984 and this increased to 66.13 sq.km in 1990 and to 73.64 sq. km in 2000. Ido LGA which had 15.54 sq km of urban area in 1984 increased to 48.25 sq.km in 1990 and 64.13 sq km in 2000. It should be noted that Ibadan North, Ibadan North West and Ibadan North East have been completely built up by 1990, hence, there was no noticeable change in the extent of urbanization in 2000. Also, within the same period, Ibadan South West and Ibadan South East grew marginally after the year 1990. Based on the table above, it can be concluded that the highest growth between 1984 and 1990 occurred in Akinyele (45.36sq km) followed by Ido (32.71 sq km) while the lowest growth occurred in Oluyole and Ibadan North West LGAs. Between 1990 and 2000, the highest growth took place Oluyole (47.44 sq km) followed by Ido (15.58 sq.km). The lowest urban growth occurred in Ibadan North West while Ibadan North East recorded no increase because they were already built-up and no visible undeveloped area remain in the LGAs. Generally, between 1984 and 2000, Oluyole, (53.18sq km). Akinyele (52.87 sq km) and Ido (48.59 sq km) experienced high levels of change in urbanization.

The growth of the population of Ibadan has also been equally remarkable. From a war camp consisting in 1829 of a motley collection of soldiers, the population rose to an estimated figure of 175,000 in 1911. Between, 1911 and 1921, it increased at about 3.1 percent per annum to 238,075. The rate of increase between 1921 and 1931 was 5.0 per cent per annum while it was only 0.8 percent for the period between 1931 and 1952 when the population rose from 387,133 to 459, 196. The result of the 1991 census, which is controversial put the population of the city at 1,222,570.

Table: 2.1: LGAs contribution to urbanization of Ibadan metropolis.

LGA	1984	1990	2000
Akinyele	20.77	66.13	73.64
Ido	15.54	48.25	64.13
Lagelu	7.02	21.38	25.35
Ibadan North	8.64	26.33	26.33
Ibadan North West	9.12	27.80	27.80
Ibadan North East	5.71	17.64	17.64
Ibadan South West	12.83	39.80	40.03
Ona Ara	2.57	20.38	27.51
Ibadan South East	6.12	21.22	22.06
Oluyole	1.21	6.95	54.39
Egbeda	9.74	29.80	39.03

Source: Taiwo, O.J. (2006)

2.3 Land-use and the location of activities

Ibadan is one major Nigerian city that was for a long time allowed to grow without a master plan. Consequently, there is a great mix of activities such as residential, commercial, residential and industrial, as in the case of small to medium sized establishments. However, in recent years, the government of the city has through the Ibadan Municipal Planning Board, instituted a number of control measures that are leading to the emergence of discernible patterns of land-use in the area.

<u>Residential land use</u>

The pattern of urban land-use shows that the largest use in land is for residential purpose which occupies about 61.4 percent of the total land in the metropolitan area. Mabogunje (1962) identified seven major residential districts in Ibadan- the core, older suburb, newer western suburb, newer western suburb, post 1952 suburb, Bodija estate and reservations. The core district, the oldest part of the city, is a high density area occupied mainly by the indigenes of the town. There are hardly any gaps between the buildings, many of the buildings do not face the roads or streets since they are at the back of other buildings. The roads are narrow and during the rains serve as drainage channels, making transportation especially on foot temporarily difficult. The older suburb shares the same characteristics with the core distinct except that more Yoruba immigrants may be found. The newer eastern and western suburbs and the post 1952 suburb are creations of the waves of in-migration into Ibadan and of those indigenes who have moved from the congested core to find land to build new houses. The housing density is lower than the core. For example, Oke Ado, Molete, Challenge and Ring Road.

The GRA, Bodija Estate and Oluyole Estate may be regarded as low density residential areas. Almost all the houses have fences and gardens in place. The inhabitants are mainly top civil servants and professionals who are maintained there by the organizations they work for government, companies etc. These areas can be regarded as high cost residential area.

Abumere (1994) to classified residences in Ibadan on the basis of the processes creating the classes. Mabogunje's core and the older suburb was regarded as indigenous district since a vast proportion of the residents are indigenes. Mabogunje's newer eastern, newer western and post 1952 suburbs was called the zone of market forces since the determining factor is ability to pay. The Reservations and Estates was classified as the government zone or constitutional zones as the zones are government creations. This explains the presence of an individual with relatively low income along side with business executives with superlative income in Bodija..Today, some of the estates have become commercial centres as they are now occupied by banks and companies.

Industrial land use

Industrial activities take 16.55 percent of the land use in Ibadan (Ayeni, 1994). The factory type manufacturing is concentrated in the city while the craft industry is shared between the city and its rural environs. Modern manufacturing firms have experienced a significant growth between the late 1950s and the late 1980s. From six large scale plants in 1950, the figure increased to 30 in 1964 and 61 in 1972 while there were 150 and 218 in 1979 and 1989 respectively (Alokan and Onyemelukwe, 1994).

Areas of industrial development are dispersed in the city. The core areas of the city are noted for commerce and traditional crafts and cottage industries. Areas peripheral to the traditional and modern central business districts are noted for industrial activities which are however not radial in form but in pockets. The scattered nature of modern factory industries in Ibadan is due partly to the location of the industrial estates and layouts. There are four industrial estates namely Oluyole, Old Lagos road, Old Ife road and New Lagos scheme. The Oluyole industrial estate is the most developed and is situated in the western part of the city. It is provided with water, electricity, roads and well laid out plots. Also, it has the largest single concentration of industrial plants. By contrast, the other estates are occupied by only one or two plants.

The traditional craft is organized on cottage or compound basis, so that industrial and residential spaces are in the same place while factor production especially of the large scale type is generally in buildings separate from dwelling houses. As a result, craft production concentrate in the core areas of the city while modern factory production in large scale occupy the city peripheries especially along Oyo – Ibadan road, Ibadan – Lagos road and Ibadan – Abeokuta road.

The industrial scene of Ibadan is dominated by consumer goods production. Consumer goods industries include Sunrise Bottling Plant, Eagle Flour Mills, Ladokun Feeds, West African Batteries, Nigeria Bottling company and General Gas cylinders. The capital goods industries icnldue the Triplex Safety Glass plant which produces car windscreens and Fredo Brake Pads and lining plant. Factors which encourage the location of industries in Ibadan are the availability of raw materials, its market potential and transportation facilities.

Commercial land use

Commercial activities take a low percentage of 0.34 percent of the total land use in Ibadan (Ayeni, 1994). This is because much of the commercial activities in the city are done in traditional markets within residential premises.

Vagele (1972) identified 26 officially recognized markets in the city. Filani and Iyun (1994) observed that the city markets have inceased to 36 while four new ones were under construction. Three years later, the number had increased to 47 locations in the city. Most of these markets operate business during the day from about 8am till late in the evening while a few of them operate periodic marketing when more sellers and buyers come from far and near and beyond the state boundary.

In all, 16 markets are located in the indigenous section of the city while 21 are found in the modern areas. Each market serves an average population ranging between 32,000 and 147,000. The markets are not evenly distributed but are clustered. The types of market stalls include covered and lockable stalls; open stalls; open trading units and those in the form of counters. The number of market stalls range from less than 100 at Ijokodo to over 5000 stalls at Dugbe, Gbagi, Agodi, Aleshinloye, while Amunigun and Gbagi has the largest number of stalls. In few of the markets namely Ode-Oolo, Basorun, Sango, Ayeye and Ile-Tuntun over 50% of the stalls are make shift type.

The quality of the physical environment in the city markets is generally deplorable as the markets lack essential amenities. With respect to accessibility of the markets to city dwellers, most of the markets are relatively accessible to their respective neighbourhood with the exception of New Gbagi and Aleshinloye, which are not very accessible. Almost all of them are open to the major roads but only 40 percent of the markets have parking spaces.

The sale of foodstuffs of various kinds, including raw, floured and cooked types dominate most the city’s markets. There are however, a few exceptions where foodstuffs are not sold. These include Amunigun, Gbagi and New Gbagi. A few of the markets concentrate on bulk sales of broad green leaves for wrapping and preparing cold pap. These include Ogbere, Elekuro, Apata and Oja Oba. The sales of rams and goats are largely controlled by Oja Oba and Oranyan while Orisunbare, in addition to rams and goats, also deals with the sales of cows. About 72 percent of the markets are involved in the sales of traditional herbs and the five most important ones are Ibuko, Oje, Oja Oba, Oranyan and Aleshinloye. The sales of manufactured goods also show a concentration of some items in certain specific markets.For instance, Aminugun specializes in bulk sales of pharmaceuticals and drugs. On the other hand, Oja Oba, Agbeni, Gbagi, Ayeye, Gege and Oritamerin have numerous parent medicine stores. Gbagi and New Gbagi specialize in both bulk and retail sales of both imported and home-made textiles.

Transportation

Transportation in Ibadan can be viewed from two perspectives of spatial linkages – the intercity and intracity linkages. Ibadan’s transport connections with its regions are highly related to its geographical location, administrative and commercial functions. Ibadan serves as the Oyo state capital and the seat of Ibadan Municipal Government Council making it the site for the location of office headquarters for both local and state governments. Adequate transportation and communication system is required for the city-region political linkages. Ibadan also serves as a commercial center with highly developed distributive trade. Within the city are several commercial and industrial companies, banking institutions, large departmental stores and markets. The various types of interaction between Ibadan and its hinterland depend on the availability of transport facilities.

The growth of the city rests on the extent of its market which in turn depends on transport facilities which tend to bridge the spatio-economic gap between the city as the producer and distributor of goods and services and the hinterland as the consumer of these products. Commercial, social and business transactions between the city and its region were made through caravans and human portrage before the advent of modern means of transport. Today, this has been replaced by motor vehicles, lorries and the trailer.

The railway line from Lagos reached Ibadan in 1901. Today, this railway line passes through the city dividing it into two parts – east and west and linking it with the south through Abeokuta, and to the north through Osogbo. Major commodities transported include livestock and foodstuffs such as beans, millet and guinea corn some or which are impoted from Kano, Jos, Bornu and Yola. However, the intensity of use of the railway line has decreased overtime due to several problems confronting the Nigerian Railway Corporation.

The type of roads in the city include bush path (mostly in rural areas),earth surfaced and bituminous surfaced roads. The total road length in the metropolis is 1,230,401.93 kilometer. The major roads connect Ibadan through Oyo to the North, Lagos to the south, Ile-Ife and Iwo to the east and Abeokuta to the Southwest. Within the city, these major roads pass through Fajuyi – Mokola – University of Ibadan road, Mapo-Isale-Ijebu stretch, Queen Elizabeth – Parliament road and Ogunmola street. The peak periods of the traffic that pass through these roads are 5-10 am when people are going to work and 3-5p.m. when people are returning from their work places. The eastern bypass constructed in 1979 links the toll gate/Challenge interchange in the south with Ojoo in the north. The by-pass reduces the transit time by urban commuters and also serves to facilitate the movement of interregional traffic passing through the city. The secondary roads in the city include the Orita Aperin – Olorunsogo – Akanran road: Agugu – Oremeji road and

Academy – Olomi road all of which make an overhead connection with the eastern by-pass. Figure 1.5 shows the transport network in Ibadan.

The administration of roads is undertaken by the 3-tier of government- Federal, State, and Local . Local Government manages 67 percent of urban roads, State Governments 27 percent and Federal Government 6 percent only (Adalemo,1999). The present federal system arrangement puts urban transportation predominantly under the control of the local government, whereas the local government is grossly under-funded and itself lack fund generating drive, technical expertise and other resources to provide for efficient urban transport infrastructure and service delivery Adelemo,1999;Schelling,2000). Thus, in Ibadan, like any other urban area in Nigeria, the provision and management of urban transport services and urban road networks is the responsibility of the local government which is the least able to respond to urban transport needs both financially and technically (Onakomaiya, 1983;1988, Adelemo,1999).

The major modes of road transportation in the city are private cars, taxis, buses, unlicensed private vehicles used for passenger's transport popularly known as 'kabukabu' as well as commercial motorcycles popularly called 'okada'.

CHAPTER THREE

THEORETICAL/CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

3.0 Introduction

In this chapter, the conceptual/theoretical framework and the relevant literature are discussed. Specifically, spatial interaction theory, theories of location, urban spatial structure and trip generation models are those of interest. They are concerned with the pattern of land use, location of activities and the movements of people in an urban centre. To some degree, their application is helpful in explaining intra-urban travel pattern and gasoline consumption.

3.1 Theoretical/conceptual framework

3.1.1 Spatial interaction theory

Spatial interaction implies reciprocal relations between different places and it is based on the principles of complementarity, intervening opportunities and transferability (Ullman, 1956). Complementarity implies areal differentiation and the existence of supply and demand in different areas. Bertikerlim (1933) argued that specific complementarity is a function of both the natural and cultural areal differentiation based simply on the operation of economics of scale.

The concept of intervening opportunity was originally postulated by Samuel Stoufer (1940) to explain the cause and dynamics of population movements. Intervening opportunities set up a constraint as to the possibility of interaction taking place. Complementarity between places can generate spatial interchange only in the absence of intervening opportunities. Intervening opportunity implies substitutability and is therefore a ‘spatial sponge’ which soaks up potential interaction between complementary places (Abler, Adam and Gould, 1971). However, intervening opportunity is not always a limiting factor to long distance interactions. It is possible for a sequence of such opportunities to create spatial interaction between widely separated regions by making intermediate transport links economically rewarding and consequently paying part of the costs of the link between distant places.

Transferability, on the other hand, relates to the ease with which such demands could be met and, in fact, it is distance measured in real terms of transfer and time costs. This results in agglomeration of human activities since some commodities are more readily transferred than others. If the time and money costs of traversing any distance are too large, movement will cease despite complementary relation and absence of intervening opportunity. If the time and money cost generate the stagnation of movement of commodities, the response will be either the substitution of products or people will forego the use of such commodities.

Thus, while complementarity may generate interaction, the factor of intervening opportunity results in a substitution of areas and the factor of transferability results in a substitution of products. The spatial interaction theory offers an explanation to the issue of spatial interaction in urban centers. The day to day movements of people which embraces activities like trip making to and fro from places of work, school, recreation and shopping centers are influenced by some of the determinants of the propensity to generate trips at the household or individual level and the location of the various land uses and activities. The travel behaviour of urban residents is thus viewed both as the prerequisite and the consequence of spatial separation of activities.

3.1.2 Theories of urban spatial structure

The classical theories of urban spatial structure strives to explain the patterns of land use through three major models. The organizing theme of these theories is the notion of economic rent, which can be defined as the net return from investment on land. The notion of economic rent was implicitly assumed in the concentric zone model developed by Burgess (Park et al, 1925). It postulates that urban land use is arranged around a single center, the central business district, in concentric zones made up of the zone in transition, the zone of the independent working men's houses, the zone of better residences and the commuters zone. The first zone, which is at the center, is the Central Business District. The predominant land uses here are financial, economic, social and recreational functions. It may also have some light manufacturing activities towards its outer fringes. The second zone comprise areas of residential deterioration as a result of the encroachment of business and industrial activities from the first zone. The third zone, the zone of independent working men's homes comprise largely the residences of second-generation migrants into the city, while the fourth transport zone contains the residences of the middle class and is occupied by managers and professional people. The commuters zone is a ring of encircling small cities, towns and hamlets which serve as dormitory suburbs for the wealthier city dwellers. The operation of the economic rent mechanisms underlies the process of invasion and succession of land uses which leads to the extension of the zone.

The sector model developed by Hoyt (1939) had its origins in the work of Hurd (1924) who described urban expansion as axial growth, pushing out from the centre along transportation lines. Hoyt's formulation was based on the empirical investigation of rent differentials and the ability of urban functions to bid for city lands. The effect of land pricing leads to the occupation of the central zones by central business district functions alone as they can afford the rent. On the other hand, the major lines of transportation constitutes lines of least resistance for growth in addition to their being important arteries along which similar types of land use are situated. This leads to the emergence of a star-shaped pattern of city growth in which different types of land uses radiate from the CBD along particular sectors towards the periphery of the city. Unlike the concentric model which emphasize distance from the city centre in the arrangement of land uses, this model takes into consideration both distance and direction.

The multiple nuclei model developed by Harris and Ullman (1965) postulated that the land use of a city is built around several discrete nuclei rather than one single nuclei as identified by the sector and concentric models. The number and the location of these nuclei vary from city to city depending on the size, the overall structure and the historical development of the city. Also, each of the land use type is spatially separated from one of a similar nature.

These models implicitly accept the fact that only central business functions such commercial and economic functions are able to pay the high rent demanded for such as central locations (see figure 3.1). Hurd (1903) and Haig (1926, 1927) formulated a micro-economic theory of urban land values by applying the ideas of von Thunen to the location of urban activities. Two concepts which featured prominently in their formulations are those of urban land rent and transportation accessibility. Hurd (1903) contended that urban land values depend on nearness to the most accessible points in the city. He pointed out that nearness is a relative term which has to be evaluated in terms of growth and physical structure of the city on one hand and the nature of the land use on the other. Haig (1926) saw economic rent as the price paid for accessibility or relative efficiency of various locations within the city arguing that transportation and rent combine to produce a pattern of land use. The optimal city structure according to Haig (1926), was one in which every site within the city was used in such a way that profit from the land was maximized.

As in earlier economic theories of urban land use, the notion of bid rent is very central to the urban land rent theory by Alonso (1964). Urban land is seen as scene of competition among different land uses which have different abilities to pay rent. The city center and areas with dense transportation network enjoy high accessibility, that is, they can easily be reached from all parts of the city. Hence, different land uses will compete for space near such sites. Competition for space near such areas, however forces up the values of land. But there is a decline of land values as one moves toward the periphery.

With respect to gasoline consumption, land use models attempt to describe and predict the geographical location of economic activities in an area. The location of agricultural land, household residences, retail shopping centers, industries and so on has a crucial effect on the distance traveled for passenger and freight movement within an urban area. Urban travel is undertaken by individuals who seek to reach destinations where their demand for
goods and services can be satisfied and workplaces. The aggregate distance traveled is a function of the spatial arrangement of land uses. Due to the high value of land in the city center only central business functions such as whosaling, retailing and manufacturing are able to pay the high rent demanded. In addition, the increasing population of the urban

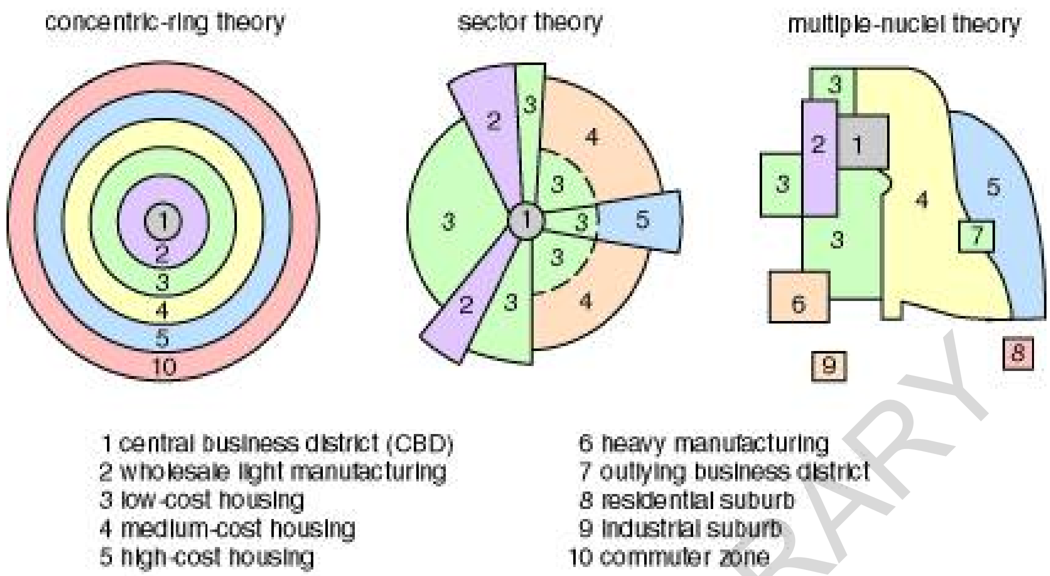


Figure 3.1: Models of urban spatial structure

Source: Ayeni(1980)

centers, urban poverty and the high cost of central city land leads to the construction of low income housing in the periphery of urban areas. Both the number of potential passengers and the distance component of their transport demand increases, thus, influencing their level of gasoline consumption.

3.1.3 Theories of location

The importance of transportation cost as a locational determinant can be seen through the examination of the facility location theories of Von Thunen (1966), Weber (1929) and Hoover (1948).John Heinrich Von Thunen (1906) was one of the first writers to theorize about the factors of production that affect the location of a facility. He proposed a theory of agricultural location in which he minimized transportation cost and maximized profits for a given product. He assumed an isolated city-state surrounded by a plain of equal fertility. Any product could be grown with equal success at any location on the plain. The city produced all the manufactured goods required for farming and the farms produced all the food required by the city (the market). The only mode of transport available was the horse-drawn wagon. Transportation was assumed to be equally accessible for all locations, that is, there were no transportation constraints. Also, transport cost was a constant rate per ton mile for all commodities. The farmers in the areas are all economic men. The concept of the economic man implies that such an individual is rational, has complete information for decision-making at his disposal, completely flexible and maximizes profit.

With complete mobility of production facilities, agricultural production would occur at the location where the farmer would maximize the difference between the market price and costs (production and transportation)- the profit maximizing point. With the market price fixed and production cost not varying by location, the transportation cost factor was the major location determinant impacting profitability. The concept of economic rent was used in the analysis. Because economic rent depends on transport cost, the intensity of land use varies inversely with transportation cost or distance from the market (figure 3.2). Locations at greater distance from the market would incur a greater

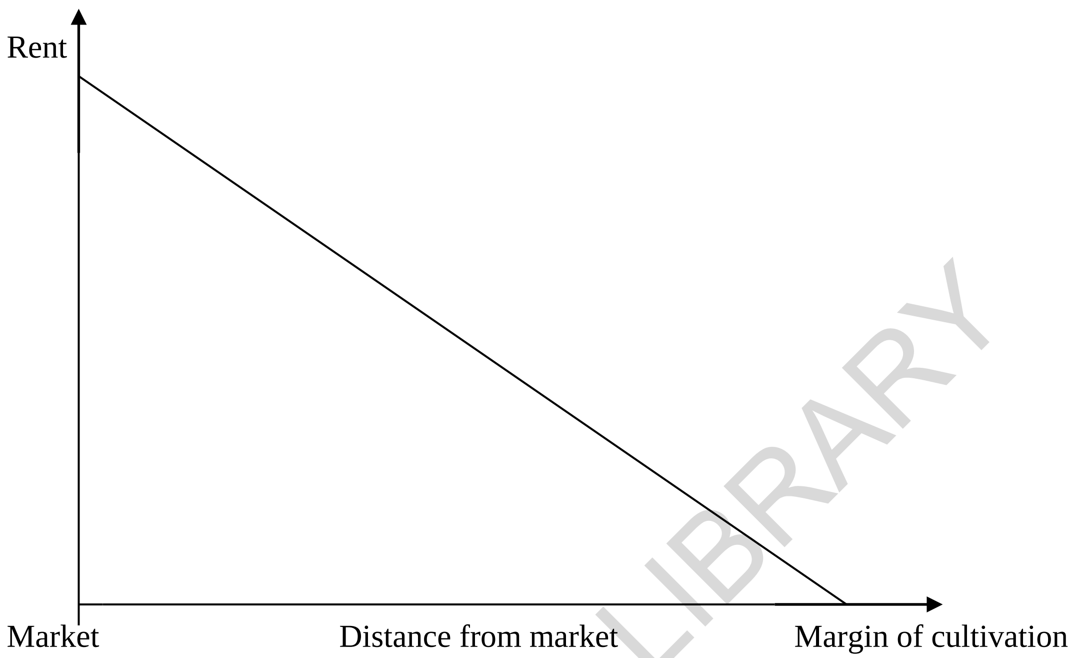


Fig 3.2: Economic rent curve

Source: Waugh (1995)

transportation cost according to Von Thunen. For products with low-value to-weight ratios, locations at greater distances from the market would not be economical, since the high weight would mean high transportation costs which the low-value products could not sustain. The importance of transit time for determining the location of perishable products such as fresh fruits and vegetables was also considered. In other words, perishable products should be produced near the market to minimize the transit time, thereby assuring delivery of the products in good condition.

The outcome of his work was the development of a series of concentric rings around the city. Within each ring, the agricultural product that should be produced at that location was identified so that profitability could be maximized and the transportation cost and transit time minimized. The first ring would be used for horticulture and dairy farming (perishable and low value products), this would be followed by sylviculture, intensive arable rotation, arable with long ley, three-field arable and ranching.

Alfred Weber (1929) developed a theory for the location of industrial plants. In formulating his model he assumed that the area of interest is uniform; the location of the raw material source is known: the location and the size of the market is known: there are fixed labour locations: institutional factors such as taxation and interest rate are unimportant; and transportation would be equally accessible at a constant rate with respect to distance and weight. The rate was the same for both raw materials and finished goods. His theory is based upon total transportation cost minimization. The least cost location is one that minimizes the cost of moving raw materials to the plant and finished goods to the market
(see figure 3.3).

He classified raw materials according to geographic availability and the weight lost in processing. The geographic availability characteristic states that a raw material is either ubiquitous or localized. An ubiquity is a raw material that is found at all locations, hence, do not require transportation to the plant. A localized raw material is found in certain locations only and requires transportation from its source to the plant. A raw

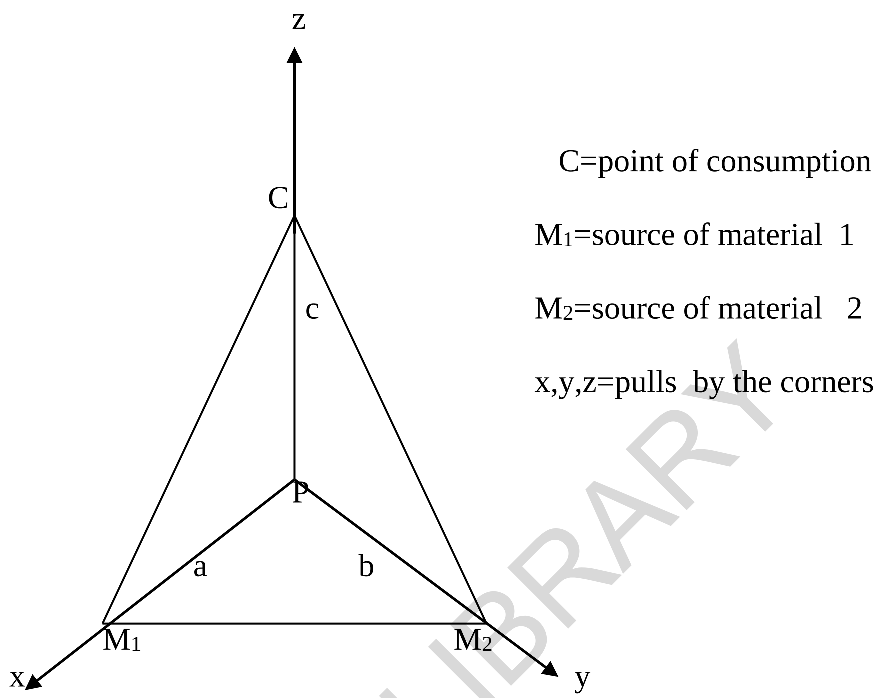


Fig. 3.3: A locational triangle in Weber's space economy.

Source: Smith (1980)

material possesses a weight lost-in-processing trait. A raw material that does not lose weight in processing is termed a pure raw material and one that loses weight is a weight loosing material.

He introduced the concept of material index which he defined as the ratio of the weight of the raw material to that of the finished product. A market oriented plant location is the least-cost location when an ubiquity, either pure or weight-losing is used. If the raw material is localized/pure, the optimum location for a plant is the raw material source, then market, the midpoint between the two or anywhere in between. The optimum plant location for a localized/weight-losing raw material is the raw material source.In addition, he also contends that in addition to transport costs, labour cost and agglomeration economies are fundamental in the choice of plant location. This happens where the saving from such locations exceed the additional transport costs.

Hoover (1948) developed a least-cost approach to facility location. He considered demand factors such as the effect of transportation costs on the price of the product, and the resultant demand for the product; agglomerative forces and industrial costs (see figure 3.4). According to him, transportation rates increase with distance, but not in direct relationship to distance. This non linearity of rates to distance is known as the tapering rate principle (Taafe and Gauthier, 1973). For localized pure raw materials, the tapering rate principle makes the location of a plant at either the supply source or the market the optimum location (not anywhere in between as Weber suggested). He noted that carrier availability is not homogeneous throughout the country. A location that has few carriers available to provide service may charge higher transportation rates than areas that have many carriers who carry at lower rate to attract shippers. Also, transportation cost varies from company to company. For firms shipping in less-than-truckload quantities, transportation cost may be more important than for firms shipping in truckload quantities. The transportation characteristics of the firm's product affect the rates charged and the importance of the transportation cost factor as a locational determinant.

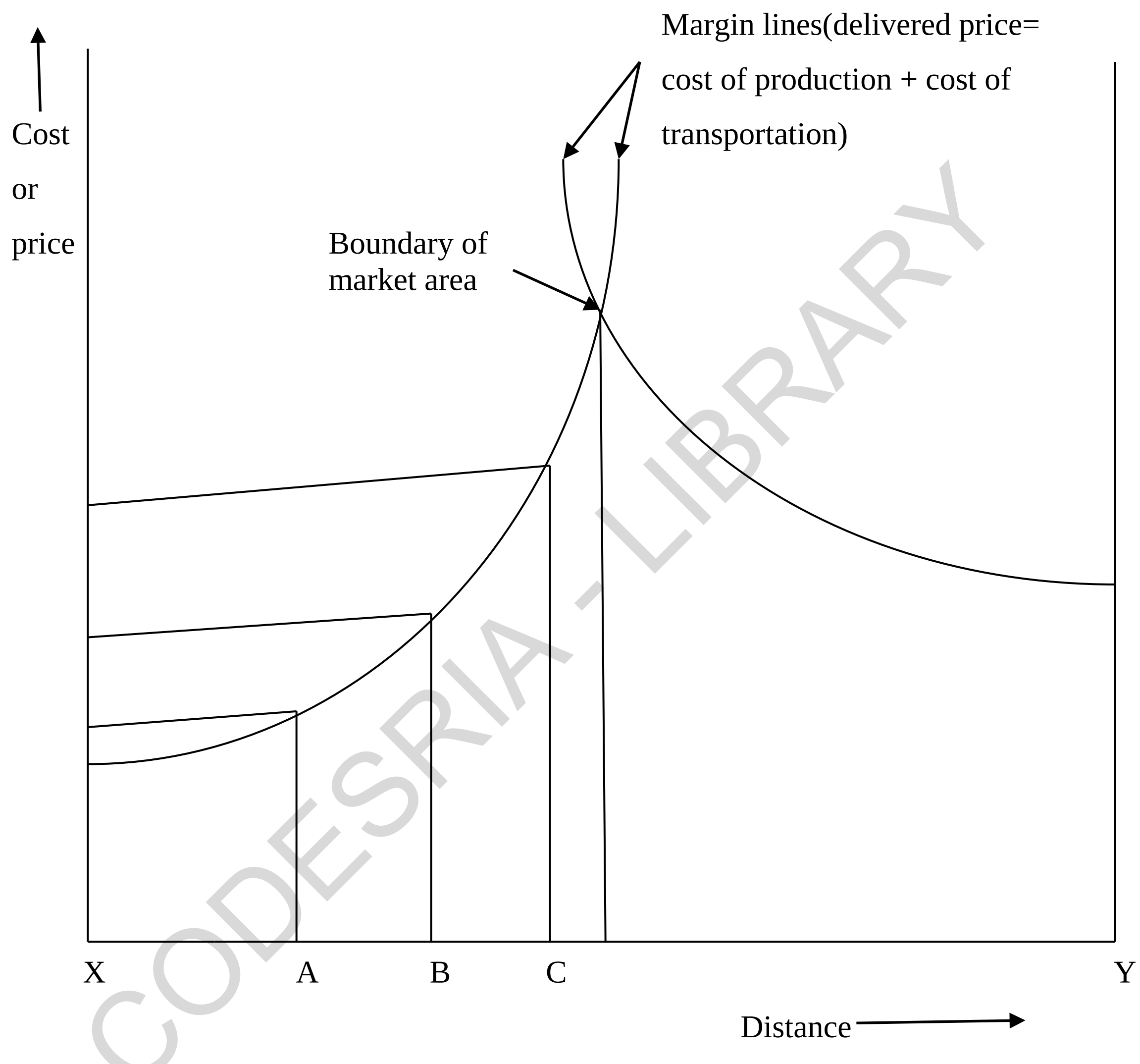


Fig. 3.4: The boundary between the market areas of two producers under conditions of diminishing returns to scale.

Source: Smith (1980)

The theories of location view transport cost as the primary determinant of plant location and the least-transport cost location is considered the best location in the absence of production costs. Transport costs are considered as a function of weight to be carried and distance to be travelled. Since the amount of energy used to drive the vehicle (gasoline for highway transport) is influenced by distance traveled, then, an attempt to minimize transport cost also leads to a reduction in transport energy consumption. Hence, a least-transport-cost plant location seeks to minimize gasoline consumed for passenger and freight transport.

3.1.4 Trip generation models.

Trip generation models are widely used in household trip generation studies and they include, the Growth factor, Cross-Classification or Category analysis and Multiple Linear Regressions (see Stopher and Meyburg,1975; Ortuzar and Willumsen, 1990; Oyesiku,1990, 1995a; Bruton,1975; Turton,1992;Ayeni,1979; Robinson,1998).

(a) Growth Factor Model

The growth factor model attempts to estimate future number of trips by households for a specific purpose by any of specified categories of household attributes based on current trip rates. The model is of the form in equation 1.

$$Ti = Fi\ ti \ldots\ldots.1$$

Where Ti = future trips in zone i

ti = the current trips in the same zone,

Fi = the growth factor

The growth factor (Fi) is defined as in equation 2.

$$Fi = f(P_i^{d} I_i^{d} C_i^{d}) / f(P_i^{C} I_i^{c} C_i^{c}) \ldots\ldots\ldots..2$$

where ‘f’ = direct multiplicative functions,

P,I,C = variables such as population, income and car ownership respectively

D,c = the future and current situations respectively.

The growth factor assumes that the average trip rates will remain constant. Based on this estimate, future number of trips can be derived. Because of this assumption of constant trip rates, the model has been described as crude and tending to over-estimate total number of trips (Bruton,1975;Ortuzar and Willumsen,1990;Oyesiku,1995a).

(b) Cross-Classification or Category Analysis

Cross-classification or category analysis is a similar model to the growth factor because it also attempts to estimate the number of trip productions on household basis for a given trip purpose as a function of household attributes. Furthermore the model assumes that trip generation rates are relatively stable over time and space, and household categories are defined so that within-category variations in trip rates are negligible. The number of zonal trip generations may then be estimated by simply multiplying the appropriate trip rates by the number of households, by category and zone and by summing up the products over all household categories. The model in its standard form is in the form of equation 3:

$t^p(h) = T^p(h) / H(h)$……………………………..3

where

$t^p(h)$ =the total average number of trips with purpose P by households of type h at a period t;

$T^p(h)$ = the observed trips by members of households of type h for a purpose P:

H(h) = the number of households in type h

Like growth factor model, the cross classification model in its rudimentary form has some disadvantages. It is not possible to test the statistical significance of the explanatory variables used to define the categories; the technique is also relatively inflexible when it comes to adding new variables which create another dimension of categorization; and computer programs are much less readily available (White and Senior,1991).

(c) Multiple Regression Model

To gain insight into the reasons for travel demand variations, the widely applicable multiple regression model could be used to relate, for example, a measure of household trip generation to plausible explanatory variables such as car ownership, household size and income. In general terms this model relates a dependent variable, Yu, trip generation, recorded over a set of observation units, u (which may be households, organizations or zones), to a set of independent variables, Xu1 Xu2…..Xui , measuring various characteristics of these same units which are deemed to explain variations in the value of the dependent variable. This may be specified as:

$$Yu = a_o + a_1Xu_1 + a_2Xu_2 \ldots\ldots\ldots\ldots\ldots aiXui + eu$$

Y = dependent variable

a_o = constant term/intercept

a_1, a_2, au = regression coefficient

x_1, x_2, xu = independent variables

e = error term or residuals.

The approach of this model is entirely mathematical, therefore, statistical test of reliability of the derived relationships can be applied with ease and computer programs are readily available. Although multiple regression appears a highly attractive technique for exploring multivariate travel demand situations, its validity is dependent on a set of assumptions which should not be seriously violated (Silk,1979; Johnston,1978);

1. the dependent and independent variables are observed without measurement error;
2. the array of the dependent variable for a given combination of independent variables(x1, x2……..xj) follows the normal distribution;

3. that for each specific combination of values on the independent variables x1, x2……xj, the dependent variable, Y, is a univariate random variable;
4. the regression of the dependent and independent variable is linear;
5. the variance of the dependent variable should be the same for any fixed combination of the independent variables x1,x2….xj;
6. the independent variables must not be strongly correlated with each other, otherwise multucollinearity is said to exist – indicating that two or more variables are at least partly explaining the same variation in the independent variable. A correlation coefficient in excess of 0.8 is usually taken as indicating serious problem of collinearity or multicollinearity;
7. the dependent variable is statistically independent, that is, there should be no serial or spatial autocorrelation.

The regression model performs two basic functions: explanatory and predictive. The explanatory function of the model is concerned with an attempt to explain the separate influence of the independent variables in order to establish the importance of each or some combination of some of them on the dependent variables. The predictive function is concerned with the aggregate or combined influence of all the independent variables on the dependent variable. In this study, both the explanatory and predictive functions of the model are used. The explanatory function is used to examine the influence of vehicle registration, number of industries, population size, density, length of roads on gasoline consumption in Nigeria; the influence of each of the socio-economic variables like income, age, auto ownership etc on household trip generation and gasoline consumption, while the predictive function is used to establish the combined effect of all the independent variables on gasoline consumption at the national and household levels.

An important advantage of the multiple regression model over and above others in trip generation modeling is its capacity to allow for dummy variables to be included in the model. A number of household variables as trip generation determinants could not be measured at interval, ratio, or continuous scales, but in binary forms. The inclusion of the dummy or binary variables in the regression model is a process that increases the application of the model and does not cause its estimates to lose any of their properties.

In this study, the multiple regression techniques are used to explain gasoline consumption both at the national and household levels. Two main reasons account for the choice of this model among other trip generation models: first, its wider applicability, the ease of inclusion of dummy variables as determinants of gasoline consumption and disaggregated nature of the data in trip generation as utilized by Stewart and Bennet,(1975); Ayeni, (1979); Keyes, (1982); Holtzclaw et al,(2002); Spence and Frost,(1995); Naess et al (1995); Ojo,(2004); Banister,(2007)Giuliano and Narayan, (2000).

The explanatory and predictive functions of multiple regression model make it particularly relevant to this work than any other trip generation model. It has the ability to reveal the relative influence of urban form and socio-economic characteristics on household travel pattern and gasoline consumption.

3.2 Literature review

Analyses of the influence of urban development patterns on travel behaviour can be traced back to the beginnings of the modern practice of transportation engineering. For many years the task was predominantly "predictive" _ predicting where land development would occur, estimating the associated travel demand, and providing the necessary infrastructure. For example, an early review of metropolitan transportation studies in the United States focused on the relationship between population density and transportation system requirements, aiming to assess how urban growth patterns influence travel demand and transport system needs; the analysis provides no mention, however, of how densities might be used to produce desired transportation outcomes (Levinson and Wynn, 1963).

Nonetheless, evidence of a "prescriptive" focus (that is, land use as a transport strategy) can be found in at least the early 1950s.For example, Carrol (1952) looking, basically at the jobs-housing balance in several still-industrial U.S cities, concludes with a call for "cohesive satellite development" of urban areas as part of a strategy to reduce the quantity of work travel, thereby "attacking the traffic problem at the most effective point" (p 282). An analysis conducted from 1948-1953 in 30 US cities, aimed to understand the factors influencing public transportation and automobile use also included the influence of land use distribution factors. In the Netherlands, explicit policies using spatial planning to influence travel behaviour began in late 1960s, with the advent of large scale modeling of the relationships between land use and transportation, came several analyses of hypothetical cities aiming to gauge the influence of various structural differences in urban form (for example, linear versus cartwheel) (see Jamieson et al, 1967) on transport costs. The early 1970s, at least in part spurred by the energy crisis, saw a growing number of relevant studies in the United States both simulation and empirically- based (Gilbert and Dajani , 1974 provide a review). At that time, some analysts were already calling for restructuring cities in the US- expressing concern over the development patterns of the previous thirty years and calling for a focus on multi -centric urban development, with a proximity focus and the promotion of non- motorized transport (Orski,1974). Simulation and empirical comparative studies continued to be developed in the 1980s (for example, Edward and Schofer,1976;Cheslow and Neels,1980: Small,1980: Kim and Schneider, 1985). At this time, sustainable transport began seeping into relevant discourses.

Towards the end of the 1980s, a focus on "neo-traditional development" emerged, which grew into the "new urbanism movement", largely reflecting the principles of the "urban village" concept (CNU, 2001). Today, these principles can largely be found within the rhetoric of the broader new urbanism family, including traditional neighbourhood development, transit –oriented development, and more broadly "smart growth". Within these urban planning and design philosophies, resolving transportation ills (such as congestion, auto dependence and energy consumption) figures highly, as evidenced in a seemingly never-ending flow of relevant analyses, including more recent effort to make direct links to other public policy concerns such as obesity and public health.

3.2.1 Studies on the influence of land use on travel characteristics outside Nigeria.

The rest of the world outside Nigeria offers a wide scope for sampling studies on the influence of land use on travel characteristics. Different studies have examined the relationship between various land use characteristics and travel patterns (such as travel distance, journey frequency, modal split, travel time, transport energy consumption, etc). These studies can be differentiated based on; the spatial scales (the metropolitan, intra-metropolitan and neighbourhood scales); whether the travel data used are aggregate (that is, averages for cities or zones) or disaggregate (that is household or individual observations); and whether the analytical techniques are largely comparative; based on multivariate regression or based on discrete choice models.

The broader analytical categories, simulation or empirical aim to differentiate between those analyses which explicitly contain some projective modeling effort ("simulation") and those which simply aim to explain observed behaviour ("empirical") . Within the simulation category, ''real'' refers to simulations based on actual empirical data; hypothetical refers to analyses based on "hypothetical" cities/data (not on hypothetical future conditions of an actual city). Simulations can also include very basic projections based on regression models: some empirical analyses include some explicit simulations/projections. It is helpful to recall that simulation generally depend on some empirical (observed) relationship. So, while empirical methods aim to detect differences, simulations use known relationships (based on empirics to estimate/ predict effects.

Several studies (Edwards and Schofer, 1976; Gordon et al, 1986:Hanson and Schwab, 1987: Kain and Fauth, 1977: Newman and Kenworthy, 1988: Payne-Maxie consultants, 1980 and Pushkaver et al, 1982) have revealed a wide variety of measures used in empirical studies of transportation- urban form relationships. They can be divided into three groups: measures of urban form, transportation supply and transportation demand.

Urban form measures are based on the distribution of activities e.g. population and employment. These distributions can be used to develop measures of concentration (for example, degree of compactness) and of spatial distribution (for example monocentric vs polycentric). They are also used to develop more descriptive measures of overall form (for example, square, circular, axial) or of internal structure (sectoral, concentric zone, multiple centers). Indirect measures of urban form such as city age, decade of most rapid growth and modal orientation are also used.

Transportation supply measures are of two types: those that describe network characteristics and those that express quantities of transportation system components. Network characteristics include geometric form, mode and extent or intensity. Measures of transportation system components include quantities of transit services provided, freeways, arterial and the types of facilities provided. Also, there are measures of transportation system performance which reflect the outcomes of supply and demand on the system such as freeway and arterial level of service, intersection capacity utilization.

Transportation demand measures can be divided into two categories: aggregate measures and disaggregate measures. Aggregate measures include both indicators of total demand (for example vehicle mile travel, gasoline consumption, transit passenger miles) as well as rates (for example vehicle mile travel/population, transit trips/population, average daily travel). Disaggregate measures focus on individual or household travel demand. These include trip characteristics (time of day, mode, cost, length), amount of travel (trips per day, vehicle per day), and measures of travel propensity.

Population density is the single most frequently used indicator of urban form. Traditional urban economic theory posits household location as a function of job access, housing costs and the costs of all other goods and services. It is assumed that all employment is located at the center of the city. Under these conditions, households compete for locations as close as possible to the city center, generating a declining land rent gradient that is reflected in a corresponding declining population density gradient.

The population density distribution has been used to measure changes in urban form (Griffith, 1981:Guest, 1975: Greene, 1980), to compare the relative concentration (or extent of decentralization) between different urban areas (Clark, 1951: Mahanassani, et al., 1988) and to test for the existence of monocentric urban form (Odland, 1978: Gordon et al, 1986: Getis, 1983). Research results indicate a consistent trend of population decentralization, declining densities throughout urban areas as well as flattening of the density gradient.

In the early 1960's, Levinson and Wynn (1963) reviewed several studies from the late 1950s and early 1960s in select U.S. cities, examining relationships between city age, and density and automobile ownership (and use) and public transportation patronage; they find "the most significant effect of density" to be the "close relation" with public transport use and suggest that city density is a valuable basis criterion for evaluating urban transportation needs. In the mid-1960s, Beesley and Kain (1964), using data from 45 US cities in 1960, developed a regression model to predict automobile ownership as function of median household income and gross city-wide population density; and Kain and Beesley (1965) using data from the same 45 US cities, derived reduced form equations to predict transit use based on income and density, finding the indirect effect of density influencing auto ownership and , thus, transit use to be larger than the direct effect of density influencing transit use.

In the 1970s, Pushkarev and Zupan (1977), investigated inter-city comparisons to identify metropolitan area land use characteristics (for example, size of residential densities) that influence public transport demand (e.g. percent of workers using public transport for trips to work). Cheslow and Neels (1980) drawing from data on eight US metropolitan areas, conclude "the more compact or dense an urban area is, the less fuel used" (p. 764).

Keyes (1982) analysed the linkages between energy and metropolitan development by employing direct measures of energy use, that is, gasoline consumption in gallons from the 1972 census of retail trade as the dependent variable. The key development variables chosen were (i) total population in the urbanized region(the contiguous area to each

SMSA with a population density of at least 100 people per square miles) (ii) population density of urbanized region (iii) the proportion of the urbanized region population living in census tracts of 10,000 or more people per square mile (iv) a regional population clustering index (the standard deviation of census tract population densities divided by the mean density) (v) the population of total SMSA employment located in the CBD transport variables include the miles of freeways and roads with four or more lanes: the line miles of bus, commuter travel and travel routes. Economic variables used were the household income levels and average gasoline price levels of 1972. Values for the transportation system variables were taken from the 1972 national transportation survey conducted by the US Department of transportation 1972. Values for the household income were obtained from US Bureau of census and labour statistics while the price of gasoline was taken from the oil and gas journal. The number of SMSA's investigated varied from 15 to 49 reflecting the availability of data for the various explanatory variables. The result of the multiple stepwise regression analysis showed that metropolitan areas with high average densities, one or more high density nodes and many residents living in neighborhoods of 10,000 or more people per square miles have lower gasoline consumption levels. Those with large populations and higher employment level in the CBD are associated with higher levels of gasoline. Large metropolitan areas with centrally focused employment opportunities require greater distances for residents to reach travel destinations. With respect to population size and density, large SMSAs showed lower per capita gasoline consumption levels. Also, gasoline prices and the transportation variables had significant effect on gasoline consumption.

At the end of the 1980s, Newman and Kenworthy (1989) offer some of the most oft-cited studies-an international comparative analyses of urban areas, which, through simple bivariate correlations, they claim support for the argument that denser cities result in lower per capita gasoline consumption. This is because high density environments which imply spatially concentrated origins and destinations or high accessibility are associated with traffic congestions, lower travel speeds and shorter trips. Under these conditions, transit, walking and bicycle trips are more frequent. The cities with the highest densities were those with low car usage and high levels of provision of public transport. Low density environments imply spatially dispersed origins and destinations. These environments are associated with long trips, high travel speeds, less congestion and reliance on the private automobile.

Figures from research by Gordon et al (1989a) show no easily identifiable relationship between urban population size and modal choice. In a study of commuting patterns in the ten largest urbanized areas in the United States, the proportion of car journeys was found to be least in New York(which has the largest population of the areas studied) and highest in Detroit (which has the sixth largest population of the areas studied). In the 1990s, Schimek (1997) through multivariate regression models, explored several influencing factors on public transport rider ship in US and Canadian cities, found a modest influence of urban area population density and central city employment relative to other factors, including public transport fares and service levels and household auto ownership.

Several studies have identified the influence of city size and structure on travel pattern and gasoline consumption. Stewart and Bennett (1975) employed a purely empirical approach to determine the effect of city size and structure on gasoline consumption. Using 1972 gasoline oil sales by service stations reported in the census of Business (U.S Bureau of the census), (1967), variations among 134 standard metropolitan statistical areas (SMSA'S) were related by regression analysis to various characteristics of these areas and their populations. Population size, population density (both inside and outside the central city) and rate of growth (1960-70) served together with city age and a rough measure of industrial character (based on Rand McNulty classification of the city as a diversified or manufacturing center) as descriptors of urban structure. A direct measure of transit usage (percent of workers using public transit for work trips) was also included. Other explanatory variables include demographic and socio-economic aspects of the population; income, proportion of the population 16 years and over, 65 years and over and the percentage of non whites and the price of gasoline. To reflect the importance of non residents as purchasers of gasoline, the ratio of receipts from hotels, motels and tourist courts to SMSA population was introduced as independent variables.

The authors argued that per capita dollar sales of gasoline to SMSA residents should be lower in older, slower growing or declining SMSA'S and those with (a) smaller populations, (b) more compact development patterns (greater percentage of people in the central city), (c) higher population densities (d) diversified economies (e) high transit patronage. They found however, that among these variables, only SMSA size, growth and transit usage were statistically significant and size had an effect opposite to what was postulated. Also, status as a diversified manufacturing center significantly raised per capital gasoline sales while status as a sea or lake port on the other hand significantly reduced per capital gasoline sales. A possible explanation of this result is that sales of gasoline and oil products in an SMSA do not significantly reflect gasoline actually consumed by SMSA residents for personal travel. Sales to non residents or to residents for non travel purposes could obscure underlying relationship.

Simulations were used by Edwards (1979) in his study on the effect of structure of urban land use and transport networks on the consumption of energy in urban passenger travel. Data from an existing city was utilized together with spatial allocation models to simulate travel behaviour in a series of hypothetical cities. The basic attributes of the selected case study city were those of Sioux Falls, South Dakota found in a 1965 metropolitan transportation study. The major factors found to be important in explaining differences in energy use were (i) the urban form (ii) the overall level of service provided by the transportation system and (iii) extent to which public transit play a role in the transport system. With respect to the first component, four dimensions were separately identified as contributing sub-components namely (a) urban shape, whether concentric, ring, linear, poly-nucleated or cruciform (b) the geographic extent (developed land area in square miles) (c) the degree of concentration of population about the city centroid and (d) the degree of employment concentration about the city. A total of 35 experiments were conducted. Total energy was defined as the energy required to accomplish all daily person travel, from home to work, from home to service establishments type, N, from home for social purposes and one half of the total daily non home based travel. Regional accessibility to population was defined as the product of the population residing in a zone and the work-trip friction (impedance) factor incurred between zones i and j.

The author observed that urban structures characterized by sprawling land use patterns have energy requirements which are much large than those that are relatively compact. Also, cities which utilize only the automobile as the only means of transport have energy requirement which are generally much larger than those cities which employ public transport. Urban structures with the same basic urban shape (concentric ring) vary in energy requirements and accessibility according to whether the density pattern of activities (population, employment of each type) is sprawled or concentrated and depending upon the relative importance of the automobile in the overall transportation system.

Schneider et al (1985) investigated the relationship between urban form and energy consumption in passenger transportation. A hypothetical test city composed of 52 zones arranged in a square 10 mi on each side was used as a base for the experiments. The city consist of a CBD with an area of 1 mi divided into four zones. Three additional rings of zones surround the CBD resulting in a grid pattern. The city was assumed to have a population of 100,000 and includes 15,000 employees in basic industries out of a total employment of 40,000). The city was centralized with over 50% of the population and total employment located in the CBD and its fringe.

The transit network was a set of radial notes focused on the CBD. All zones including the CBD were served by at least one of the six bus routes and each route begins and ends in the zones. A simulation model which consist of four sub-models: a Lowry type land use model, a binary logit model, choice model, a capacity restrained equilibrium assignment model and a transportation energy consumption model was used to allocate population and service employment among the zones. The urban form statistical program was used to compute urban form measures grouped into six categories: the Lorenz Curve and derived measures: Bachi measures; cartographic and related measures, potential aggregate travel and density gradient measures. Eighteen experiments were formulated and simulated on three types of urban patterns (concentration, dispersion and poly-nucleation) to obtain the data used to examine the relationship between urban form and transportation energy consumption. A simple linear regression where total energy consumption was the dependent variable and each urban form measure (standard distance, potential measures, aggregate travel measure, population density in the CBD was the independent variable was used.

The study revealed that higher concentration of population in the center of the city, better access to the center and higher population densities reduce energy consumption. The concentrated urban form was the most energy efficient and the dispersed form was the least energy efficient with the dispersed form was the least energy efficient with the poly-nucleated form falling in between. With respect to standard distance, a measure of spatial dispersion, a longer standard distance produced greater level of energy consumption.

Recently, Bento et al, (2004) used the 1990 Nationwide Personal Transportation Survey (NPTS) to explore household travel behavior in the urbanized portion of 114 US Metropolitan Statistical Areas (MSAs). This study differs from previous studies in that it uses disaggregate individual travel data together with macro-level land use measures, together in a discrete choice modeling framework. For the urban areas, they construct various measures of urban structure and public transport supply, including city shape (how close to "circular" the city is), city size (urbanized area), road network density, population centrality, jobs-housing balance (deriving a zip-code based Gini-coefficient), and normalized bus and rail route miles supplied. They use this data to estimate multinomial logit (MNL) choice model (0,1,2, 3 vehicles): and an ordinal least squares model (using the selectivity correction approach to link the vehicle choice MNL) to predict vehicle distances traveled. Their findings indicate some influence of urban structure measures: increased road density decreases rail choice: increased sprawl decrease bus use but increase rail use; and jobs-housing balance increase non- motorized mode choice. For the vehicle choice models, they find increased sprawl to increase vehicle ownership trends, but confounding effects of density and land area. Finally, in the OLS regression, they find road density to increase vehicle use for 1 vehicle households and more circular city to decrease auto use for one vehicle households. Overall, the detected macro- level urban structure variables are insignificant (furthermore, the OLS equations have very low explanatory power: the relevant statistics for the MNLs were not reported.

The relative separation/ location of different activities influence travel distance and gasoline consumption. Spence and Frost (1995) describe the changes in commuting distance between 1971 and 1981 in the three largest cities in Great Britain: London, Manchester and Birmingham and show how commuting distance changes with increasing distance between home and the urban center. In London, commuting distance increases almost linearly with distance between home and urban centre. At a distance of 20 kilometres from the centre of London, commuting distance continues to increase with increasing distance from the centre of the city. In Manchester and Birmingham, however, the relationship is different. Commuting distance in Birmingham first increases with increasing distance between home and the urban centre but at a distance of around 7 kilometres from the urban centre, commuting distance reaches a plateau. At a distance of around 9 kilometres from the centre, commuting distance begins to decease as distance from the urban centre increases. Commuting distance in Manchester first increases with increasing distance from the urban centre. At a distance of around 5 kilometres from the centre, commuting distance reaches a plateau and does not change with further increases from the city centre unlike the trend in commuting distance in Birmingham which begins to decrease at a distance of 9 kilometres from the city centre. The trends in commuting distance by distance from home to the urban centre in the three cities between 1971 and 1981 are similar.

Naess et al, (1995) identified a statistical relationship between the distance from the urban centre and travel distance per person in Oslo in which total distance increases with increases between home and the urban centre. It is claimed that the distance between home and the urban centre is an important determinant of travel distance in addition to factors such as car ownership and the proximity to local facilities from the home. In a study of travel patterns in various locations in and around Oxford, Curtis (1995) shows that average work journey distance may be linked to the distance between home and urban centre. A link between average non-work journey distance and the distance from home to urban centre is much less apparent. Average work journey distance is lowest in the two locations closest to the centre of Oxford (Botley and Kiddlington) and highest in the two locations furthest from the centre of Oxford (Bicester and Witney). As for non-work journeys, average travel distance is highest in Witney, Bicester and Botley, the first two locations being most distant from the city centre and the latter being closest to the city centre of Oxford. The lowest average non-work travel distance was recorded in Kiddlington, a location close to the centre of Oxford. According to the data collected by Curtis (1995) the frequency of work and non-work journeys does not vary significantly according to the distance between home and the urban centre. The proportion of journeys by car may be related to some extent to the distance between home and city centre. The proportion of car journeys is lowest in the two locations closest to the centre of Oxford and highest in the two locations furthest from the city centre.

Naess et al (1995) examined the effect of distance from the home on transport energy consumption. Transport energy consumption increases as the distance between home and the urban centre increase. A causal model containing a variety of land use and socio-economic variables were constructed. It was claimed that car ownership has the greatest influence on energy consumption, followed by the distance between home and the urban centre, the proximity to local facilities from the home, income per capita and various other socio-economic factors. Mogridge (1985) demonstrates a near linear relationship between distance from home to the centre and energy consumption. The relationship is shown to be very similar in both London and Paris. On average, residents living at a distance of 15 kilometres from the urban centre consume more than twice the transport energy consumed by residents living 5 kilometres from the urban centre. Similarly, Newman and Kenworthy (1998) identify the relationship between transport energy consumption and the distance from the central business district in Perth. Like Mogridge (1985), Newman and Kenworthy demonstrate a linear relationship although the latter is not as steep. It is reported that residents living at a distance of 15 kilometres from the central business district consume approximately 20 % more transport energy than residents living 5 kilometres from the central business district.

A study of Dutch residential areas found relative location (that is, “inner city” or “outer city”) to predominate in determining total household transportation energy use (although, most other potentially influencing factors such as income are not apparently controlled for) (van Diepen and Voogd,2001). Similar effects of distance to CBD increasing travel length have been reported for Oslo (Roe, 1999) while Hanson (1982) reports of more modest effects of ‘relative location’ on average trip distances for Uppsala. For San Diego, Crane and Crepeau (1998) find increasing distance from the CBD to be positively related to household car trip frequency. The role of relative location (measured by gravity function-type accessibility measures) on travel distance is confirmed by Cervero and Kockelman (1997) and Krizek (2003c) and on (auto) travel time by Srinivasan (2001). Krizek (2003c) finds no influence of regional accessibility on the number of tours (that is, trips with potential chaining) nor on the number of chains in a tour, while Srinivasan (2001) does find an apparent influence of auto accessibility on trip chaining propensity and travel time.

The proximity to transport networks also influences travel patterns and consequently transport energy consumption. Better access to major transport networks, particularly road and rail networks increases travel speeds and extends the distance which can be covered in a fixed time. Major transport networks can have a powerful influence on the dispersal of development- both residential and employment development. The proximity to major transport networks may lead to travel patterns characterized by long travel distances and high transport energy consumption. Headicar and Curtis (1994) report that the proximity to major transport networks has a substantial effect on work travel distance. They conclude that the proximity to either a motorway or a main road is associated with longer travel distances and a higher proportion of car journeys. Kitamura et al (1997) report that the distance from home to the nearest bus stop and railway station affects the modal share. The proportion of car journeys increases and the proportion of non-motorised journeys decreases with increasing distance from the nearest bus stop; the proportion of rail journeys increases with increasing distance from the nearest railway station. Cervero (1994) shows how the proportion of rail journeys decreases with increasing distance from the railway station. Residents living within 500 feet (approximately 150 metres) of a railway station in California use rail for approximately 30 percent of all journeys. The further the distance from the railway station, the lower the proportion of rail journeys made. Residents living at a distance of around 3,000 feet (approximately 900 meters) from the nearest railway station are likely to make only about half the number of rail journeys than residents living within 500 feet of a railway station. This pattern of rail use is similar in Washington, Toronto, and California. However, Stead (1999) finds little evidence in Britain of a link between the proximity of homes to a railway station and travel distance. Thus, the proximity to transport networks influence travel patterns and consequently transport energy consumption.

Another factor contributing to the increase in gasoline consumption is the increase in vehicle ownership. Automobile ownership rose throughout the world in the last twenty years (Morris, 1993) and in Nigeria in particular (Okpala, 1981). Lave (1992) described auto dependency as an irresstible force that is essentially unstoppable anywhere in the world where affluence is increasing. As income rise, the value placed on time increases and this shifts transport demand from lower, cheaper modes of transportation to speedier, more expensive modes, which means, in most urban transport situations, the automobile. The continuous increase in private car ownership brings with it a very large increase in per capital energy use for transport (Meyers and Sathaye, 1991).

The study by Hoch et al (1989) examined the relationships determining transport energy consumption in developing countries. Data on transport energy consumption and other variables were obtained from secondary sources such as the International Energy Statistics and so on. For most countries, road transport accounted for about 80% of the total with the exception of countries that has well developed railway system such as India. Gasoline was the major road transport fuel and its consumption rose rapidly between 1960-1982 in all countries. This increase went hand in hand with the expansion of the vehicle fleet. Consumption of gasoline per car was higher in low and middle income countries than in industrial countries. This was due to the use of more fuel efficient cars in industrialized countries. Also, increase in gasoline consumption was closely associated with increase in per capita income. Data on consumption of transport fuels, levels of income and prices of fuels and automobiles were used in a number of regression equations to obtain estimated income and price elasticity's. For developing countries as a group, 1 percent increase in per capita income was estimated to cause more than 1 percent increase in gasoline consumption and automobile registration.

Various studies (Kockelman, 1996; Fisher and Dumphy, 1990: Schimek, 1996: Gordon and Richardson, 1989) have analyzed variables influencing auto ownership and use. The mixing of land uses affect the physical separation of activities and is therefore a determinant of travel demand and auto use. Some evidence suggests that the mixing of land uses is not as important as density in influencing travel demand (Owens, 1986; ECOTEC, 1993). Nevertheless, the level of mixed use may contribute to travel demand particularly through the decentralization of less specialised employment (ECOTEC, 1993). The mixing of land uses is commonly measured using job ratio, the ratio of jobs in the area to workers resident in that area. According to Frank and Pivo (1994), land use mix is the variety of activities within a given area. Using a household travel study in the Seattle area, they found that employment density, population density, land use mix and jobs-housing balance are associated with less auto use. Land use mix was measured using an entropy index. This index has a significant influence on work trips (negative for car use and positive for walk and bicycle use), but not on non-work trips. For Camagni et al, (2003), land use mix is the jobs-housing balance. In the province of Milano, it proves to be negatively related to the mobility impact, which measures the environmental impact of daily travels.

Ewing et al (1996) investigated the effect of the various land use mix characteristics on trip generation including the balance of homes and jobs. They report that there is no statistically significant relationship between the balance of homes and jobs and journey frequency. In a study of commuting patterns in San Francisco, Cevero (1989) reports a negative relationship between job ratio and the proportion of journeys undertaken by foot and cycle: where there are many more jobs than houses, the proportion of journeys by foot or cycle falls. Cervero concedes that the statistical relationship is not very strong but suggests that the encouragement of balancing houses and jobs may encourage walking and cycling. Giuliano and Small (1993) question the importance of job ratio on travel patterns and present the results of a commuting study in the Los Angeles region to show that job ratio has a statistically significant but relatively small influence on commuting time. They conclude that attempts to alter the metropolitan structure of land use are likely to have small impacts on commuting patterns even if jobs and housing became more balanced. Stead (1999) reports that higher job ratios are associated with lower travel distance but recognize that it is not possible to achieve high job ratios in all areas (since this would require a surplus of jobs or a deficit of employable residents). In a study of transport energy consumption in various locations in Great Britain, Banister et al (1997) identify a relationship between job ratio and energy use per trip in one of their case studies ,Oxford). An aggregate measure of land use mix (termed diversity) was examined by Cervero and Kockelman (1997), who report a link between land use mix and total non-work travel distance but no link between land use mix and total distance traveled.

At the neighbourhood level, Holtzclaw et al (2002) analyzed the statistical relationship between locational variables-residential density, proximity to jobs, local shopping, public transit accessibility, the pedestrian and bicycle friendliness of the neighbourhood and auto ownership and driving. The author collected data for Chicago, Los Angeles and San Francisco areas from various secondary sources. Models were developed to predict auto ownership per household and vehicle miles traveled. Average vehicles available for each zone was obtained from the 1990 U.S. Census data. Vehicle mile traveled (VMT) per vehicle was derived from 1990 to 1995 odometer readings.

The dependent variables were fit to a range of potential explanatory variables including the socio-economic factors of average income per household , average household size and the locational variables. The density measures tested were households/residential acre, population/acre and population/residential acre. Local shopping is the number of service and retail jobs per developed area within the zone and the measure of pedestrian/bicycle friendliness is the number of census blocks per hectare.

The correlation of each of the independent variables (locational and socio-economic) with auto ownership and VMT was tested in all three regions. Using the same equation forms, the variables that consistently explain the most variance in vehicles/household were net residential density (household/residential acre), per capita, income, household size and transit accessibility. For VMT, the variables were total residential density, household size, pedestrian/bicycle friendliness and per capita income. Household/residential acre had the strongest correlation to vehicle ownership while household/total acre had the strongest correlation to vehicle mile travel/vehicle.

The provision of local facilities and services may clearly reduce travel distance and increase the proportion of short journeys capable of being traveled by non-motorised modes. Winter and Farthing (1997) report that the provision of local facilities in new residential developments reduces average trip distances but does not significantly affect the proportion of journeys by foot. ECOTEC (1993) report from neighborhood case studies that a clear relationship emerges between the distance from a local centre, the frequency of its use and average journey distance. Hanson (1982) and Stead (1999) report similar findings, showing that proximity to local facilities is positively associated with average distance after taking into account the effects of various socio-economic differences of the areas studied. Hanson also shows that the provision of local facilities is associated with increased journey frequency although the effect of increasing journey frequency is not as strong as the effect of reducing trip length. In the Dutch setting, Meurs and Haajer (2001) find, after controlling for relative location and socioeconomics, that neighborhood characteristics primarily local shopping availability, increases bike and walk trips, but also increases all shopping and social/ recreation trips, which seems to support the Handy (1993) and Handy and Clifton (2001) conclusions for US cities.

Kitamura et al (1997) shows that the availability of residential car parking is linked to both trip frequency and modal choice. As the availability of residential parking increases, the average number of trips per person decreases : an observation that is perhaps counter-intuitive. The authors suggest that residents with more parking spaces make fewer, longer journeys, while residents with fewer parking spaces make more journeys but these tend to be short. Also, as the availability of residential car parking increases, the proportion of car journeys increases. This would imply that residents with more parking spaces not only make fewer, longer journeys but also that these journeys are more car-based. Conversely, the research implies that residents with fewer parking spaces make more journeys but which are short and less car-based.

Balcombe and York (1993) identify a correlation between the availability of residential parking (expressed as the ratio of vehicles to spaces) and the proportion of car owners making short journeys by foot (in order to retain their parking space. The research indicates a greater tendency to walk in areas where residential parking is limited. Similarly, Valleley et al (1997) suggest a relationship between the modal split of commuting and parking provision at work. Stead (1999) reports that limited residential parking is associated with lower travel distance and suggest that the limited availability of parking may lead to more rational car use as residents seek to reduce the number of journeys and hence the number of times they have to search for a parking space on their return home. Limited residential parking may also indirectly contribute to less travel by suppressing car ownership which the study identifies as a strong determinant of travel distance. However, Balcombe and York (1993) showed that difficulties in finding a parking space may not necessarily deter car ownership or intensions to acquire additional vehicles even with increasing parking problems.

Individual economic and demographic characteristics have been recognized as influencing travel behavior. From an individual choice-oriented perspective, it has been argued that attitudes towards travel and land use have to be taken into account and that observed correlations between travel and land use may reflect residential self-selection process (Kitamura et al, 1997: Schwanen and Mokhtarian,2005a,b). Eleven types of socio-economic factors can be identified from the review of literature on travel patterns and socio-economic factors. These eleven types comprise: income, car ownership and availability: possession of driver's licence: working status: employment type: gender: age: household size and composition: level of education: attitudes: personality type. The effect of these factors are summarized in the conceptual framework proposed by Frank and Pivo (1994-figure 2.1). Here, the non-urban form factors consist of economic and demographic characteristics, individual preferences etc.

These socio-economic factors are interconnected and it is often difficult to separate the effect of one from another (that is they are often multicollinear). Household income, for example, is linked to employment type and working status (whether full-time or part-time and how many members of the household are employed). This may influence car ownership and use. Car ownership and use is also influenced by the possession of a driver's licence, age and gender.

Transportation economists have long argued that per capita income is the single most important explanatory factor in auto ownership and use(Meyer and Gomez-Ibanez, 1981; Lave, 1996; Ingram and Liu,1999). The effectiveness of policies that affect the price of auto ownership and use declines as relative income increases. Value of time increases with income, effectively offsetting the higher monetary costs of faster modes such as the automobile and increasing demands for such modes. Also higher income lead to increased demand for leisure- related travel.

Hoch and Dunkerly (1981) examined the relationship determining transport energy consumption in developing countries. Data on transport energy consumption, vehicle stocks and price of fuels were obtained from the International Energy Agency for the period 1960 to 1981. For most countries road transport was the largest single transport sector accounting for about 80% per cent of the total transport energy consumption (with the exception of countries with well developed railway system such as India). Gasoline was the major road transport fuel and its consumption rose rapidly 1960 and 1982 in all countries. This increase went hand in hand with the rapid expansion of auto registration, increase in per capita income and changes in the price of gasoline. Auto registration rose throughout the world in the period under review. In 1982, in low income countries, there were on average about two cars per 1000 people, 12 in middle- income countries, 70 in higher- income developing countries and 400 in industrial countries. Rate of increase in per capita gasoline consumption and income were identical. With respect to fuel price, for middle- and high income developing countries, there was a cessation of growth in consumption immeadiately after price increases occurred. In industrial countries, consumption leveled off after 1974 and fell after 1979 due to price increase. In low-income developing countries where the price increases were more moderate, consumption continued at a relatively stable level. In high-income oil-exporting countries where prices continued to decline after 1973, consumption continued to rise rapidly.

The effects of socio-economic characteristics on travel pattern and energy consumption can be better recognized in disaggregate studies. Hanson (1982) reports that trip frequency is linked to household income: people in higher income households make more journeys than in lower income households. Cervero (1996) shows how commuting distance increases with increasing income. Naess and Sandberg, (1996) identify a positive link between household income and the total distance traveled per person. Transport energy consumption is reported to increase as household income increases (Naess,1993;Naess et al, 1995). Flannelly and Mcleod (1989) show how income is linked to the choice of mode for commuting. Income is also linked to land use patterns, which may explain some of the variation in travel patterns in different locations. Mogridge (1985), for example, shows how average incomes in Paris and London increase with increasing distance from the city, with the exception of residents

Figure 3.5: The conceptual framework: relationships between travel behavior and factors that affect it.

Travel Behavior

Urban form Factors → Travel Behavior ← Non -urban Form Factors

Source : Frank and Pivo, 1994

in very central locations (within approximately 4 kilometres of the city centre). Kockelman (1997) also reports a positive correlation between travel distance and income. Hanson (1982) reports that trip frequency increases with car ownership, whereas Prevedonros and Schofer (1991) contend that car availability does not explain the variation in trip frequency. Total travel distance is reported to increase with car ownership (Naess and Sandberg, 1996: Kockelman, 1997), as is transport energy consumption (op.cit.) and the proportion of car journeys (Naess, 1993).

Flannelly and McLeod (1989) show that the number of cars per household is linked to the choice of mode for commuting. Ewing (1995) reports that travel time increases as car ownership levels increase. Like income, car ownership is also linked to land use patterns and may explain some of the variation in travel patterns in different locations. Gordon et al (1989a), Levinson and Kunnar (1997) and Naess et al, (1995) identify links between car ownership and population density. Higher density areas tend to have lower levels of car ownership. According to evidence from the United States presented by Gordon et al (1989), car ownership tends to be lower in larger cities. Other studies show that car ownership increase as the distance from the city centre increase (Mogridge, 1985: Naess and Sandberg, 1996). Flanelly and Mcleod (1989) show how the possession of a driver's licence is linked to the choice of mode for commuting. People who use the bus are likely to come from households where fewer members have a driver's licence. Interestingly, it is reported that people who share cars to work are likely to come from household with more driver's licences than acreage (op. cit.)

Prevedouros and Schofer (1991) report that work status does not explain the variation in trip frequency. Ewing et al (1996) report that journey frequency increases as the number of workers per household increases. Ewing (1995) states that average travel time per person increases as the number of workers per household increases, reflecting the fact that where there is more than one worker in a household,home location may not be near to the workplace of each worker.

Hanson (1982) shows no difference in total trip frequency according to gender in Sweden. Gordon et al (1989b) indicates that the frequency of non-work trips is higher for women than men in the United States, and that women have shorter work trips than men, regardless of income, occupation, marital and family status.Evidence from Flanelly and McLeod (1989) suggests that age has no significant effect on the choice of mode for commuting.

3.2.2 Studies on gasoline consumption in Nigeria

The first comprehensive study on the spatial distribution of gasoline consumption in Nigeria was carried out by Ikporukpo (1978). The author analyzed the supply and consumption and the efficiency in the organization of the gasoline distribution system. Data on the demand and supply of gasoline both for the country as a whole and for the individual consumption centers were obtained from various sources. Also, data on the socio-economic and geographical characteristics of the consumption centers were obtained from various secondary sources. The study was based on 52 towns and the number of retail outlets for gasoline distribution in each town was used as a surrogate measure of the volume of gasoline consumption.

The analysis revealed that for the ten year period 1965-74 consumption of gasoline fell from 427.7 million litres in 1965 to 357 million litres in 1968 and increased to 418 million lites in 1970. The pattern of variation in the consumption of gasoline from one town to the other for the four year period 1971-74 showed the predominance of Lagos as a major consumption center. The southern belt had the greatest concentration of large consumption centers- Lagos, Ibadan, Benin, Onitsha, Port Harcourt and Enugu while Kano and Kanduna were the major centers in the northern zone.

The ordinary least square method of the multiple regression and correlation model was used in the analysis of the determinants of gasoline consumption. The explanatory variables were motor vehicle population, size of industrial establishment, number of industrial establishment, distance from source of gasoline supply, accessibility, number of retail outlet, vehicle type and population. The results showed that the variables significantly explain the quantity of gasoline demanded. In the determination of the most efficient depots, heuristic programming approach was employed. It was revealed that most of the existing depots were not properly located and that half of the proposed depots are located in the optimum points.

Other studies on gasoline consumption in Nigeria emphasize price of gasoline as a determinant of gasoline consumption. Adegbulugbe et al (1986) analyzed the demand of gasoline consumption based on disaggregated states level data using pooled cross-section and time series models. Secondary data for the period 1979-85 were obtained from the Federal Office of Statistics and United Nations Statistical Year Book. Two different approaches were used in modeling gasoline demand. In the first approach, gasoline consumption was assumed to compose of three separate determinants, namely; the utilization of passenger car, fleet efficiency and stock of vehicles. Fleet efficiency was neglected due to unavailability of data, utilization of vehicle was assumed to be dependent on gasoline price, prices of alternative fuels and transportation models. Also, the effective stock of vehicles depended on disposable income, the price of vehicle and the availability of vehicle.

In the second approach flow adjustment model was used to forecast gasoline consumption. The model stated that gasoline demand at any given time is regarded as a dynamic adjustment on the quantity demanded in previous periods influenced by income and prices. The result of the gasoline demand analysis showed that the stock of vehicles consuming gasoline per capital was positive and statistically significant. The author concluded that the stock of vehicles was the major factor driving gasoline consumption.

Adenikinju (1995) noted that appropriate energy pricing would not only foster efficiency in energy use but also promote the use of environment friendly mixes of energy resources. In a study on energy pricing policy and the environment in Nigeria, the author examined the impact of an efficient energy pricing policy on the macro-economy. Using data obtained from United Nations Year Book of World Energy Statistics, it was found that the transport sector was the largest consumer of energy products between 1970-1989, this comprised essentially of gasoline and diesel. The sectors share of total demand grew from 59.7% in 1970, 62.6% in 1980 but declined to 55.7% in 1989. A macro econometric model was developed to capture the relationship between energy and growth. The behavioural equations of the model were all estimated by the ordinary least squares method over the sample period 1970-1990. The result showed that GDP was not significant in explaining demand for petroleum products. However, there was an insignificant relationship between energy prices and energy demand. This implies that the decline in the relative share of petroleum products in energy consumption in recent years was due mainly to increases in petroleum prices and intermittent disruptions in the supply of products.

Furthermore, Iwayemi and Adenikinju (1996) examined the impact of rising energy cost on the various sectors of the economy and the macro economic impact of higher energy prices on GDP, government balances, exports, investments and domestic price levels. A multi sector static computable general equilibrium model for Nigeria was used. Data on prices of selected petroleum products between 1970 and 1992 was obtained from NNPC and CBN. The simulation results showed that an increase in the domestic price of petroleum products will cause reductions in its consumption which may consequently be directed to exports or conserved for future use.

This research attempts to draw on this review of previous literature focusing on bringing together the broad range of previous analysis and also some of the perceived research gaps. The studies reviewed reveal more than anything else, that despite a continuously growing body of research and increasingly sophisticated analytical techniques, we still cannot make conclusive and generalizable statements about the role of urban land use on travel behaviour. This inconclusiveness owes itself in part to the lack of consistent, behaviorally- rigorous analyses (as suggested, by Crane, 2000). Additional interpretative problems come from the variety of analytical techniques used and possible data differences, including those arising from variation in survey instruments and potential variation in types of trips counted. In some cases, the spatial scale or measures of urban form remain vaguely defined. Furthermore, the variety of travel outcomes measured (mode choice, number of trips by a given mode, total trip rate, trip time, etc) only further complicates conclusions. This relates back to the call for improved transportation performance indicators that truly represent meaningful outcomes (travel time, travel distance) but, that also represent actual behavior (for example, trip chaining). Both Srinivasan (2001) and Krizek (2003a,c) offer explorations in this area. Finally it may well be possible that as Handy (1996) declares, the impacts are “different in every context” (p.196).

Except for the most recent approaches, very few analyses actually control for transportation levels of service, which clearly play a major role in determining travel choices. Many of the studies do not even control for income effects (for example, Holtzclaw et al, 2002) which also have an important role. It seems in general, that analyses based on aggregate data tend to reveal more conclusive and (dramatic) results than those based on disaggregate data- this may be a sign of ecological fallacy. Along these exact lines, Handy (1992) calls for disaggregate analyses, noting that average effects mask local variation. The author also suggests the need to focus on more than a single day’s travel; this would be particularly important to capture broader possible effects related to potential constant travel time budgets as detected by McCormack, et al (2001) in the Seattle neighborhoods and suggested, more globally by Schafer (2000). Both Handy (1992) and McCormack et al (2001) point to the need for local effects to be examined in the broader regional context (that is, the meso-scale).

Another important issue is the interaction between land use characteristics and socio-economic variables. We can’t override the fact that the location in the metropolitan area is determined by economic (such as income) or demographic (such as household size) characteristics of the inhabitants, which interacts with individual preferences. So, there will arise a problem of interpretation: even if we accept a relationship between land use characteristics and travel pattern and transportation energy consumption , how can we know that the underlying causes of this relationship are not based on socio-economic characteristics?

Several studies do not explicitly recognize that different land use characteristics are associated with different socio-economic factors, which also have an effect on travel patterns. Consequently, they do not attempt to differentiate between the effects of land use characteristics and socio-economic factors. Studies that recognize the effect that socio-economic factors may have on travel pattern and energy consumption employ a research method that attempt to hold socio-economic variables constant in order to observe the effects of land use and socio-economic characteristics. Two methods have been employed to hold socio-economic variables constant. The first and more popular approach uses multiple regression analysis, in which socio-economic variables and land use characteristics are treated as explanatory variables (examples include : Cervero, 1989; Ewing, 1995; Ewing et al, 1996; Keyes, 1982; Dunkerly and Hoch, 1987; Stewart and Bennet, 1975; Frank and Pivo, 1994;Kitamura et al, 1997; Naess, 1993; Naess et al, 1995; Naess and Sandberg, 1996; Prevedonros and Schofer, 1991). The method allows identification of the main socio-economic and land use characteristics that are associated with certain travel patterns and energy consumption. The method does not, however, allow the identification of causal relationships (as discussed earlier). The second and less popular method employed to hold socio-economic variables constant involves the selection of case study areas which have similar socio-economic profiles but different land use characteristics. In this way, socio-economic differences are minimized and the variation in travel patterns is assumed to be the result of land use characteristics (examples include Handy, 1992; Curtis, 1995; Giuliano and Narayan, 2003, 2004; Clarke and Kupers-Linde, 1994; Puchev and Lefevre, 1996).

Similar to some of the studies reviewed, this research is empirical in its approach as it tries to test the relationship between land use, socioeconomic variables and travel characteristics and their effect individually and in combination on energy use in transport. Both aggregate (national and city-wide) and disaggregate (household) data were utilized. Travel was measured in terms of journey to work, school, shopping and recreation for each member of the household and for each day of the week: trip length, travel time and energy consumption. Also, the study was carried out in a developing city, Ibadan, as against most of the studies reviewed which reflected results from developed cities in the United States, United Kingdom, Canada, and Australia. Since different geographical areas of research give varying results, the results from this study will increase our understanding of the relationship between land use, socio-economic variables and energy consumption.

Some of the variables used in the previous studies were also utilized. Land use characteristics include population size, population density, public transport accessibility, number of schools, hospitals, markets, financial institutions, industries etc in each of the local government areas. Travel is measured in terms of mode choice and trip frequency. Socio-economic variables include income, car ownership, and availability, working status, employment, gender, age, household size, household composition, level of education etc.

CHAPTER FOUR

SPATIAL AND TEMPORAL PATTERN OF GASOLINE CONSUMPTION IN NIGERIA

4.0 Introduction

This chapter is concerned with the spatial and temporal pattern of gasoline consumption in Nigeria. It discusses the development of the oil industry, upstream sector of the industry, spatial and temporal variation in gasoline consumption in the country. Lastly, it examines the determinants of the pattern of consumption of gasoline. The hypothesis that there has been a significant change in the spatio-temporal pattern of gasoline consumption in Nigeria is tested.

4.1 Development of the oil industry in Nigeria

Oil exploration in Nigeria began in 1908 when a German Bitumen Company made some discoveries in the Araromi area of present Ondo State. However, by 1938, Shell d'Arcy Petroleum Development Company of Nigeria, an affiliate of the mineral oil companies Shell Petroleum Company, became the sole concessionaire prospecting for Nigerian oil (Schatzl,1969). The discovery of oil at Oloibiri by Shell-BP in 1956 evoked a display of interest in the Nigerian crude oil economy by other mineral oil companies. By 1961 eight of them were already operating in the country. After the interruption of the oil exploration and production from 1967 to 1970, occasioned by the Nigerian civil war, activity thereafter picked up with renewed vigour. The end of the war coincided with a boom in oil prices at the period. This period marked the entry of Nigeria into the Organisation of Petroleum Exporting Countries which was formed in 1960 as a vanguard for the protection and promotion of the economic interest of the member nations most of whom fall within the realm of the developing world. One of the most important factors responsible for the dramatic rise in the oil prices was the Arab-Isreali war that led to the closure of the Suez canal as well as the periodic interruption of the Tapline- the pipeline that delivers Saudi Arabian oil to the Mediterranean. These considerably increased the freight element in the oil price (Olorunfemi, 1985).

Initially, the role of the government in the oil sector was limited to the dues, royalties and other peripheral activities (Okanla,1987) but in view of the substantial foreign exchange accruing to the government as a result of oil sales at the international market, the oil sector quickly acquired the centre stage of economic resource management in Nigeria.

In 1971, the Nigerian government established the Nigerian National Oil Corporation (NNOC) as a full fledged national oil company with the responsibility of exercising control over the oil industry which was hitherto dominated by international oil companies. The Nigerian National Petroleum Corporation (NNPC) was established in 1977 by a merger of the NNOC with its operational function and the Ministry of Petroleum Resources with its regulatory responsibilities. In addition to exploration and production activities, NNPC has operational interests in refining, petrochemicals and product transportation as well as marketing.

4.2 The upstream sector of the Nigerian oil industry

The upstream sector of the Nigerian oil and gas industry is the single most important sector of the economy as it contributes about 90 percent of the country's petroleum export products. The oil exploration and production fields, onshore and offshore, constitute the upstream sector. Since 1958 when oil was first struck in the Niger Delta region with crude oil production at the rate of 5,000 barrels per day, there has been a steady and phenomenal growth in both the proven reserve of oil deposits and the consequent daily production output which invariably is contingent on OPEC regulations especially the assignment of quotas. For example, in 2005, Nigeria had a proven oil reserve of over 35.3 billion barrels. The total crude oil production in 2005 was 918,972, 465 barrels. This surpassed that of 2004 production of 911, 044, 764 barrels by 0.87 percent or 7 927 721 barrels. The increase in production was due to high demand of crude oil from Middle East, China, Asian countries, North America, Africa and Latin America: low oil stocks in advanced countries; rise in oil prices due to global economic growth especially in Unites States, China and developing countries: decline in production of oil from Russia and North Sea and increased global demand for light crude which favors Nigeria.

Nigeria is currently rated as the largest producer of oil in Africa with about 2.5 percent of the world's oil reserve and the tenth country in the area of gas reserves which is currently estimated at 124 trillion cubic feet. Exploration and production of oil and gas are financed and managed in four ways: Joint ventures, production Sharing Arrangement and Service Contract. The fourth is the Sole Risk Arrangement involving indigenous license holders and their equivalents in the operations of marginal fields.

4.3 The downstream sector of the Nigerian oil industry.

The downstream sector of the Nigerian oil industry consists of the domestic refineries, petroleum product depots and retail/ distribution outlets. Nigeria has four NNPC owned refineries- Kaduna Refinery and Petrochemicals Company Limited, Kachia Road, Kaduna; Port Harcourt 1 and 11 Refining Company Limited, Alesa Eleme, Port Harcourt and Warri Refining and Petrochemicals Company Limited, Ekpan, Warri, Delta State, with a total nameplate capacity of 445,000 bpd.

Warri Refinery and Petrochemical Company was commissioned in 1978.It was set up to process crude oil into petroleum products, manufacture and market petrochemical products through effective resource utilization . The initial capacity was 100,000 BPSD but was upgraded to 125,000 BPSD. The petrochemical plants were added in the late 1980s. The refinery processes the Gulf Escravos oil to produce LPG, Kerosene, Diesel oil, Premium Motor Spirit (Petrol) and Fuel oils. The petrochemical plants produce Carbon black and Polypropylene.

The Kaduna Refinery and Petrochemical Company was established to process crude oil into refined petroleum products and manufacture Linear Alkyl Benzene (LAB), tins and drums for domestic consumption. The KPRC is actually two refineries in one; the 50,000 BPSD Fuel Plant commissioned in 1980, and the 50,000 lubes plant commissioned in 1983. The Fuels Plant capacity was upgraded later to 60,000 BPSD so that the installed capacity is 110,000 BPSD. The refinery processes two different crudes; the local Gulf Escravos crude in the fuels plant and an imported Arabian light crude for the lubes plant. Its products include LPG,PMS, kerosene, diesel oil, fuel oil, lubes base oils, waxes asphalt and LAB.

The Port Harcourt Refining Company is made up of the old simple Hydroskinning 65,000 BPSD refinery (OPHR) which was commissioned in 1965 and the new more complex export oriented 150,000 BPSD refinery (NPHR).PHRC processes Bonny light crude to produce LPG, PMS, kerosene diesel oil and fuel oils. It has evacuation problems because of its location and a small jetty at Okrika. It lacks pipeline connection with Lagos so needs coastal tankers and offshore reservoir services.

Petroleum products from the refineries are distributed through the depots. Depots serve as product reservoirs. The major depots belong to the NNPC while some marketers have considerable storage capacity. Depots dispersal in the country is important not only for supply but for national security. Presently, there are the following depots; Port Harcourt, Warri, Kaduna refineries, Benin, Enugu, Aba, Makurdi, Ibadan, Ilorin, Calabar, Jos, Gusau, Kano, Gombe, Maiduguri, Lagos satellite town, Atlas Cove Lagos (for receiving imported products and those brought by coastal tankers from Port Harcourt especially) and Mosimi Shagamu (for receiving products from Atlas cove and distributing these as the largest tanker loading bay). New storage and distribution depots were recently commissioned in Suleja (Abuja), Minna and Yola as part of the Pipeline Phase 111 project. Figure 4.1 shows the product distribution pipeline in Nigeria.

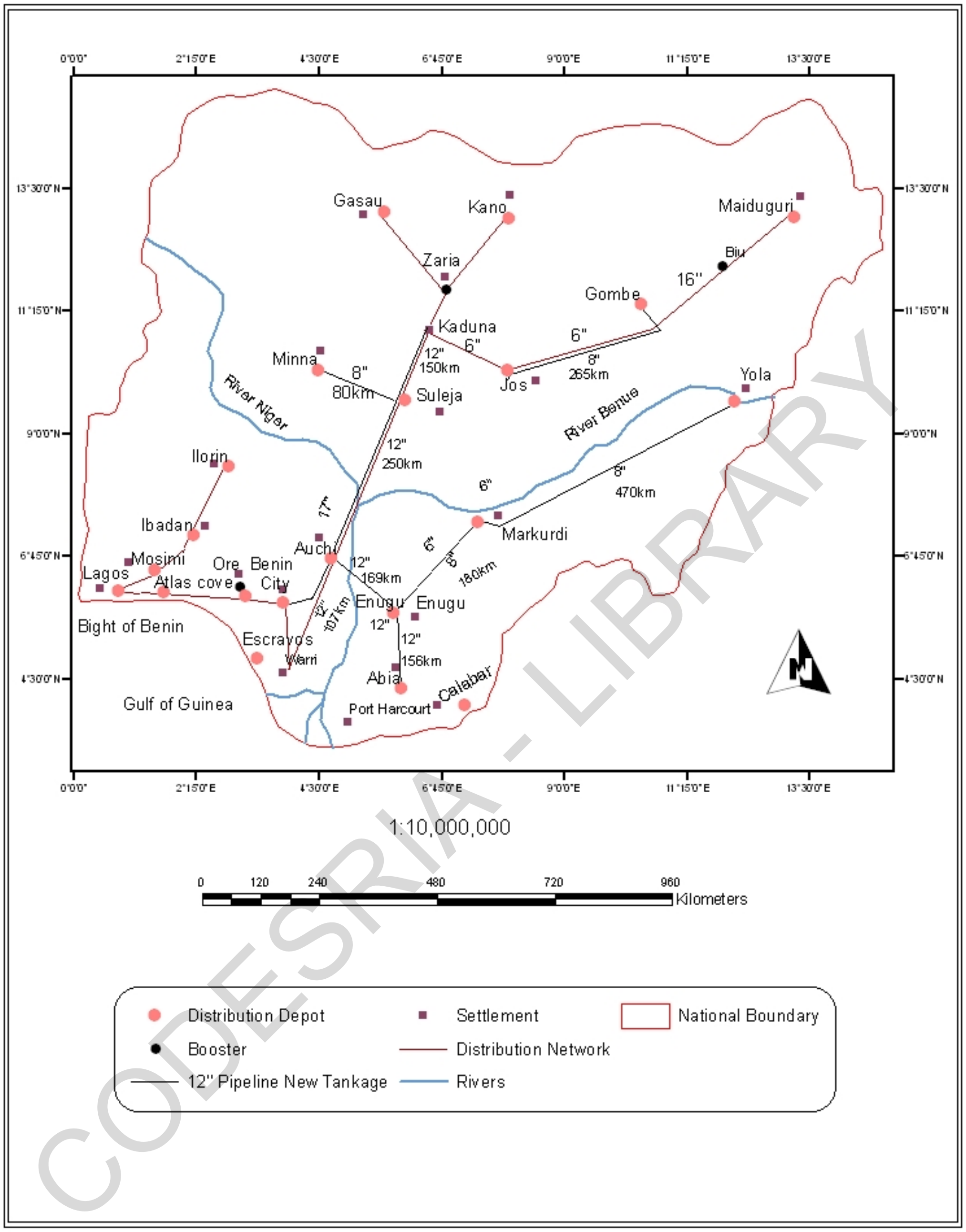


Fig.4.1: Production distribution pipeline map
Source: (Eromosele (1997)

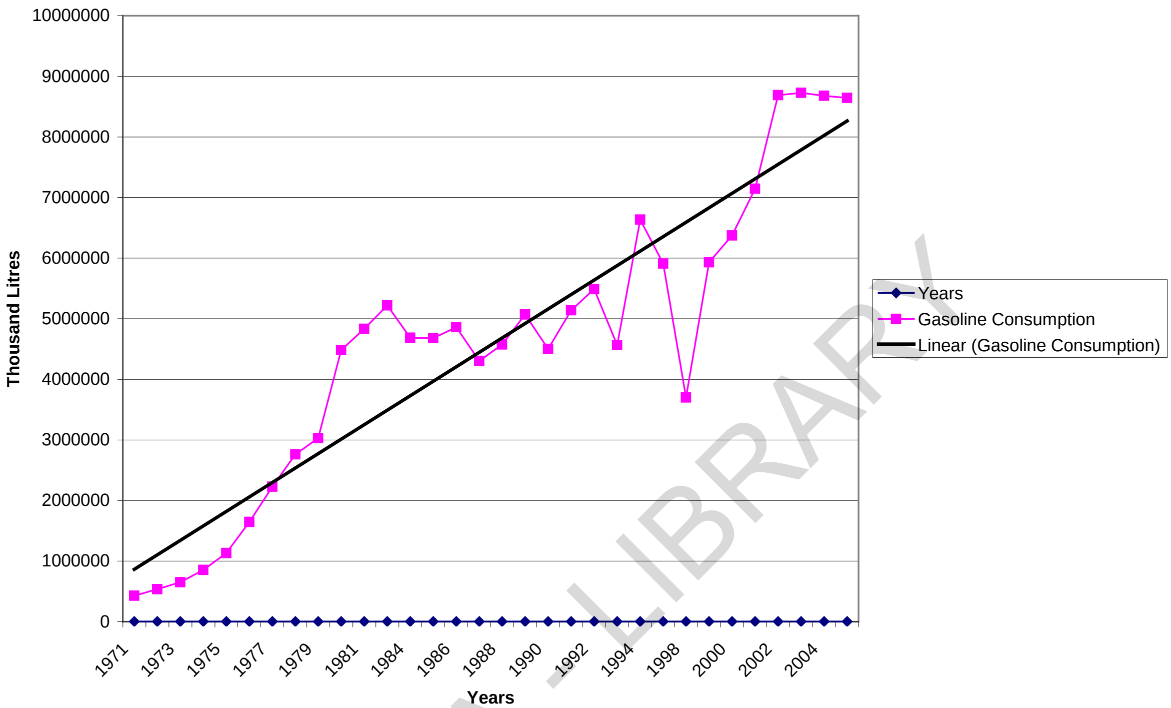
4.4 Trends in the consumption of gasoline

4.4.1 Temporal Trend

The consumption of gasoline in Nigeria for the thirty-two year period within 1971-2005 for which data is available displays three distinct trends. In the first instance, consumption increased from 427,937.7 litres in 1971 to a peak of 5,219,957 litres in 1983, an increase of 1,120 percent as shown in figure 4.2.The key factors in the rapid growth in gasoline consumption during these years were the rapid income expansion due to strong oil export performance and subsidized and administered energy prices. The second time interval, 1984-1998 is marked by fluctuation in the consumption of gasoline with rises and falls. The economic recession in the post-1982 period was accompanied by a decline in the level of demand culminating in the significant fall from 5,219,957 litres in 1983 to 4,302,174.3 litres in 1987,a decrease of 17.5 percent. This was when the economy went into depression consequent to the two-thirds fall in world crude oil prices within the first six months. Consumption of gasoline increased from 4,565,852 litres in 1993 to a peak of 6,635,302.6 litres in 1994, an increase of 45 percent. There was a sharp decline from 1994 to 3,699,547 litres in 1998, representing 44 percent decrease. After this sharp decline, gasoline demand increased steadily to a peak of 8,725,938 litres in 2003 (135 percent increase from 1998 to 2003) which is the maximum level of consumption throughout the period 1971-2005.Consumption level then stabilized between 2004 and 2005 when 8,676,812 and 8,644,260 litres were consumed respectively. The general growth in the economy may have been responsible for this increasing trend in gasoline consumption, as there is usually a close relationship between energy use and economic development (Naess et al, 1995).

To analyse the temporal variation in gasoline consumption over the thirty-two year period, hypothesis 1 is tested. The computation of between group and within groups estimate of variance is carried out using the analysis of variance technique. Having

Figure 4.2 : Gasoline Consumption in Nigeria 1971-2005



computed the between and within sample variance estimates an F-value of 2.776 is obtained (table 4.1). At a significant level of 5 percent, degree of freedom df 1 = 26 and df 2 =972, the F- value is significant. Therefore, there is a significant difference in the temporal distribution of gasoline consumption in Nigeria at 95 percent confidence level. The trend after 2004 in figure 4.2 shows a flat curve meaning that a peak has possibly been reached.

Figure 4.3 shows the monthly trend in gasoline consumption. Data on monthly gasoline consumption were published by NNPC for eleven years only. Hence, the analysis of the monthly trend of gasoline consumption is based on these eleven years, since, it is representative of the period being studied. Figure 4.3 indicates fluctuations both within a year and the whole period taken together. The most remarkable characteristics of the trend are

(a) the trend for the individual months is one of oscillation, that is, rising and falling intermittently. The volume of gasoline consumed for the individual months decreased between 1983 and 1984, increased in 1985, decreased in 1986 and 1988 and increased thereafter. This is true of several months. The trend observed is disturbed only in a few cases. For instance, December consumption figures show a decrease from 576 million litres in 1983 to 466 million litres in 1984 (19 percent decrease). This is followed by a rise to 541 million litres in 1985 (16 percent increase), fall to a minimum of 399 million litres in 1989, representing 26.2 percent decrease and a rise to a peak of 837 million litres in 2004 (109 percent increase).

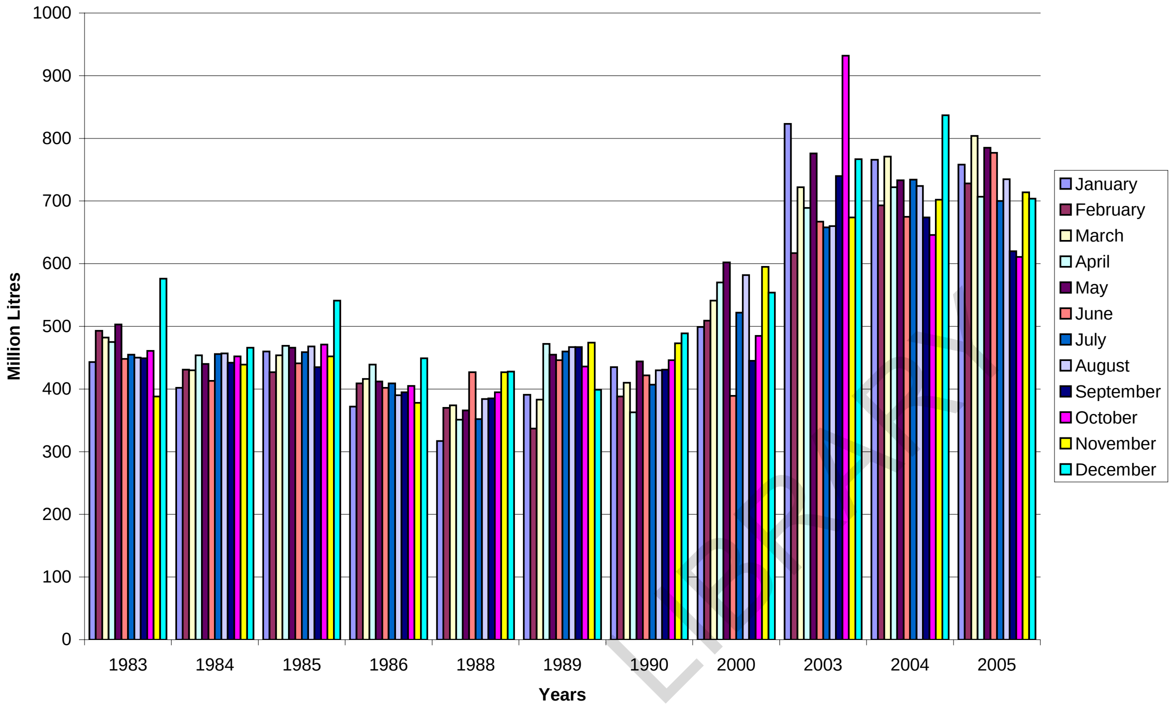
(b) the peak period of consumption for each year is around the end and middle of the year with the exception of 2003, 2004 and 2005 when the demand was high in the early part of the year.

Table 4.1: Analysis of Variance for Temporal Variation of Gasoline Consumption in Nigeria

Data	Sum of squares	Df	Mean Square	F	Level of significance
Between Groups	2.05E+12	26	7.902E+10	2.776	0.000
Within groups	2.77E+13	972	2.846E+10		
Total	2.97E+13	998			

Author's Analysis,2008

Fig. 4.3 :Monthly Consumption of Gasoline 1983-2005



(c) the trend for the individual years varied, although, consumption level was relatively stable in some years, for example 1983,1984 and 1985. A typical case is the 2003 trend. From a January consumption quantity of 823 million litres, there is a fall through February to September. There is then a rise to a peak in October when 932 million litres is consumed. A fall is witnessed in November followed by a rise to 767 million litres in December.

(d) the maximum quantity consumed in each month occurred in 2003,2004 and 2005.

The rise and fall in monthly consumption of gasoline is associated with the fluctuation in per capita income and the level of motorization in the country over the years. Increase in gasoline consumption between 1984 and 1985 for all the months occurred as a result of the increase in per capita income. Per capita income increased from US$860 in 1984 to US$950 after which it declined up to 1996 and has increased since 2000 (Ariyo, 2006). Similarly, the number of newly registered gasoline using vehicles decreased from 75,711 in 1984 to 4,927 in 1989 and increased to 124,956 in 2000.The fall in number of vehicles registered was due to high cost of vehicles.Thus, fluctuation in income and vehicle registration affected the volume of gasoline consumption.

The variation in monthly consumption of gasoline is estimated using the ANOVA technique. Having computed the between and within groups variances, an F-value of 0.214 is obtained (table 4.2).At df 1=11 and df2=120 , the F-value is not significant at the 5 percent level of significance. Hence, there is no significant difference in monthly consumption of gasoline with 95 percent confidence level.

Table 4.2: Analysis of Variance for Monthly Variation of Gasoline Consumption

Data	Sum of squares	Df	Mean Square	F	Level of significance
Between Groups Within groups Total	48291.538 2456173 2504464	11 120 131	4390.140 20468.105	0.214	0.996

Author's Analysis,2008.

4.4.2 Spatial Pattern

The pattern of variation in gasoline consumption from one state to the other in Nigeria for the twenty-seven year period within (1971-2005) is shown in figures 4.4-4.9. The states were subdivided into the six geographical zones so as to make the variation over space more visible. Figure 4.4 shows the pattern of gasoline consumption in the South-East zone which comprises of Abia, Anambra, Ebonyi, Enugu and Imo states. Generally, there was a rise in the consumption of gasoline in all the six states from 1971 to a peak in 1980. This is followed by a fall in 1981 and fluctuation in demand between 1981 and 1990. There was a marked increase in demand in 1992, followed by a gradual decrease between 1993 and 1999. Consumption levels increased steadily from 2000 to 2005, although, there was a fall in 2003. For the entire period, Imo state had the highest level of consumption of gasoline with 2,582,727 litres (26 percent) followed by Enugu state with 249054 litres (25.4 percent). Anambra state had the lowest level of gasoline demand with 1,414,415 litres (14.4 percent).

The pattern of gasoline consumption in the South-South zone which comprises of Akwa Ibom, Bayelsa, Cross River, Delta, Edo and Rivers States is shown in figure 4.5.Demand for gasoline increased in all the states between 1971 and 1981. After 1983, the pattern shows a series of rise and fall in gasoline demand in most of the states. Generally, between 1971 and 1992, Edo State had the highest level of gasoline consumption in the zone. There was a significant rise in consumption level in Rivers State from 69,971.8 litres in 1990 to a peak of 420,361 litres in 2004 (500 percent increase). Thus, Rivers State had the highest level of gasoline consumption between 1997 and 2005. Edo and Rivers States consumed a total of 3,815,737 and 3,674,979 litres of gasoline in the entire period, representing 25.4 and 24.5 percent respectively of the total gasoline consumed in the zone. Demand was lowest in Akwa Ibom State with 638,746.8 litres being consumed.

Figure 4.4: Gasoline Consumption in South East Zone 1971-2005

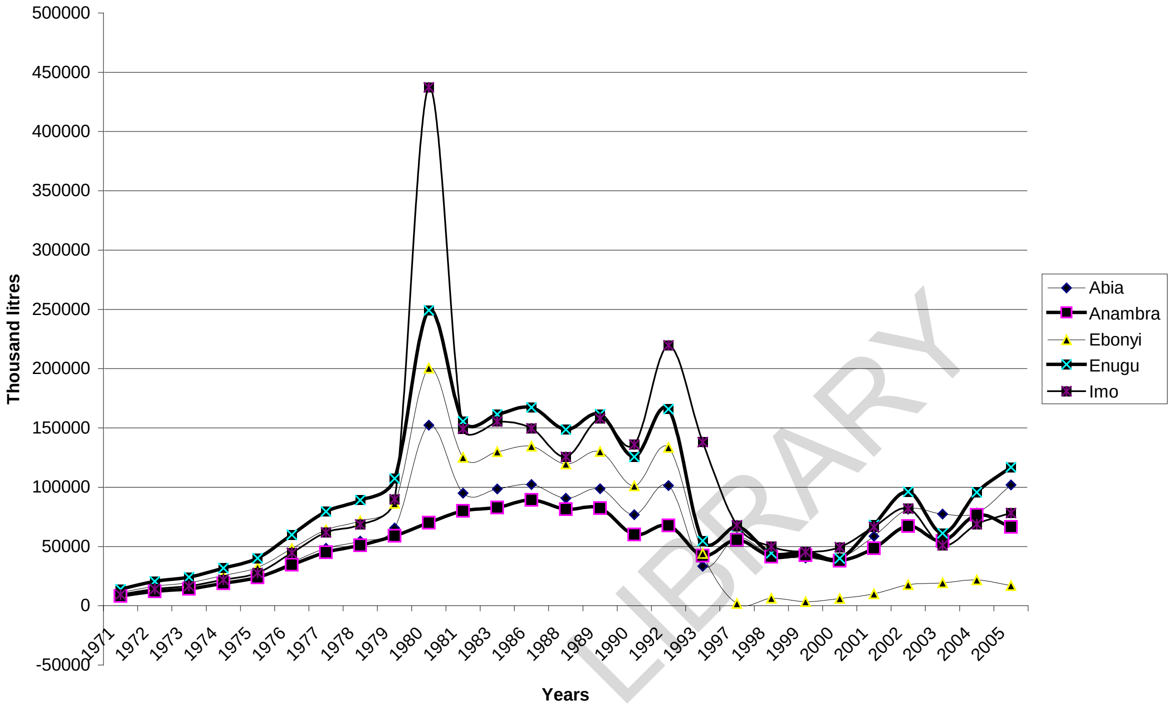
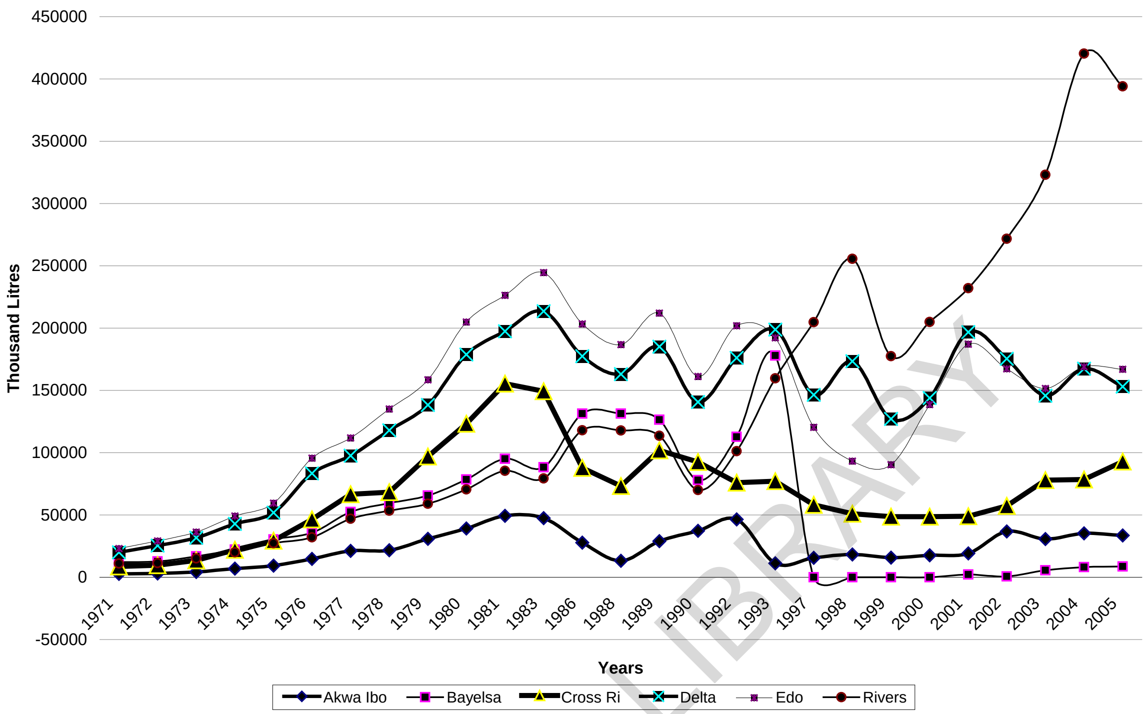


Fig. 4.5: Gasoline Consumption in South South Zone 1971-2005



The South-West zone comprises of Ekiti, Lagos, Ogun, Ondo, Osun and Oyo States. Figure 4.6 shows the variation in gasoline consumption in the zone between 1971 and 2005. Generally, there was an increase in gasoline consumption in all the states between 1971 and 1983. This is followed by fluctuation in demand up to 2005. However, a marked feature in the zone is the fact that Lagos State had the highest consumption level in the zone throughout the period.

From a minimum level of 122,724 litres in 1971, gasoline demand increased to 1,366,301 litres in 1993 (1,013 percent increase). This was followed by a decline in 1997 to 952,777 litres (a decrease of 30 percent).After 1997, there was a steady rise to a peak of 1,852,267 litres in 2003, representing an increase of 1,409 percent of the value in 1971. Hence , for the entire period , major consumption areas are Lagos and Oyo state with 24,200,352 litres (59.3 percent) and 6,260,901 litres (15.3 percent) while Ekiti had the lowest volume of gasoline demand with 711,338.5 litres (1.7 percent).

The North-Central zone comprises of Abuja (Federal Capital Territory), Benue, Kaduna,Kwara, Kogi, Nasarrawa, Niger, and Plateau States. Figure 4.7 shows the variation in gasoline consumption in the zone between 1971 and 2005.Kaduna state dominated gasoline consumption in the zone between 1971 and 2000. Abuja had the highest consumption level between 2001 and 2005 with a maximum volume of 486,288 in 2003. The predominance of Abuja during this period is due to an increase in vehicular traffic in the FCT occasioned by increase in commercial activities and the transfer of major government parastatals to the FCT. The major consumption areas in the zone for the period are Kaduna State with 4,832,045 litres (28.2 percent) and Abuja with 2,656,821 litres (15.5 percent) while Kogi State had the lowest level of 1,282,837 litres (7.5 percent).

Fig. 4.6: Gasoline Consumption in South West zone 1971-2005

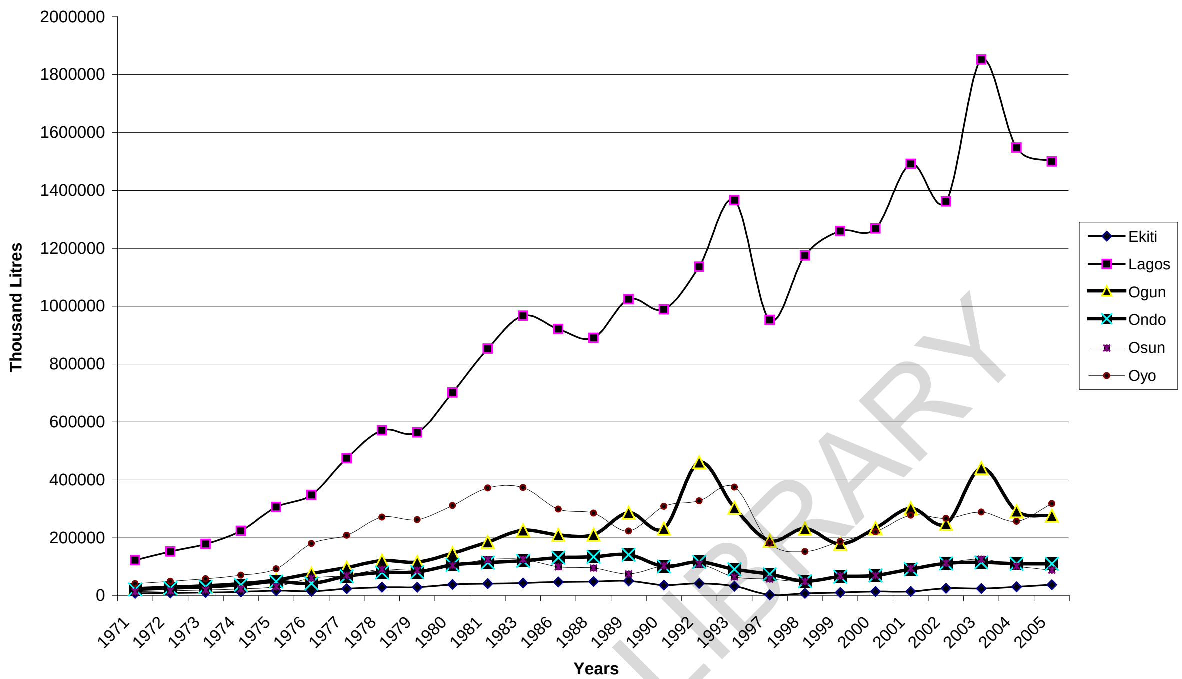


Figure 4.7 : Gasoline Consumption in North Central Zone 1971-2005

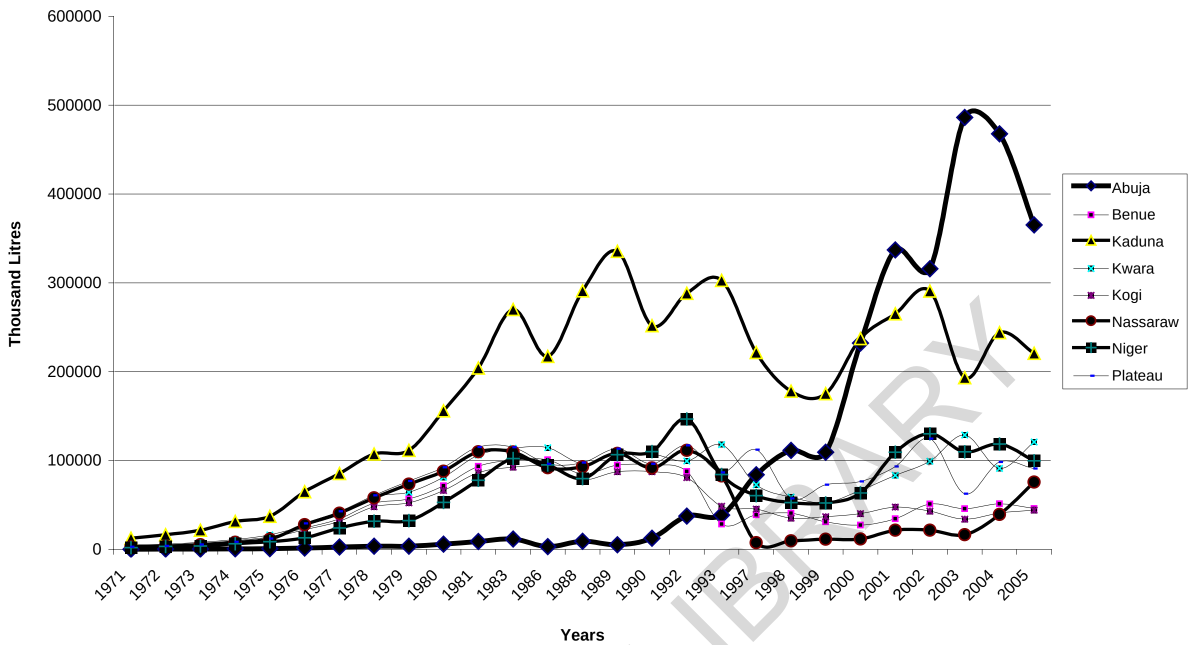


Figure 4.8 shows the variation of gasoline consumption in the North-East zone. There was a rise in the consumption level in the six states-Adamawa, Bornu, Bauchi, Gombe, Taraba and Yobe- between 1971 and 1981. Bornu State had the highest demand in 1981 with 124,695.8 litres. The period after 1981 is marked by rise and fall in gasoline demand in all the states. Generally, Bornu State had the highest level of consumption with 1,573,996 litres (29.6 percent) followed by Bauchi State with 964,984.9 litres (18.2 percent) while the lowest demand was recorded in Gombe State with 416,026.6 litres (7.8 percent).

The pattern of gasoline consumption in the North-West zone is shown in figure 4.9. The North West zone comprises of Jigawa, Kano, Katsina, Kebbi, Sokoto and Zamfara States. There was a rise in gasoline consumption in all the states from 1971 to 1981. This is followed by a series of rise and fall in demand till 2005. Jigawa had the highest consumption level between 1971 and 1992 with a maximum of 181,918.4 litres in 1989.There was rise in demand in Kano from 124,370.2 litres in 1992 to a peak of 299,223 litres in 2002, representing 140 percent increase. Thus, Kano State had the highest gasoline consumption from 1993 to 2005. The high demand in Jigawa State may be attributed to the derivation of the values for Jigawa state from that of Kano State from 1971 to 1992. For the period,1971-2005, Kano state had the highest gasoline demand with 3,356,553 litres (38.7 percent) while Kebbi had the least with 684,517.7 litres (7.9 percent).

The spatial pattern of gasoline consumption in the thirty-six states for the twenty-seven year period is shown in figure 4.10. The spatial pattern shows that Lagos state had the highest consumption level of 24,200,351 litres (25 percent) followed by Oyo (6.5 percent), Ogun (5.4 percent), Kaduna (5.0 percent), Edo (3.9 percent), Rivers (3.79 percent), Delta (3.79 percent), Kano (3.5 percent), Abuja (2.7 percent) and Imo (2.7 percent) States. Therefore, the largest consumption centres are in the South West and South South zones.

Fig. 4.8: Gasoline Consumption in North East Zone 1971-2005

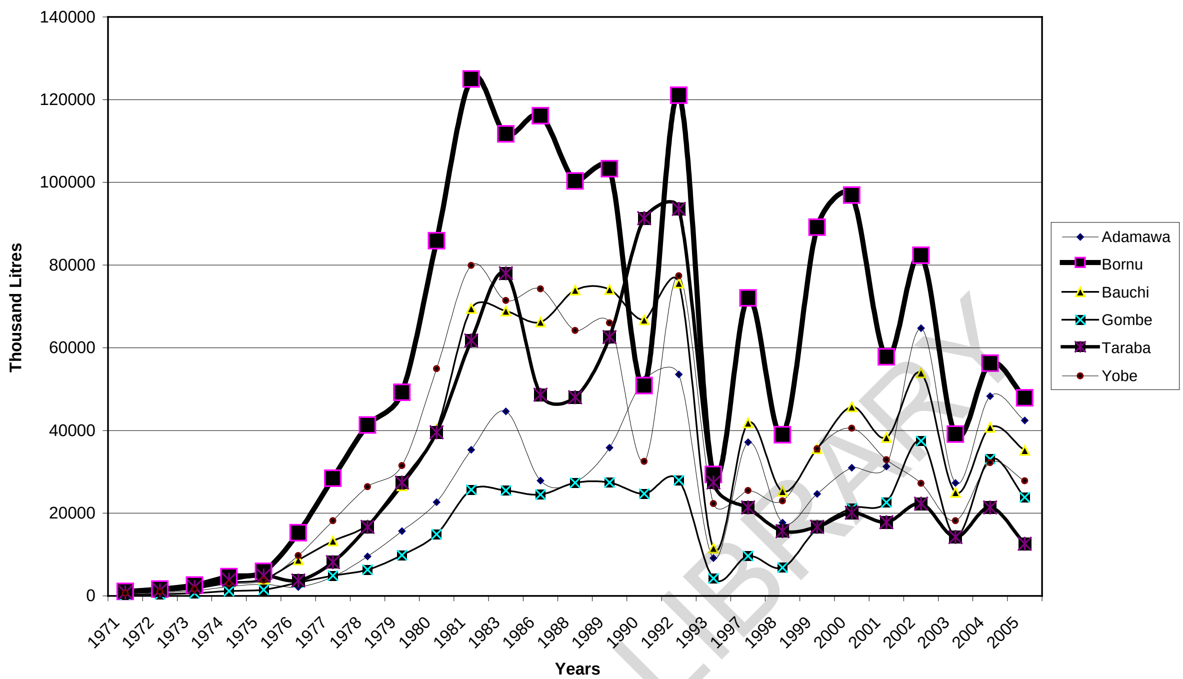
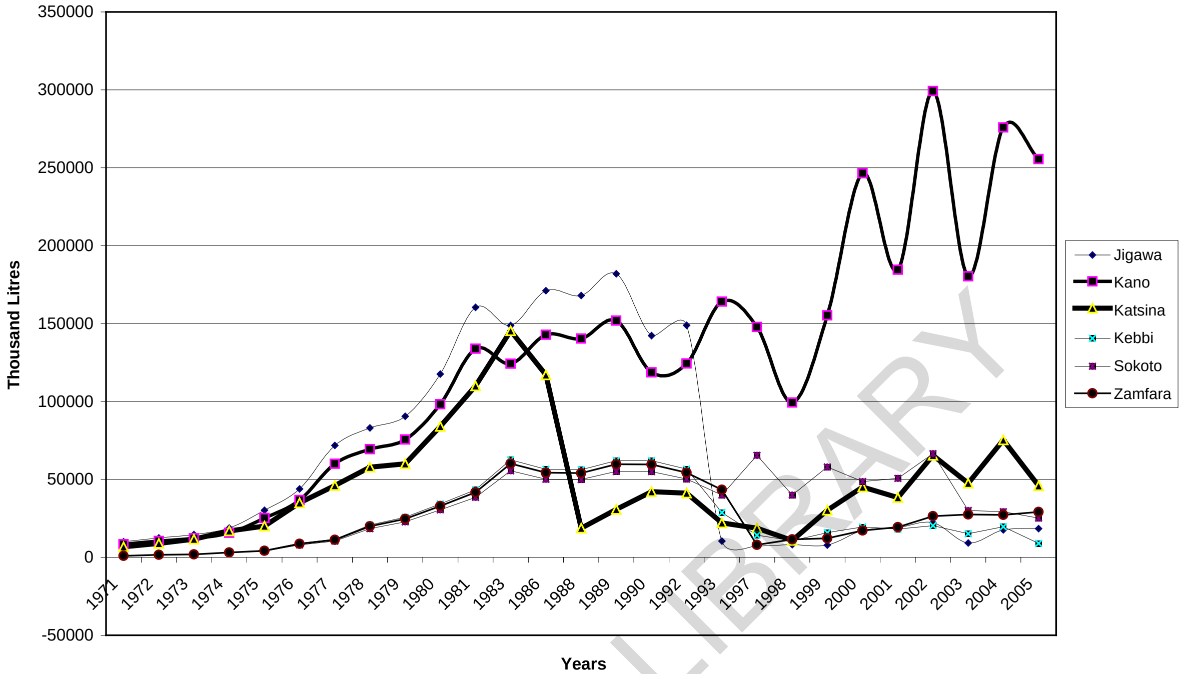


Fig. 4.9: Gasoline Consumption in North West Zone 1971-2005



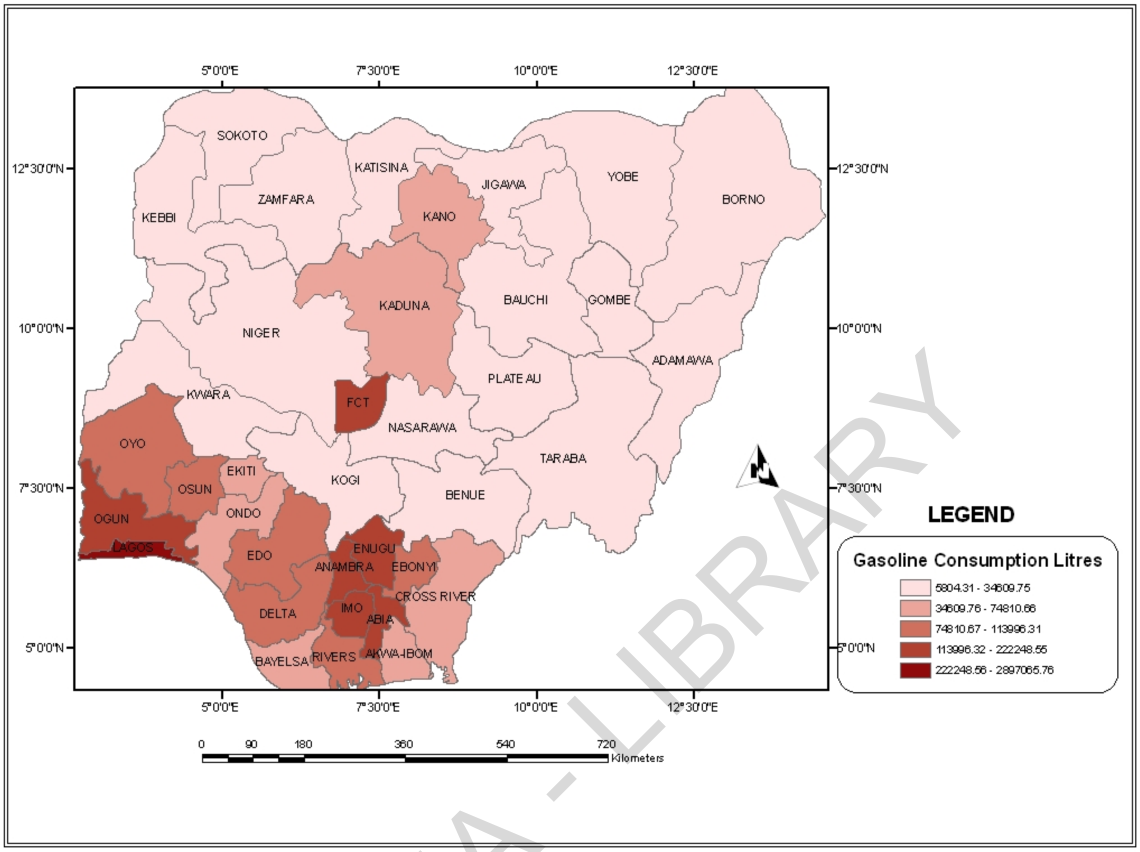


Fig. 4.10: Gasoline consumption in Nigeria 1971-2005

Compared with the work of Ikporupko (1978), four new (additional) major consumption centres have been identified in this study, namely, Ogun, Delta, Imo, states and Abuja (FCT). Ikporupko collected data on the quantity of gasoline consumed in 50 towns for a period of four years (1971-1974) from seven oil marketing companies operating in the country. His analysis showed that the Southern belt had the greatest concentration of large consumption centres, namely, Lagos, Ibadan, Benin, Onitsha, Port Harcourt and Enugu. Others are Kano, Kaduna, and Ilorin. Since the attempt in this study is to examine gasoline consumption in all the states, it was not feasible to obtain the necessary data on each town for the 27 year period under study. This is because data on gasoline consumption published by the NNPC is on the basis of states and not towns.

Besides the fact that the oil marketing companies do not publish the volume of gasoline distributed in each town, the number of oil marketing companies and retail outlets in each town has increased over time. Hence, it is difficult to ascertain gasoline consumption in each town for the period under review. As a result, data on gasoline consumption in the 36 states was utilized. However, some of the major consumption centres identified by Ikporukpo (1978) represent the state capitals of some of the largest consumption states identified in this study: Lagos-Lagos State, Ibadan-Oyo State, Benin –Edo State, Port Harcourt- Rivers State, Kano- Kano State and Kaduna- Kaduna State. This is because a high percentage of the population and socio-economic activities in each state are concentrated in the cities. The high consumption centres (states) which were not included in Ikporukpo's study are Ogun, Delta, Imo states and Abuja(FCT). Gasoline consumption in these states may have increased tremendously after 1974 due to growing population, administrative, commercial and industrial activities, in particular, the FCT.

To analyse the spatial distribution of gasoline consumption in the country, the analysis of variance technique is utilized. The between and within groups variance are estimated and the F-value of 56.933 is obtained (Table 4.3). This value is significant at 5 percent level

Table 4.3: Analysis of Variance for Spatial Variation of Gasoline Consumption in Nigeria

Data	Sum of squares	Df	Mean Square	F	Sig
Between	2.0E+13	36	5.6E+	56.9	0.000
Group	9.5E+12	958	11	33	
Within groups	3.0E	994	9.9E+ 09		
Total					

Author’s Analysis,2006

with df1=36 and df2=958. Hence, there is a significant difference in the spatial variation of gasoline consumption in Nigeria.

The significant variation in the spatial pattern of gasoline consumption in the country is attributable to the pattern of development. The larger consumption centres are either administrative, industrial or commercial centres and of necessity consume a lot of gasoline.

4.5 Determinants of the spatial pattern

In the preceding section on spatial and temporal pattern of gasoline consumption in Nigeria, the variation in gasoline consumption over space and time was discussed. In this section, an attempt is made to determine the precise relationship between the quantity of gasoline consumed and critical variables likely to significantly explain consumption volume. Although the factors identified as explaining demand here relate mainly to variation over space, these factors may also apply to variation over time. Before the analysis is carried out, a review of the theoretical basis of the choice of variables is provided.

4.5.1 Theoretical Basis for Choice of Variables

In this study, the choice of explanatory variables has been influenced mainly by the theoretical and practical relevance to the Nigerian situation and the availability of data. The following seven variables were selected:

Population Size: The population size affects the range of local jobs and services that can be supported and influences the range of public transport services which can be provided. Population size is a rough proxy measure of accessibility and urban structure (Giuliano and Narayan, 2003). Smaller areas that are unable to support a large range of services and facilities may force residents to travel longer distances in order to access the services that they require. Very large, centralized settlements may on the other hand, lead to longer travel distances as the separation between homes and the urban centres become large. Several studies, for example, Orfeuil and Salomon, (1993) and Breheny (1995) show that areas with low population size are associated with long trip distances and high transport energy consumption while short distances and low transport energy consumption are observed in large cities.

Population Density: Population density when measured at a sufficiently disaggregate level, h as proven to be an effective proxy for intra-metropolitan spatial structure (Pushkarev and Zupan,1977;Neimener and Butherford, 1994; Schimek,1996). High density is a surrogate for greater transit availability, more walkable environments, mixed use and high accessibility. Low density is a surrogate for low accessibility (Giuliano et al, 2003). Newman and Kenworthy (1989) claim support for the argument that denser cities result in lower per capita gasoline consumption. The population density of each state is derived by dividing the population of the state by the computed area.

Per Capita Income: Per capita income influences auto ownership and use both at the aggregate and disaggregate level. The value of time increases with income, thereby offsetting the higher monetary costs of faster modes, hence, increasing demand for the automobile. High demand for gasoline is associated with increase in per capita income. High income households make more trips and travel long distance. Therefore, transport energy consumption increase as income increases.

Number of Industrial Establishments: Industries that make use of motorized equipment use gasoline for various production processes. It is therefore hypothesized that the more the number of firms in a given place, the more the quantity of gasoline that location may consume. Since not all firms necessarily make use of gasoline, perhaps a better approach would have been to make use of those industrial establishments that really use gasoline in their production process. However, this group has not been used in the analysis because of the problem of identifying them.

New Registration of Gasoline using Vehicles: The gasoline consumption capacity of vehicles varies. Thus, states with high number of vehicles with heavy gasoline consumption capacity will have high levels of gasoline consumption than those with less of such vehicles. The number of gasoline using vehicles registered in each state is used as a proxy variable for the total number of vehicles operating within each state. However, vehicles registered in each state are by no means the total number in circulation. This is because some people register their vehicles outside their state of residence either for social identification with their place of origin or to reduce the cost of registration. The gasoline using vehicles include motorcycles, private and commercial vehicles.

Length of Roads: Construction and improvement in the quality of road network is usually necessitated by increased vehicle numbers. Consequently, areas with high road length are assumed to have high number of vehicles and high transport energy consumption. At the other extreme, there are many minor roads in remote parts which carry low traffic. The total length of all types of roads (both federal and state) in the states were used in the analysis.

Number of People Employed: Work status influence journey frequency. Journey frequency increases as the number of workers per household increase (Ewing et al,1996).Thus, areas with high number of people employed have high trip frequency and consume more energy for transportation.

4.5.2 The Model

The step-wise multiple regression equation which expresses the relationship between gasoline consumption and various predetermined independent variables is expressed as follows:

$$Y= a+ b1x1+b2x2+b3x3+b4x4+b5x5+b6x6+b7x7+b8x8 +e$$

where Y = gasoline consumption in the states (dependent variable) x1-x7= the various predetermined variables (independent variables):

x1 =population size

x2 = new registration of gasoline using vehicles

x3 =per capita income

x4 =number of industrial establishments

x5 = population density

x6 = number of people employed

x7 = vehicle registration

x8 = length of roads

e = an error factor or stochastic disturbance term

a = Y intercept, it indicates the value of Y when X = 0

b1-b7 = regression coefficients

In the equation, all the explanatory variables are hypothesized as having a positive and linear relationship with the dependent variable.

4.5.3 Result

The multiple regression model, like any other statistical technique, makes some basic assumptions. These assumptions are that there should be no autocorrelation, multicollinearity, homoscedasticity, and that the samples are randomly selected from the total population. Other assumptions are that the data set are normally randomly distributed , and that the independent variables are measured error free. The presence of high linear relationships of 0.8 among the explanatory variables is termed multicollinearity. When there is multicollinearity, it becomes difficult to sort out the contributions of each of the independent variables to the total sum of squares or total variance of the dependent variable, the inverse of the matrix of correlation would involve computational error, the coefficient of multiple determination and the standard error of the regression coefficients would be enlarged. A large standard error indicates that the probability of getting an individual partial regression coefficient that is far from the population partial coefficient is increased. However, to Mather (1976), this problem is not critically dangerous if the regression model is being used purely for descriptive purposes.

Traditionally, geographers used to resort to the use of principal component analysis to reduce the number of independent variables. Mather (1976: p.73) held a strong view that ''a multiple regression based on principal component scores would amount to one building an artificial boundary between the regression equation and the system which is described by the variables. In addition, eliminating one of the variables from the regression analysis would involve throwing away useful information''.

The logarithm (base 10) of the data was used in the analysis since the data have different metrics. Table 4.4 shows the correlation matrix between the dependent variable (Y) and the independent variables(X_1 toX_8) on one hand, and amongst the independent variables on the other. The correlations between the dependent variable and the independent variables are high. The highest is 0.729 between the volume of gasoline consumption and new registration of gasoline using vehicles. The correlation coefficients of population size, per capita income, number of industrial establishments, population density, number of people employed, vehicle registration, and length of roads are 0.349, 0.666, 0.727, 0.446, 0.521, 0.702 and 0.326 respectively. The correlation coefficients of all the independent variables are positive and significantly related to gasoline consumption at 0.05 level of significance. This implies that gasoline consumption increases as the independent variables increase. However, table 4.4 also indicate that a high positive correlation in excess of 0.80 exists between population size and number of people employed (0.835) and between new registration of gasoline using vehicles and vehicle registration (0.854). These are indications of multicollinearity problem among the variables. As a result, the principal component analysis is employed to solve the problem.

The principal component analysis is a technique used for collapsing a set of intercorrelated variables into a smaller or same number of uncorrelated dimensions or variates. The technique is useful in a situation where the number of explanatory variables that are theoretically relevant in a regression model is very large relative to sample size.

Table 4.4: Correlation Matrix of Gasoline Consumption and Independent Variables

Variable	Y	X1	X2	X3	X4	X5	X6	X7	X8
Y	1	0.349	0.729	0.666	0.727	0.446	0.521	0.702	0.326
X1		1	0.659	0.043	0.460	0.406	0.835	0.613	0.633
X2			1	0.304	0.553	0.378	0.649	0.854	0,.46 4
X3				1	0.463	0.312	0.294	0.256	0.115
X4					1	0.628	0.497	0.561	0.236
X5						1	0.556	0.484	0.048
X6							1	0.598	0.647
X7								1	0.375
X8									1

Author's Analysis,2008.

Principal component would help create new and fewer variables or make a selection from the old set of variables that could be used in the regression analysis. The method could also be used when there is a high degree of multicollinearity in a data set and the research interest is in determining the fewer set of variables that could be used in the regression analysis (Ayeni, 1995). The aim of the principal components analysis is the construction of a new set of variables Y1, Y2, Y3,……….Yn called principal components from a set of variables X1,X2, X3,………..Xn such that although the X variables may be correlated, the Y variables are uncorrelated and are linear combinations of the X variables.

The result of the principal component analysis on the eight variables in table 4.5. show that only two components have an eigenvalue that is greater than one. This implies that only two components were extracted. Table 4.6 shows how the variables correlate with the components and the relative importance of each component. The first component accounting for 41.43percent of the total variation correlate highly with the number of people employed, new registration of gasoline using vehicles, vehicle registration, and population size. On the other hand, the second component which accounts for 30.05 percent of the variation correlate highly with per capita income only. Thus, the two components accounts for 71.48percent of the variation in the original data. The first component is named demographic and motorization factor while the second component is named economic factor.

The result of the regression analysis (table 4.7) using the components scores as independent variables against the dependent variable (gasoline consumption) show that the multiple correlation coefficient (R) is 0.825 and R^2 is 0.68. This implies that 68 percent of the variation in gasoline consumption is explained by the independent variables. With an F value of 36.345, the model is significant at 0.001 level of significance. Furthermore, regression analysis using the components with high correlations as independent variables against the dependent variable reveal that the t-values for new registration of gasoline using vehicles and per capita income are 5.006 and 5.312 respectively (see table 4.8). These t-values are significant at 0.005 significance level. This implies that new registration of gasoline using vehicles and per capita income

Table 4.5: Eigenvalues of the Correlation Matrix

Components	Eigenvalues
1	4.384
2	1.334
3	0.794
4	0.664
5	0.370
6	0.236
7	0.125
8	0.092

Author's Analysis,2008

Table 4.6 : Principal Components and Factor Loadings of the Correlation Matrix

	Component 1	Component 2
Volume of gasoline (litres)	0.882	-0.193
Population size	0.853	-0.064
New registration of gasoline using vehicles	0.834	0.025
Per capita income	0.831	-0.392
Number of industries	0.738	0.444
Population density	0.642	0.483
Number of people employed	0.608	-0.585
Vehicle registration	0.408	0.606
Eigenvalue	4.384	1.334
% of Variance	41.43	30.05
Cumulative %	41.43	71.48

Author's Analysis,2008

Table 4.7: Summary of Regression Model of Component Scores and Gasoline Consumption

Model		Unstandardized Coefficients								
		B	Std. Error	Beta	t	Sig.	R	R^2	F	Sig.
1	(Constant)	4.813	.033		147.385	.000	0.825	0.681	36.34	0.000
	Component Score 1	.131	.033	.382	3.943	.000				
	Component Score 2	.250	.033	.732	7.559	.000				

Author's Analysis, 2008

Table 4.8: Summary of Regression Model of Components and Gasoline Consumption

Model		Unstandardized Coefficients				.				
		B	Std. Error	Beta	t	Sig.	R	R2	F	Sig
1	(Constant)	1.237	.901		1.373	.179	0.866	0.75	32.924	0.000
	Population Employed	.001	.178	.000	.003	.998				
	Gasoline using vehicles	.508	.101	.580	5.006	.000				
	Per capita income	.676	.127	.490	5.312	.000				

Author's Analysis, 2008

are significant in explaining the spatial distribution of gasoline consumption in the country.

CHAPTER FIVE

DETERMINANTS OF HOUSEHOLD GASOLINE CONSUMPTION FOR INTRA-URBAN TRAVEL

5.0 Introduction

In chapter four, the spatio-temporal pattern of gasoline consumption in Nigeria was examined using aggregate data. Oyo state was identified as the second largest gasoline consumption centre after Lagos. Hence, it is important to identify land use, household socio-economic and trip characteristics that influence household gasoline consumption at a disaggregated level in Ibadan metropolis. As noted earlier, disaggregate studies use household observations of vehicle usage and either city-wide, zonal, or neighbourhood averages for urban form variables. Four hypotheses are tested, namely (i) location of jobs, shopping, service centres has a significant impact on household gasoline consumption,(ii) gasoline consumption is significantly related to household's trip distance, (iii) socio-economic characteristics of households and vehicle ownership significantly affect gasoline consumption and (iv)households respond to increase in price of gasoline by shopping trips, shifting to fuel efficient cars and the use of public transport.

5.1 Spatial pattern of household gasoline consumption in Ibadan metropolis

This study focuses on the energy used by all vehicles owned or leased by households including vehicles available to households for the general use of household members. Household vehicles are defined as all vehicles including motorcycles, cars and buses. Out of the 1327 respondents, 640 (48.2 percent) had at least one vehicle while 687 (51.8 percent) had none. A distinction is therefore made between vehicle owners that

Table 5.1: Vehicle Owners by Households in each Local Government Area of Ibadan Metropolis

LGA	*Sample Size*	*Vehicle Owners*	*Percentage of sample Size*
North West	167	96	57.5
North East	188	62	33
South East	137	69	50.4
North	218	141	64.7
South West	156	46	29.5
Oluyole	52	20	38.5
Ona Ara	118	40	33.9
Lagelu	70	22	31.4
Ido	115	43	37.4
Akinyele	140	61	43.6
Egbeda	90	40	44.4
Total	1451	640	

Author's Analysis,2008.

consume gasoline directly and non-vehicle owners that consume gasoline through the use of public transport vehicles. Table 5.1 shows the number of households in each local government area that has at least one vehicle. Ibadan North has the highest number of vehicle owners with 141(64.7 %) of the sample size. This is followed by North West with 96 (57.5%) and South East with 69(50.4 %). South West has the least with 46(29.5%). The concentration of vehicle owners within the urban area of the metropolis is due to the fact that majority of the commercial, industrial, educational, residential and medical facilities are located within the urban areas. Thus, the residents have access to jobs and high income which enable them to own vehicles compared to residents in the rural areas that are predominantly farmers with low income.

A breakdown of the number of vehicle(s) available to households that have vehicles shows that 521(81.4%) households have one vehicle, 84 (13.1%) have two vehicles, 25 (3.9%) have three vehicles, 8 (1.3 %) have four vehicles and only 2 (0.3 %) have 5 vehicles. The ownership of multiple vehicle households is a reflection of the increase in people's personal income compared to 1982-1986 when per capita income was low and the level of motorization in principal cities was low, culminating in mobility crisis (Filani, 1988). Several claims have been made that increasing wealth automatically tends towards high automobile dependence (Lave,1992: Kirwan,1992 and Gomez-Ibanez, 1991). Increase in vehicle ownership is made more obvious when one considers the number of private vehicles on Nigerian roads and the increasing trend of gasoline consumption in the country. Ariyo (2006) noted that per capita income which measures the average disposable income available to a citizen towards meeting his/her daily needs of life ranged from US$860 in 1984 to a maximum of US$950 in 1985 after which it witnessed a steady and sharp decline up to 1996. However, marginal improvement has commenced since then, and this rate of improvement has increased since 2000. Increase in per capita income has significant implications for transport energy consumption. This is because as income rises, the value placed on time increases and this shifts transport demand from lower cheaper modes of transportation to speedier more expensive modes, which means, in most urban transport situations, the automobile. The continuous increase in private car ownership, thus, brings with it a very large increase in per capita energy use for transport. Hanson, (1982): Naess and Sandberg, (1996): Kockelman, (1997) report that trip frequency, total travel distance, proportion of car journeys and transport energy consumption increase with car ownership.

Table 5.2 shows the spatial distribution of gasoline consumption for various trips. Gasoline consumption for each trip was estimated by multiplying the volume of gasoline consumed by the number of trips. The value obtained was summed to obtain the volume consumed in a week for each trip. A total of 40182.5 litres of gasoline were consumed for work, school, shopping and service/recreational trips among the eleven local government areas in Ibadan metropolis. Out of these, 29,425 (73.2%) litres were consumed for work trip, 4,844.5 (12.1%) litres for school trip, 3,264(8.12%) litres for service/recreational trip and 2,649(6.7%) litres for shopping trip. The dominance of work and school trip in total gasoline consumption for intra-urban travel is not surprising as journey to work and school constitute the most important travel purpose in urban centres. People travel from their homes to workplaces daily so as to earn income and students also travel from home to school daily except on weekends. Since these activities have time restrictions (resumption and withdrawal time), households tend to utilize the automobile which is the fastest available mode of transport in an urban centre. On the other hand, shopping and service/recreational trips are not compulsory trips as the frequency of trips is determined by the individual. Destination is not fixed because an individual may choose different shopping centres, hence, households may utilize non-motorised modes of transport for shopping and service trips.

Figure 5.1 shows the spatial pattern of gasoline consumption for work, school, shopping and service/receational trips in Ibadan metropolis. Ibadan North has the highest level of consumption for work trip with 6287 (21.4%) litres followed by North West with 4647 (15.8%) litres and North East with 3579 litres(12.2%) respectively. Oluyole local government area has the least with 761 (2.6%)litres. Ibadan North has the highest proportion of gasoline consumption for school trip with 1322 (27.2%) litres. This is followed by North West with 645 (13.3%) litres and Akinyele with 602.5 (12.4%) litres.

Table 5.2: Spatial Distribution of Gasoline Consumption for Various Trips in Ibadan Metropolis.

LGA	Work trip	%	School trip	%	Shopping trip	%	Service /Recreational trip	%	Total
North West	4647	15.7	645	13.3	304.5	11.5	465	14.2	6061.5
North East	3579	12.1	180	3.7	140	5.3	178	5.5	4077
South East	2292.5	7.8	610	12.6	251	9.5	278	8.5	3431.5
North	6287	21.4	1322	27.2	713	26.9	742	22.7	9064
South West	1833	6.2	275	5.7	107	4.0	181	5.5	2396
Oluyole	761	2.6	219	4.5	42	1.6	104	3.2	1126
Ona Ara	3128	10.6	195	4.0	225	8.5	261	8.0	3809
Lagelu	913	2.7	45	0.9	40	1.5	45	1.4	1043
Ido	1794.5	6.1	576	11.9	393.5	14.9	463.5	14.2	3227.5
Akinyele	2731	9.3	602.5	12.4	356	143	431.5	13.2	4121
Egbeda	1459	5	175	3.6	77	2.9	115	3.5	1826
Total	29425	100	4844.5	100	2649	100	3264	100	

Author's Analysis, 2008

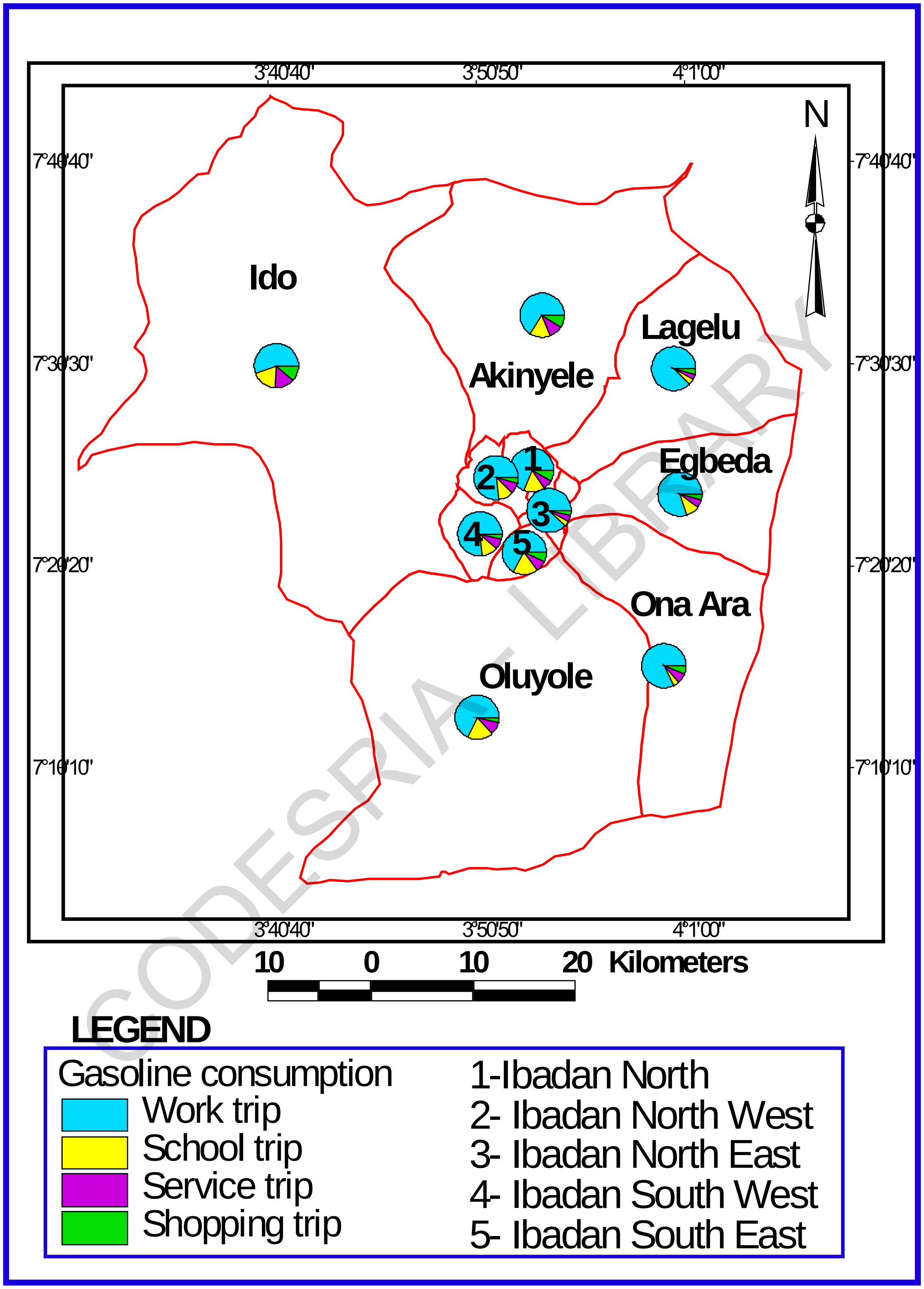


Fig. 5.1: Spatial pattern of gasoline consumption for various trips in Ibadan Metropolis

On the other hand, Lagelu had the lowest volume with 45 (0.9%) litres..The high level of gasoline consumption for work and school trips in Ibadan North LGA may be attributed to the high concentration of population and educational facilities in the area. For example, Ibadan north had the highest number of nursery, primary and secondary schools and tertiary institutions in the metropolis. As a result, the number of work and school trips generated is high, thus increasing the level of gasoline consumption.

The spatial distribution of gasoline consumption for shopping trip in figure 5.1 show that Ibadan North has the highest level of gasoline consumption with 713(26.9%) litres followed by Ido LGA with 393.5(14.9%) litres, Akinyele with 356 (13.4%) litres and North West with 304.5 (11.5%) litres. Lagelu had the least volume of gasoline consumption for shopping trips with 40 (1.5%) litres. Figure 5.1 shows that Ibadan North had the highest **l**evel of gasoline consumption for service/recreational trip with 742 (22.7%) litres. This is followed by Ibadan North West with 465(14.2%) litres and Ido with 463.5 (14.2%) litres. Lagelu has the least with 45 (1.4%) litres. The high level of gasoline consumed for shopping trip in Ido LGA is due to the long travel distance which households travel to shopping centres. Ido LGA has the least number of markets in the metropolis. The four markets in the area, namely, Akufo, Omi Adio, Ido and Elenushonsho are periodic as they operate every five days. Consequently, households travel to markets which are far from their residential area for shopping activities. The major modern markets such as Bodija, Oje and New Gbagi are far from Ido LGA. Thus, household travel distance and gasoline consumption for shopping trip are high.

5.2 Land use pattern and gasoline consumption

Khisty (1990) defines an urban area as a locational arrangement of activities or land-use pattern, where the location of activities affects human beings and human activities modify locational arrangements. This definition involves the notion that due to human needs- social, economical, political and cultural, interactions which are performed between individuals lead to the establishment of activities. Obviously, these activities are related both to spatial position in an urban area (locational arrangement) and to the characteristics of the surface they are occupying (land–use). In dynamic terms, activities and their characteristics (location and land use) affect human beings, and vice-versa (urban interactions).

According to Khisty, urban form is the spatial pattern or arrangement of individual elements such as buildings, streets, parks, and other land uses (collectively termed the built environment) as well as social groups, economic activities and public institutions within the urban area. Urban form encompasses the layout and spatial relationships between residences, employment centres, entertainment centres, retail centres and the overall supporting infrastructure. Thus, it may simply be defined as the spatial configuration of fixed elements within a metropolitan region. Urban form is dynamic. Incremental changes such as redevelopment, infill development or expansions of the structures and communities make the urban form dynamic and ever growing.

Urban interaction on the other hand is the collective set of interrelationships, linkages and flows that occurs to integrate and bind the pattern and behaviour of individual land uses, groups and activities into the functioning entities or subsystems. Urban spatial structure combines the urban form, through the urban interaction, with a set of organizational rules, into a city system .

Urban form as it relates to energy consumption is based on the spatial relationships between uses with transportation options to connect uses playing a major role. There are two main components of urban form that significantly influence energy consumption. These are land use distribution and pattern and transportation networks and modes. The distribution of land-uses and spatial layout of a city affects many components of urban growth and community interactions including access, environmental quality, resident activity levels and health. The density, mix, and spatial arrangement of land uses in a community heavily influence the amount and mode of travel and transportation energy use. Greater separation of land uses necessitates increased travel between uses and may result in increase in energy consumption. Decreasing separation between uses allows for the decreased travel distances and greater opportunities for the use of non- vehicle modes such as walking and cycling.

5.2.1 Basis and spatial distribution of land use variables

The land use variables used in this study are population size, population density, number of nursery/primary schools secondary schools, tertiary institutions, public health institutions, private health institutions, markets, industrial establishments, post offices, banks, recreational centres, hotels and length of roads. These variables were chosen because they are measurable and relatively available. In addition they have been recognized as potentials of urban trip generation (Filani,1972; Oyebamiji,1981; Oyesiku,1990; Ademiluyi,1996).

These land use variables can be categorized into six main groups, namely, population density, health facilities, educational facilities, commercial centres, industrial centres and recreational centres. The theoretical basis for the choice of some of these variables (population size, population density, industrial establishment, and length of roads) have been discussed in chapter four, hence, need not be repeated here.

The importance of education (formal or informal) in the overall development of a society cannot be overemphasized as it is the bedrock of development. At the individual level, education serves as the means of enriching knowledge, skill and developing full personality. At the community level, education is seen as a weapon against ignorance, disease, and poverty as well as an agent of obtaining an enlightened, living and industrious citizenry (Taiwo, 1980; Ogunkola,2000). For a developing country in particular, education represents an investment in human capital required not only for economic development and material well- being but also for cultural development, social equality as well as political emancipation.

Education could be formal or informal. Informal education takes place out of a classroom environment, does not have a detailed curriculum and many of the centres where it is carried out are not registered. On the other hand, formal education involves the use of a well defined location usually a classroom, structured courses, and is registered by the government. Therefore, the facilities of educational institutions are used as a set of development indicators. Movements to and from schools generate a lot of traffic within an urban centre ,hence, the importance of education variable to this study. Following the works of Taiwo (1980), Ademiluyi (1996), and Ogunkola (2000), both public and private nursery and primary schools, secondary schools, and tertiary institutions in each of the local government areas in the metropolis are used to measure educational facilities in this study.

Health care delivery is a notable pre-condition for social and economic development of a society. It represents a very important service that affects the welfare and productivity of people. Health care delivery generally is either preventive or curative. The latter receives more attention in Nigeria (Okafor, 1988; Ademiluyi,1996). People move from their homes to public and private health care centres and vice-versa in quest for health services, thereby, generating a lot of trips within the metropolis. Thus, in this study, both public and private hospitals, dispensaries, maternity centres and clinics in each local government area are used to measure health care services.

Commercial centres are areas for shopping and business activities. Although business transactions may not necessarily take place in specific structures, shopping activities occur in markets and retail shops. The large population in cities need food and other ancillary facilities, and, as these are provided, the city expand. Trading activities allows many city dwellers to pursue livelihoods other than farming, thus, bringing specialization and development. Based on the cultural setting of the people and their low per capita income, extensive commercial activities take place in retail structures within the metropolis. According to Afolayan (1994), trading represents a major occupation of residents in Ibadan. Consequently, a lot of traffic is generated within the metropolis through movements to and from these commercial centres. In this study, both daily and periodic markets in each of the local government areas are used to measure commercial activities.

Recreational facilities are also important in any regional economy. The location of recreational facilities such as sport centres, cinema houses and parks generates traffic as people move to and from these locations. In this study, the number of stadia, tourist attraction spots and standard hotels are used to measure recreational facilities.

Table 5.3 shows the distribution of land use variables among the local government areas in Ibadan metropolis. The distribution pattern of population from the 2006 census shows the leading position of Ibadan North East with 330 399 (13.2%). This is followed by Ibadan North, 306, 795 (12.3%), South West, 282,585 (11.3%), Egbeda 281,573 (11.3%) and Ona Ara, 265, 059 (10.6%). Ido with a population of 51,511 (2.1%) has the least population size. The spatial pattern of population density in the metropolis indicate that Ibadan North East has the highest density with 18730.1(30.6%) followed by Ibadan North, 11651.9 (19%), South East,11369.5 (18.6%), and South West 7059.3 (11.5%). Ido LGA has the lowest population density with 174.4(0.3%).

The highest proportion of nursery and primary schools in Ibadan metropolis are in Ibadan North, accounting for 181 (12.9%). This is followed by South East 148 (10.5%), Ido 145(10.3%), South West 141 (10%) and Ona Ara 131 (9.3%). Egbeda has the least proportion with 77 &5.5%) schools. The distribution of secondary schools in the metropolis shows that Ibadan North has the highest proportion with 91 (17.9), followed by South West 78 (15.3%), and South East (13.1%). Ido has the least proportion with 4.3%. Tertiary institutions unlike nursery/primary and secondary schools are not found everywhere. Ibadan North has 37.5 %, Oluyole (25%),North West, North East and South West each has 12.5%.

A total of 210 public health institutions exist in Ibadan. Their distributional pattern shows that 14.8% are in Akinyele, 14.3% in Lagelu, and 11.4% in Oluyole. South East has the least proportion with 3.3%. Private health institutions are also unevenly distributed among the local government areas in Ibadan metropolis with Ibadan North having the highest proportion with 27.5%, South West (22.3%) and South East (7.8%).

Table 5.3 : Distribution of land use variables in Ibadan metropolis

	NW (%)	NE (%)	SE (%)	N (%)	SW (%)	OLUYOLE (%)	ONA ARA (%)	LAGELU (%)	IDO (%)	AKINYELE (%)	EGBEDA (%)	Total
Population	152834(16.1)	330399(13.2)	266046(10.6)	306795(12.3)	282585(11.3)	202725(8.1)	265059(10.6)	147957(5.9)	51511(2.1)	211359(8.5)	281573(11.3)	2498843
Density	5351.3(8.7)	18730.1(30.6)	11369.5(18.6)	11651.9(19)	7059.3(11.5)	714.07(1.2)	1651.4(2.7)	923.5(1.5)	174.4(0.3)	1113.6(1.8)	2533.5(4.1)	61272.53
Nur/pry	106(7.5)	127(9)	148(10.5)	181(12.9)	141(10)	115(8.2)	131(9.3)	122(8.7)	145(10.3)	115(8.2)	77(5.5)	1408
Secondary	26(5.1)	49(9.6)	67(13.1)	91(17.9)	78(15.3)	25(4.9)	32(6.2)	35(6.8)	22(4.3)	41(8.1)	42(8.3)	508
Tertiary	1(12.5)	1(12.5)	-	3(37.5)	1(12.5)	2(25)	-	-	-	-	-	8
Public health	10(4.8)	15(7.1)	7(3.3)	17(8.1)	21(10)	24(11.4)	16(7.6)	30(14.3)	20(9.5)	31(14.8)	19(9)	210
Private Health	31(5.5)	34(6)	44(7.8)	155(27.5)	126(22.3)	20(3.5)	35(6.2)	25(4.4)	22(3.9)	32(5.7)	40(7.1)	564
Markets	10(8.9)	5(4.5)	18(16)	9(8)	9(8)	16(14.3)	11(9.8)	13(11.6)	4(3.6)	8(7.1)	9(8)	112
Industries	9(2.5)	-	1(0.3)	24(6.7)	231(64.5)	36(10.1)	3(0.8)	8(2.2)	1(0.3)	6(1.7)	39(10.9)	358
Post Office	1(14.3)	3(42.9)	1(14.3)	1(14.3)	1(14.3)	-	-	-	-	-	-	7
Hotel	1(0.8)	3(2.4)	31(25)	29(23.4)	31(25)	-	2(1.6)	-	2(1.6)	4(3.2)	21(16.9)	124
Recreational centres	2(8.3)	-	1(4.2)	11(45.8)	8(33.3)	-	-	-	-	2(8.3)	-	24
Banks	8(11.4)	5(7.1)	8(11.4)	15(21.4)	21(30)	2(2.8)	-	-	4(5.7)	1(1.4)	6(8.6)	70
Road length	100547(8.2)	61623.16(5.0)	39658.12(3.2)	141852.1(11.5)	121723.7(9.9)	72580.75(5.9)	127830.7(10.4)	72773.14(5.9)	89441.4(7.3)	238447.3(19.4)	163924.6(13.3)	1230401.9

Sources : Ministry of Education, Oyo State
Ministry of Health, Oyo State
National Population Commission
Local Government Secretariats
Nigerian Postal Service
Financial institutions in Ibadan
Taiwo, 2006, Author's Fieldwork, 2008

Markets feature in all the LGA in Ibadan. However, the size and variety of goods sold in each of the markets vary. Major modern markets such as Bodija, Oje and New Gbagi operate daily and attract sellers and buyers from the rural areas of the metropolis and neighbouring towns. On the other hand, rural markets are periodic and have limited variety of goods. The spatial pattern reveals the leading position of South East with 16%, Oluyole (14.3%), Lagelu (11.6%). Ido has the least proportion with 3.6%. 358 Industrial establishments exist in Ibadan metropolis. Out of these, 64.5% are concentrated in South West, 10.9% in Egbeda and 10.1% in Oluyole. South East and Ido has the least with 0.3% each. Small scale industrial establishment which employ less than ten persons are organized on cottage or compound basis, so that industrial and residential spaces are in the same place. The small scale industries which are more than the factory industries are not in official records of the state and local government offices. Hence, the small scale industries are not included in this study.

Hotel facilities exist in 9 out of the 11 LGAs. There is no hotel facility in Oluyole and Lagelu LGA. Out of a total of 124 hotels in the metropolis, South West and South East each account for 25%, Ibadan North 23.4%, Egbeda 16.9% and Akinyele 3.2%. North West with less than 1% has the least proportion of hotels among the LGAs. The distributional pattern of banks in Ibadan metropolis shows that South west has the highest proportion with 30%, North 21.4%, North West 11.4% and South East 11.4%. Akinyele has the least proportion of banks with 1.1%.

Total road length in Ibadan metropolis is 1,230,401.9 kilometres (Taiwo, 2006). Of these, Akinyele LGA has the highest road length with 19.4 %. This is followed by Egbeda (13,3%), Ibadan North(11.5%) and Ona Ara (10.4%). Ibadan South East has the least with 3.2%. A total of 24 sport and recreational centres exist in the metropolis. The distributional pattern shows that Ibadan North accounts for 45.8%, South West (33.3%), North West and Akinyele each records 8.3% while South East has 4.2%.

Figures 5.2 and 5.3 show the spatial pattern of land use variables in Ibadan metropolis. A general observation of the spatial distribution of land use variables in Ibadan metropolis

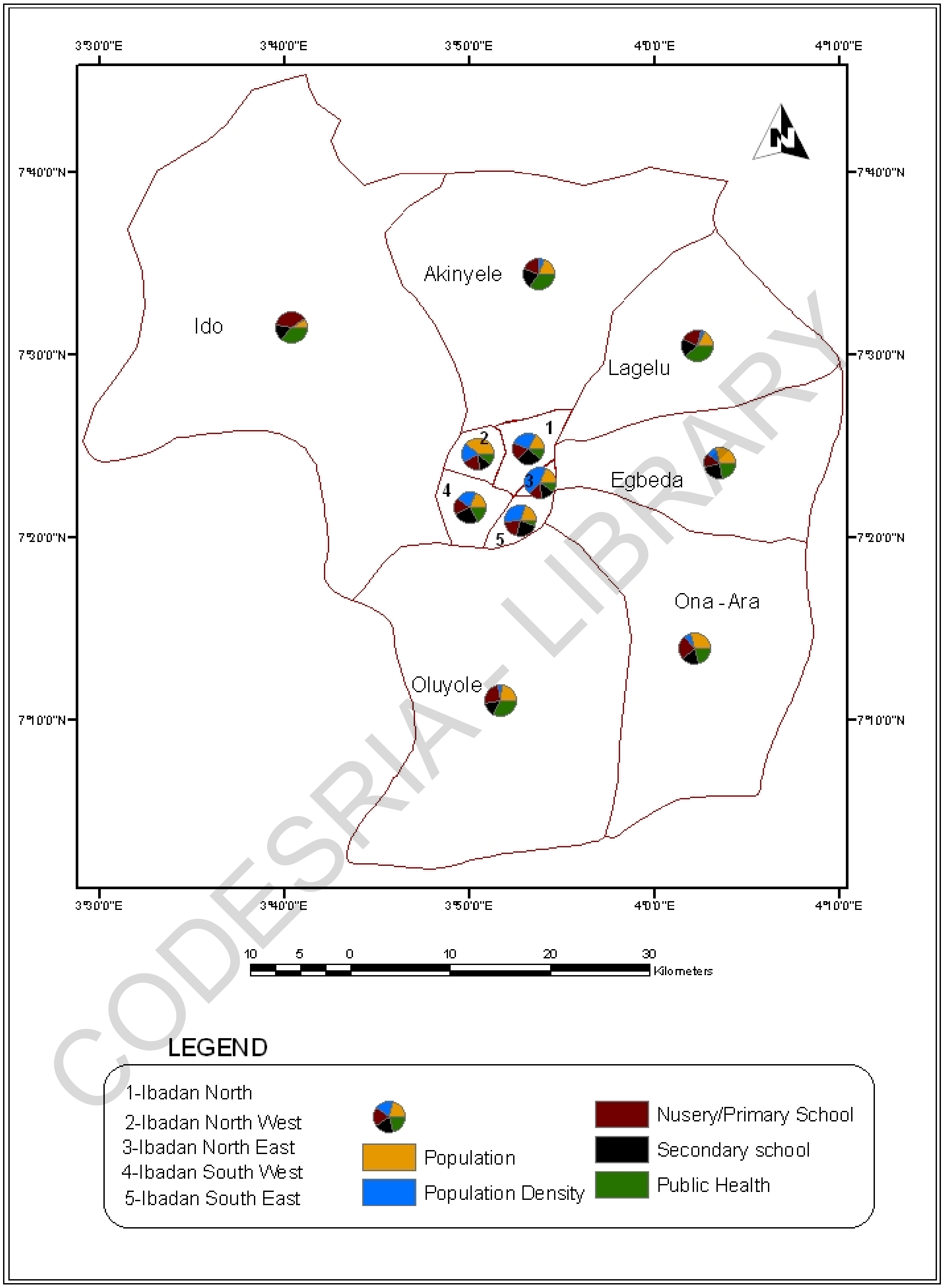


Fig. 5.2: Distribution of land use variables in Ibadan metropolis

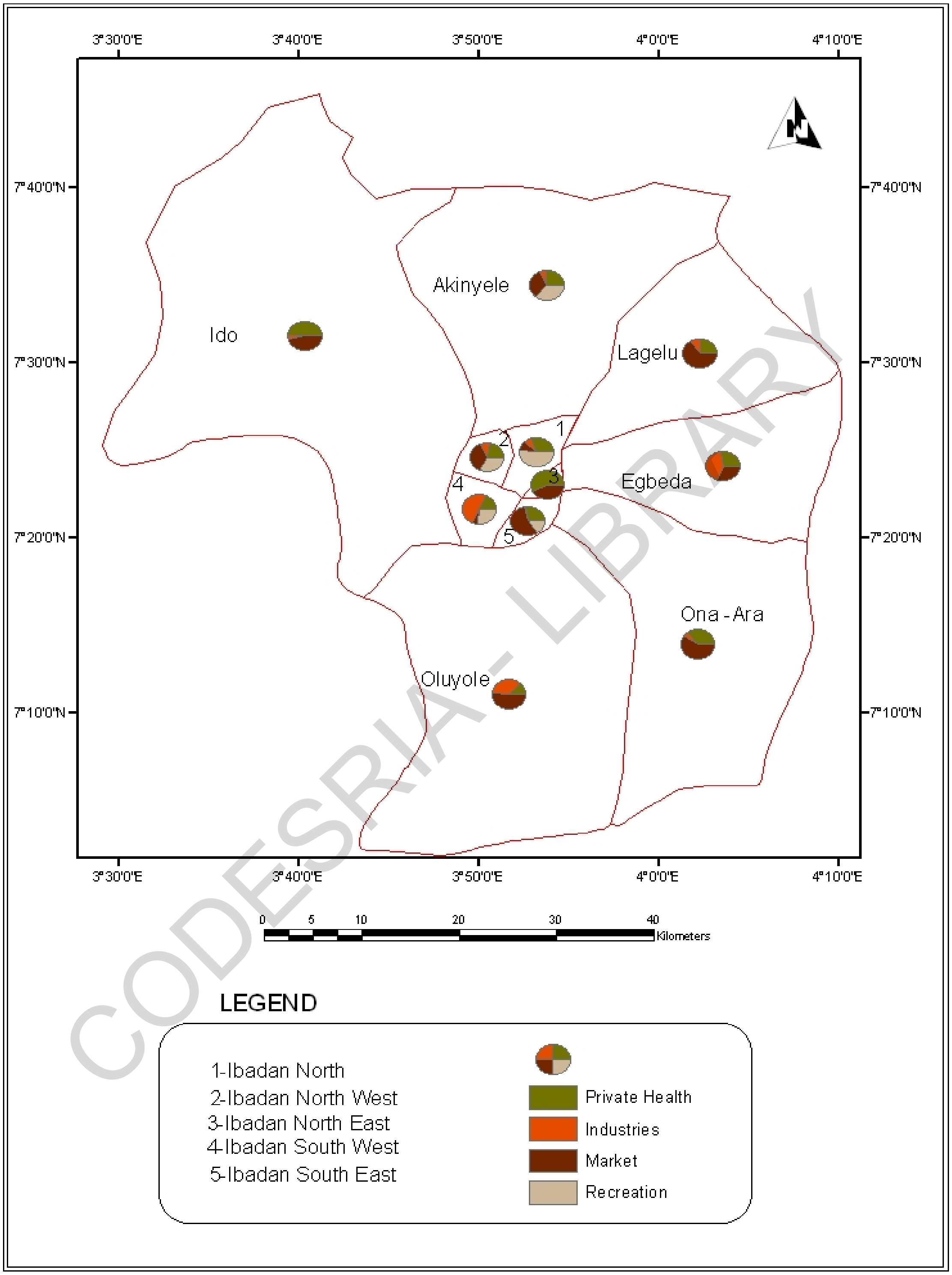


Fig. 5.3: Distribution of land use variables in Ibadan metropolis

indicate that the concentration of population in the central area of the metropolis, that is, Ibadan North, South West, South East, North West and North East, is reflected in the concentration of public and private facilities. Similarly, local variations in the distribution or concentration of public facilities are also a reflection of local variations in the distribution of population. The concentration of population and facilities in the central areas of the metropolis corresponds to the traditional urban economic theory which posits household location as a function of job access, housing costs and the cost of all other goods and services. High density environments imply spatially concentrated origins and destinations or high accessibility. High density areas are associated with traffic congestion, lower travel speeds and shorter trips. Under these conditions, transit and walking are more frequent. Also, higher densities are associated with high levels of transit demand and, therefore, with more effective transit service. Newman and Kenworthy (1989) noted that denser cities result in lower per capita gasoline consumption.

In order to determine the extent of the spatial variation of the land use variables among the LGAs in the metropolis, the coefficient of spatial variation is used. The coefficient of spatial variation (CSV) is defined as the standard deviation divided by the arithmetic mean (Thompson,1957). Several studies (Tippert,1952; Senders,1958; Lewis, 1963;Steel et al,1997) used the coefficient of spatial variation to measure the extent of variations of a phenomenon. The CSV is derived using the formular:

$$\text{Coefficient of spatial variation} = \frac{\text{standard deviation}}{\text{arithmetic mean}}$$

Typically, the CSV range from 0 to 1. 0 denotes no regional deviation of the variable from the regional pattern, thus, each region has the same percent of the variable. A value approaching 1 indicates extreme localization, that is, areal concentration. The CSV values of land use variables of LGAs in Ibadan metropolis is presented in table 5.4. Industrial establishment with CSV of 2.0679 is highly clustered. Population density, tertiary institutions, post offices, recreational centres, hotels and banks are also clustered. Nursery/primary schools has the least CSV value with 0.21087. Other variables with low CSV values are population, secondary schools, health institutions, markets and length of

Table 5.4 : Coefficient of Spatial Variation of land use variables.

Land use variable	Mean	Standard Deviation	CSV
Population size	227167.5	83353.44361	0.3669
Population density	5570.23	6039.83339	1.0843
Nursery/primary schools	128	26.71329	0.2087
Secondary schools	46.1818	22.96440	0.4973
Tertiary inst.	0.7273	1.00905	1.3874
Health inst.	70.3636	44.93389	0.6386
Markets	10.1818	4.21469	0.4139
Industries	32.5455	67.30136	2.0679
Post offices	0.6364	0.92442	1.4526
Recreational/sport centres	2.1818	3.76346	1.7249
Hotels	11.2727	13.56533	1.2034
Banks	6.3636	6.56160	1.0311
Road length	111854.7	56058.02347	0.5012

Author's Analysis, 2008

roads.The low value for these variables is not unexpected because they are scattered and close to residential areas.

5.2.2 Relationship between land-use variables and gasoline consumption for intra-urban trips

In this section the objective is to test the hypothesis which states that the location of jobs, shopping, service centres has a significant impact on household gasoline consumption. In other words attempt is made to seek to identify the most proximate determinants of the volume of household gasoline consumption based on the relationship between gasoline consumption and the location of land-use variables. To this end a step-wise multiple regression analysis is carried out. The general format of the regression model employed in this task is as follows:

$$Y=a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7+b_8X_8+b_9X_9+b_{10}X_{10}+b_{11}X_{11}+b_{12}X_{12}+b_{13}X_{13}+e$$

where Y =gasoline consumption in each local government area.

a = intercept
b = beta weights
X1 = population size
X2 = population density
X3 = nursery/primary schools
X4 = secondary schools
X5 = tertiary institutions
X6 = health institutions
X7 = markets
X8 = industrial establishments
X9 = post offices
X10 = recreational facilities
X11 = hotels
X12 = banks

X13 = length of roads

e = error term

5.2.3 Results and Discussion

In table 5.5 the Pearson's Product Moment Correlation Coefficient is used to measure the linear interrelationships between the dependent variable Y (total gasoline consumption for all trips taken together) and the 13 predetermined independent variables and between the independent variables themselves. The Product Moment Correlation Coefficient (r) is the ratio of the covariability of two variables X and Y to the product of their standard deviations.

One of the most noticeatiable features in table 5.5 is the existence of negative relationship between the dependent variable, gasoline consumption, and markets and industrial establishments. This suggests that the volume of gasoline consumption decreases as the number of markets and industries increases. Since shopping trips constitute an important travel activity, increase in the number of markets close to residential areas will reduce travel distance and gasoline consumption. All the other variables, namely, population, density, nursery/ primary schools, secondary schools, tertiary institutions, health institutions, post offices, recreational facilities, hotels, banks and length of roads, each has a positive relationship with gasoline consumption although the correlation coefficients varies from fairly high and low. However, the most significant contribution to the explanation of the volume of household gasoline consumption are recreational facilities with an r value of 0. 63 which is significant at 0.05 level of significance. The other variables in order of significance are nursery/primary schools(r=0.55),tertiary institutions(r=0.55), and health institutions(r=0.49) in the local government areas.

It is possible to infer multicollinearity from the positive and highly significant intercorrelations between some of the independent variables. For instance, recreational

Table 5.5: Correlation matrix of gasoline consumption and land-use variables

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
Y Volume of gasoline(litres)	1													
X_1 Population size	0.238	1												
X_2 population density	0.459	0.667	1											
X_3 Nursery/Primary schools	0.551	0.117	0.403	1										
X_4 Secondary schools	0.463	0.674	0.619	0.622	1									
X_5 tertiary institutions	0.545	0.326	0.377	0.456	0.460	1								
X_6 health institutions	0.490	0.458	0.310	0.603	0.862	0.613	1							
X_7 Markets	-0.281	0.098	-0.116	-0.017	0.063	0.036	-0.134	1						
X_8 Industrial establishments	-0.204	0.259	0.029	0.086	0.463	0.182	0.602	-0.044	1					
X_9 Post offices	0.355	0.531	0.943	0.247	0.404	0.312	0.158	-0.264	.060	1				
X_{10} Recreational facilities	0.630	0.375	0.331	0.634	0.830	0.673	0,969	-0.122	.538	0.193	1			
X_{11} Hotels	0.247	0.555	0.417	0.401	0.878	0.232	0.700	0.195	.516	0.176	0.661	1		
X_{12} Banks	0.375	0.393	0.452	0.439	0.790	0.485	0.812	-0.107	.754	0.370	0.835	0.793	1	
X_{13} Lenght of roads	0.227	0.112	-0.346	-0.221	0.074	-0.071	0.280	-0.370	.104	-0.375	0.269	0.048	0.002	1

Author's Analysis,2008

facilities(X10) has a positive correlation coefficient (r=0.830) with tertiary institutions (X5)and of r= 0.969 with markets (X7). Although, there is correlation between recreational facilities and tertiary institutions (r= 0.830), both variables do not have the same impact on gasoline consumption.

Table 5.6 shows the result of the step-wise multiple regression analysis. The iteration procedure was terminated after the second model. The variables that significantly explain the variance in Y (gasoline consumption) are number of recreational facilities and industrial establishments. The square of the multiple regression coefficient gives an idea of what proportion of the multiple regression models that the independent variables are able to explain. The analysis shows that 0.901 multiple regression coefficient gives an R square of 0.811. This in turn implies that 81 percent of the variations in the dependent variable, that is, household gasoline consumption have been explained by these variables.

Furthermore, table 5.7 shows the association between the volume of household gasoline consumption and the two independent variables to be statistically significant ($p<0.001$). The individual contribution of the two significant independent variables to the volume of gasoline consumption is highlighted in table 5.8. The contribution of recreational facilities(X10) which is 5.714 is higher than that of industrial establishments(X8)(-4.195).Both variables have significant contributions to the explanation of the variation in the volume of gasoline consumption (Y). Therefore, we accept the hypothesis and conclude that the volume of household gasoline consumption is associated with the number of recreational and industrial facilities in the local government areas. Recreational and industrial facilities are concentrated in few locations within the metropolis. As a result, households travel over a long distance to these facilities, resulting in high volume of gasoline consumption.

The stepwise multiple regression analysis adopted in this study provided useful insights on the results at each step of the process. In particular, it achieves parsimony in that it is found that the result at the end of last iteration procedure will be almost as good as the result obtained by using all the thirteen predictor variables. In addition the hypothesis

Table 5.6: Results of step-wise multiple regression analysis of gasoline consumption and land use variables.

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	.630(a)	.397	.330	1900.09386
2	.901(b)	.811	.764	1126.61453

Author's Analysis, 2008

Table 5.7: ANOVA of gasoline consumption and land use variables.

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	21355638.680	1	21355638.680	5.915	0.03 8
	Residual	32493210.047	9	3610356.672		
	Total	53848848.727	10			
2	Regression	43694766.286	2	21847383.143	17.213	0..00 1
	Residual	10154082.441	8	1269260.305		
	Total	53848848.727	10			

Author's Analysis, 2008

Table 5.8: Coefficients from step-wise multiple regression analysis on land-use variables

Model		B	Standard Error	Beta	T	Level of significance
1	(Constant)	2805.752	670.490		4.185	.002
	Recreation	388.301	159.657	0.630	2.432	.038
2.	(Constant)	3110.399	404.128		7.697	0.000
	Number of recreation centres	641.571	112.277	1.041	5.714	0.000
	Number of Industries	-26.340	6.278	-0.764	-4.195	0.003

Author's Analysis, 2008

which states that the location of jobs, shopping and service centres has a significant impact on gasoline consumption is verified using the result of the stepwise regression analysis. The association proves significant at 0.001 level of significance. It is therefore accepted and concluded that the volume of household gasoline consumption is a function of the location of recreational centres and industries. In this section, therefore, the land use factors that significantly explain the pattern of household gasoline consumption in Ibadan metropolis have been identified. In the next section, attempt is made to examine the socio-economic factors that determine the level of gasoline consumption in the metropolis.

5.3 Household socio-economic characteristics and gasoline consumption.

Individual economic and demographic characteristics have been recognised as influencing travel behaviour. Several studies on the relationship between gasoline consumption, travel pattern and household socio-economic characteristics have been discussed in the review of literature. In this study, following the works of Ayeni(1974), Adeniji(1982), Hanson(1982), Gordon et al (1989b), Naess(1993), Frank and Pivo (1994), Ewing(1995), Naess and Sandberg(1996), multiple item indices are used to measure the socio-economic characteristics of respondents, namely, sex, age, household head, marital status, occupation, educational level, household size, annual income, number of male adults, number of female adults, number of children working, number of cars, buses and motorcycle, employment, number of relatives, number of relatives schooling and number of relatives working. Appendix 2 shows a summary of household socio-economic characteristics for vehicle owners in Ibadan metropolis.

Attempt is therefore made in this section to examine the nature of the relationship between household socio-economic characteristics and gasoline consumption for work, school, shopping and service/recreational trips. Step-wise multiple regression analyses is used to investigate the relative contribution of household socio-economic variables to energy consumed for the various trips. Some of the variables such as sex, marital status, occupation, level of education cannot be quantified. Since the data available are qualitative, calibrating these variables in form of dummy or binary variables enable us to extend the multiple regression model in the analysis. According to Kleinbaum and Kupper (1978), a dummy variable is any variable in a regression model that takes on a finite number of values for the purpose of identifying different categories of a nominal variable. In this way, the term dummy describes no meaningful measurement level of the variable but rather act only to indicate the categories of interest. Dummy variables used in this study are calibrated as 0 and 1 (that is, binary)- a value of 1 to represent presence and 0 to represent absence of the attribute. In the social sciences, dummy variables are used in multiple regression in different ways. The dependent variables may be quantitative (that is, interval or ratio scale measurement) or qualitative (that is, binary or dummy) and the independent variables may also be quantitative or qualitative or a mixture of both. In this study, following the work of Abumere(1975), the dependent variable (gasoline consumption) is quantitative and the independent variables are a mixture of qualitative and quantitative variables. With the exception of educational level, employment, occupation, and marital status that are either 1 or 0, the other variables are continous variables.

5.3.1 The Model

The regression model is of the form

$Y = a_o + b_1X_1 + b_2X_2 + ...b_nX_n + e$

where :

Y = gasoline consumption (work, school, shopping, service/recreational trips

a = intercept

b = regression coefficient

X1 = Age

X2 = Annual income

X3 = Household Size

X4 = Number of children schooling

X5 = Number of children working

X6 = Number of relatives

X7 = Number of relatives schooling

X8 = Number of relatives working

X9 = Number of male adults

X10 = Number of female adults

X11= Number of cars

X12= Number of buses

X13= Number of motorcycles

X14 = Gender

X15 = Household head

X16 = Educational level

X17 = Employment

X18 = Occupation

X19 = Marital status

e = error term

5.3.2 Test for Multicollinearity

One of the assumptions of the multiple linear regression model is the absence of multicollinearity. Consequently, an attempt is made to examine if there is a high correlation between any two of the independent variables, that is, the problem of multicollinearity. A correlation coefficient in excess of 0.8 is usually taken as indicating serious problem of multicollinearity. Table 5.9 shows the relationship between gasoline consumption for all trips taken together and the predetermined independent variables. The table also shows the relationship amongst the independent variables. None of the independent variables have pair-wise correlation value of 0.8. Therefore, there is no multicollinearity among the variables as there is no case of partial correlation coefficient up to 0.8.

Table 5.9: Correlation matrix of gasoline consumption and socio-economic variables

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}
Y	1	-0.045	0.098	0.032	0.093	-0.059	0.007	0.048	-0.069	-.0090	-0.056	-0.039	0.317	-0.109	0.197	0.034	0.747	0.095	0.132	0.055
X_1		1	0.210	0.288	-0.103	0.494	0.148	0.014	0.214	0.240	0.163	0.237	-0.029	-0.060	0.047	-0.036	0.069	-0.264	-0.213	0.231
X_2			1	0.066	0.006	0.041	0.062	0.039	0.045	-0.022	-0.006	0.368	-0.101	-0.101	0.058	-0.014	0.124	-0.119	-0.036	-0.002
X_3				1	0.544	0.403	0.552	0.340	0.448	0.369	0.364	0.118	0.102	-0.066	-0.003	-0.189	-0.030	-0.040	-0.053	0.335
X_4					1	-0.321	-0.006	0.027	-0.081	0.006	0.142	-0.063	0.183	-0.051	0.048	0.152	-0.100	0.237	0.175	0.263
X_5						1	0.144	-0.056	0.277	0.376	0.192	0.136	-0.047	0.023	-0.030	-0.025	0.053	-0.292	-0.198	0.093
X_6							1	0.751	0.694	0.221	0.177	0.161	-0.053	-0.021	-0.078	0.023	0.033	-0.050	-0.119	0.023
X_7								1	0.158	0.089	0.063	0.132	-0.017	-0.047	-0.053	0.007	-0.017	0.037	-0.092	-0.037
X_8									1	0.235	0.163	0.112	-0.062	0.005	-0.068	0.027	0.051	-0.134	-0.063	0.004
X_9										1	0.213	0.048	0.021	0.032	0.030	0.278	0.000	-.0191	-0.146	0.192
X_{10}											1	0.034	0.051	-0.070	-0.081	0.010	-0.002	-0.072	-0.061	0.313
X_{11}												1	-0.441	-0.361	-0.075	-0.034	0.329	-0.111	-0.090	-0.012
X_{12}													1	-0.119	0.084	0.051	-0.294	0.038	0.135	0.083
X_{13}														1	0.088	0.050	-0.172	0.061	-0.086	0.019
X_{14}															1	0.391	-0.123	0.016	0.013	0.001
X_{15}																1	-0.077	0.044	0.030	0.179
X_{16}																	1	-0.079	-0.008	-0.068
X_{17}																		1	0.546	0.052
X_{18}																			1	0.035
X_{19}																				1

Author's Analysis,2008

5.3.3 Results and discussion

The results of the stepwise multiple regression analysis of gasoline consumption for work trip and the independent variables in appendix 3 shows that six steps are possible. The criterion for selecting variables in the analysis is set at 0.005 range of tolerance. In appendix 3 up to the sixth step, each variable included in the analysis is significantly related to the dependent variable. After the sixth step, no other variable met the 0.005 significant level for entry into the model. The implication is that the six variables in the sixth step are actually those ones that ought to be included in the model. These variables are number of buses, gender, number of male adults, educational level, occupation and number of cars. The variables contained in steps one to six are significant at the 0.0001 level of significance. In the sixth step, the R value is 0.49 while multiple R is 0.24.

This implies that the six variables taken together account for 24 percent of the variation in gasoline consumption for work trip. The significance of the individual contribution of each of the six variables in explaining the spatial distribution of gasoline consumption for work trip is further shown by the t values. The t values for number of buses, gender, number of male adults, educational level, occupation and number of cars are 0.543,4.110,-2.602, -3.023, contribution of each of the six variables in explaining the spatial distribution of gasoline consumption 2.377 and 2.157 respectively. The level of significance of the six variables are 0.000, 0.000, 0.009,0.003. 0.018 and 0.031. This implies that apart from number of buses, gender, educational level, all other variables are not significant in explaining the volume of gasoline consumption for work trip. Furthermore, table 5.10 reveals that number of buses alone explains 18 percent of the volume of gasoline consumption for work trip. Therefore, the hypothesis which states that socio-economic characteristics of households and vehicle ownership significantly affect gasoline consumption is accepted for work trip.

The result of the step-wise regression analysis of gasoline consumption for school trip on all the predetermined independent variables (X1-X18) is shown in appendix 4. From the table, not all the eighteen independent variables need to be included in the regression model as the programme cut-off the procedure after the fifth step since no other variable met the 0.005 significance level. This implies that only number of cars, age, number of relatives at school, marital status and gender explain the variation in gasoline consumption for school trip. The multiple R value in the first step is 0.03 with a level of significance of 0.000. Hence, number of cars only accounts for 3percent of the variation in gasoline consumption for school trip. In the fifth step, the R value is 0.266 while multiple R is 0.071. The implication is that the five variables taken together account for 7percent of the variation of gasoline consumption for school trips. The t values in appendix 4. shows the individual contribution of each of the five variables in explaining volume of gasoline consumption for school trip. The t values for number of cars, age, number of relatives at school, marital status, and gender are 5.505, -3.689,2.319, 2.222, and 2.194 respectively. Of these five variables, number of cars and age are significant in explaining the variation in the volume of gasoline consumption for school trip. Therefore, the hypothesis which states that socio-economic characteristics of households and vehicle ownership significantly affect gasoline consumption is accepted for school trip. But the low figure shows that not many of the vehicle owners use their vehicles to take children to school, hence the low gasoline consumption.

Appendix 5 shows the result of the step-wise regression analysis of gasoline consumption for shopping trip and socio-economic variables. Only four variables were included in the analysis. In table 5.12, up to the fourth step, each variable included in the analysis is significantly related to the dependent variable. In the first step, the multiple correlation coefficient, R, value is 0.247 while multiple R is 0.061. Thus annual income account for 6percent of the variation in gasoline consumption for shopping trip. Furthermore, at the fourth step, the R value is 0.352 while the multiple R is 0.124. Socio-economic variables included in the fourth step are annual income, number of cars, household size, and number of relatives. Hence, the four variables taken together accounts for 12 percent of gasoline consumption for shopping trips. The t values indicate the significance of the individual contribution of the independent variables. The t values for annual income, number of cars, household size and number of relatives are 4.650,4.515,-5.045 and 2.946 respectively. The level of significance of the four variables are 0.000, 0.000, 0.000 and 0.003. All the four variables are significant in explaining the variation in gasoline consumption for shopping trips. Therefore, the hypothesis which states that socio-economic characteristics of households and vehicle ownership significantly affect gasoline consumption is accepted for shopping trip. Low gasoline consumption for shopping trip is also because people don't generally use vehicles for shopping purposes.

The result of the step-wise regression of gasoline consumption for service/recreational trip on all the socio-economic variables in appendix 6 shows that only five variables are included in the model, namely, annual income, number of children schooling, number of cars, gender, and household size. With R value of 0.346 and multiple R of 0.120, the variables are significant at 0.0001 level of significance. This means that the five variables together account for 12percent of the variation in gasoline consumption for service trips .The t values in appendix 6 shows the individual contribution of each of the five variables in explaining the variation in gasoline consumption for service trip. The t values for annual income, number of children schooling, number of cars, gender, and household size are 4.280, -2.166, 3.961, 2.964 and -2.739. The level of significance of the five variables are 0.000, 0.031, 0.000, 0.003 and 0.006 respectively. Thus, annual income, number of cars, and gender significantly explain the variation in gasoline consumption for service trip. The hypothesis which states that household socio-economic characteristics and vehicle ownership affect gasoline consumption is accepted for service/recreational trip.

In this section, the relationship between gasoline consumption for work, school, shopping and service/ recreational trips and household socio-economic characteristics was examined. The socio-economic variables that significantly explain the variation in gasoline consumption for work trip are number of buses, gender, level of education: for school trip- number of cars and age: for shopping trip-annual income, number of cars, household size and number of relatives: for service/recreational trip-annual income, number of cars and gender. Hence, the hypothesis that socio-economic characteristics of households and vehicle ownership significantly affect gasoline consumption is accepted.

The result is similar to the findings of Naess(1993),Naess et al (1995), Flanelly and McLeod (1989),Hickman and Banister(2006).

The contribution of household socio-economic characteristics to the explanation of the variation in the volume of gasoline consumed for work, school, shopping and service/recreational trips have been examined. The contribution of the independent variables to the explanation of the variation in total household gasoline consumption (that is, for all the trips taken together) is shown in appendix 7. The result of the step-wise multiple regression analysis shows that the procedure was terminated after the seventh step, which implies that only seven variables are significantly related to the dependent variable. In the seventh step, the R value is 0.417 and multiple R is 0.174. This means that the seven independent variables contribute only 17 percent to the explanation of the variation in gasoline consumption for all household trips. The seven variables are number of buses, gender, number of cars, number of male adults, occupation, annual income and level of education. With an F value of 18.924, the relationship is significant at 0.001 level of significance as shown in table 5.15. The hypothesis that the socio-economic characteristics of households and vehicle ownership significantly affect gasoline consumption is accepted.

Breaking down the regression analysis results tells us that land use variables explain more of the variation in energy consumption for intra-urban travel (81%) than socio-economic variables (17%). Therefore, the location of land-use variables affect gasoline consumption for intra-urban trips more than socio-economic characteristics of households. This is similar to the findings of Hickman and Banister (2007). The low explanatory value of socio-economic variables is not surprising because collective land uses should generally be more important in influencing gasoline consumption than individual socio-economic characteristics.

5.4 Household travel pattern and gasoline consumption

Giuliano (2002) argued that appropriate measures of travel should capture travel for all purposes and by all modes. Total travel is measured in terms of number of trips, distance and time. Number of trips capture the total number of activities conducted. The spatial range of travel over the course of the day is captured by distance and time. Of these, distance is the more appropriate measure of mobility. Travel time is determined by both distance and speed.

In this study, journey to work, school, shopping and service/recreational centres are considered. Travel characteristics is measured in terms of number of trips, distance, time and mode of travel. A GIS package (Arcview) was used to estimate the on-network travel distance from each household's origin to the destination for all household trips. This is similar to the procedure used by Saunders et al (2006). The hypothesis which states that gasoline consumption is significantly related to trip length is tested for work, school, shopping and recreational trips using multiple regression analysis. Volume of gasoline consumed, travel time , distance and number of trips are quantitative variables while mode of travel is qualitative. Hence, mode of travel is calibrated as a binary variable, that is, walk, bicycle =0, otherwise =1. The characteristics of household travel pattern for work, school, shopping and service/recreation trips and the regression results are discussed in the sections below. Appendix 8 shows the summary of household trip characteristics for vehicle owners in Ibadan metropolis.

Out of a total of 640 households that have vehicles, 493 households (77percent) made journey to work during the week while 147 households (33%) did not make any work trip. A total of 3449 work trips were made by households in one week. With respect to mode of travel, 73.7% of the total work trips were made by car, bus(18%), motorcycle(7.6%) and walk(0.6%). This shows the dominance of the automobile in work trips. People are attracted to the elegance, convenience and speed which the automobile provides, so, it is preferred to other modes or transport. Majority of the households make use of their personal vehicles for work trips. As shown in appendix 8, 95% of the work trips were made in personal vehicles compared with public transport (4.7%) and carpool (3.2%). The high proportion of trips in personal vehicles contribute to gasoline consumption. Public transit which are more energy efficient are unattractive as the vehicles used by the public transport operators are rickety and ill-maintained due to exorbitant prices of spare parts and their inability to purchase new ones to expand their fleet of vehicles.

The daily travel distance band is dominated by short trips between 0.1 and 5 kilometers (42.2%), followed by 5.1-10 kilometers (28.5%), 0 kilometer, that is around the respondent's residential area (12.2%), 10.1-15kilometer (11%), 15.1-20kilometers (4.7%) and above 20 kilometers (1.4%). This implies that 54% of the total work trip were carried out within a distance of 0-5kilometer from the household's residence. Hence, the number of trips decline as distance increases. Since transport energy consumption increases as distance increase, it is expected that households that travel over a long distance to their work-place will consume more energy compared to those that travel over a shorter distance. Although 12.2% of the work trips occur close to the households residence (that is, distance of 0 kilometer), households still depend mostly on the automobile as indicated above. Travel time for work trip varies from less than 30 minutes (68.8%) to between 30 and 60 minutes(27%) and above one hour(4.2%). Household gasoline consumption for work trip indicates that gasoline was not consumed for 5.8% of total trips. This may be due to the use of non-motorised mode of transport, for example, walk. Less than 50 litres of gasoline was consumed for 92.9% of total work trips, 51-100 litres(1.3%) and 251-300 litres(0.03%).

With respect to school trip, a total of 2789 trips were made by 558 households(87.2%) while 82 households(12.8%) made no school trip. 1373(49.2%) trips were made by car, 711(25.5%) by bus, 605(21.7%) by walking and 100 trips (3.6%) by motorcycle. This shows that school trip is dominated by motorised mode of transport (74.7%).However, in comparison with work trip, 21.7% of total school trips were made by walking. This is due to the shorter travel distance between household's residence and school. In terms of number of trips, 545 households (97.6%) made two trips daily, 7 households(1.3%) made four trips daily and 6 households(1.1%) made one trip daily respectively.

Most of the trips were made in personal vehicles(45.5%), followed by public transit(27.5%) and walk(21.7%) and 5.8% by sharing a ride.39.1% of the trips occurred within households residential area, that is a distance of 0 kilometer, less than 5 kilometer (37.2%),5-10 kilometer (16.5%). Thus, the number of trips declines as the distance travelled increase, that is, there is a distance decay effect on school trip. With respect to travel time, 23.8% of school trips were made in less than 10 minutes, 11-20 minutes(39.6%), 21-30 minutes(22.7%) and 81-90 minutes (0.2%). Volume of gasoline consumed was recorded for 61.6% of total trips. In addition, less than 50 litres was consumed for 38.3% of the trips and between 51 and 100 litres for 0.1% of total school trips. This shows that the volume of gasoline consumed for school trip is low, due to short travel distance and low number of trips.

A total of 159 households (25%) made 1111 shopping trips in one week while 482(75%) made no trip. The low number of shopping trips is due to the fact that shopping trip was not made daily, rather, it was made once or twice a week. 52.6% of the shopping trips were made by car, bus(23.9%), walk(19.3%) and motorcycle(4.1%). In terms of vehicle ownership, 55.3% of the trips were made in personal vehicles, 25.5% in public transit and 19.3% on foot. This implies that personal vehicles were used mostly for shopping trips.

The travel distance indicates that 36.9% of the shopping trips were made around the household's residence, 0-5kilometers(32.8%), 5.1-10 kilometers(17.6%) and 15.1-20 kilometers (7.7%). The number of trips declines as distance increase. Thus, there is a distance -decay effect for shopping trip, since large number of households purchase their items close to their residential area. In addition, 34.9% of the trips were made in less than 10 minutes,26.6% between 11-20 minutes, 19.2% between 21-30 minutes and 1.3% between 81- 90 minutes. The short travel time may be attributed to the short distance travelled by households for shopping trips. With respect to gasoline consumption, less than 50 litres was consumed for 48.2% of the shopping trips, 51-100 litres (0.2%) and o litres (51.7%).

In terms of service/recreational trips had the lowest number of trips with a total of 1007 trips.144 households (22.5%) made recreational trips while 496 households (77.5%) made no trip. 70.4% of the recreational trips were made by car, bus(16.1%),walk(7.2%), motorcycle(6%) and bicycle(0.3%). With respect to vehicle ownership, 79.6% of the total trips were made in personal vehicles, 12.1% in public transit and 7.2% on foot. Personal vehicles are used mostly for recreational trips which influence gasoline consumption.

Households made an average of two trips daily. 40.2% of the trips were made between 0.1-5 kilometers, followed by trips around residential areas ,that is, 0 kilometer(31.6) and 5.1-10 kilometers(20.1%). Number of trips decreases as distance increases. The least number of trips(0.6%) were made within a distance band of 20.1-25 kilometer. This implies that 71.8 % of the trips were made within less than 5 kilometers from household's residence. However, despite the short distance travelled, households still depend on the automobile which is energy inefficient.

Number of trips decline gradually as travel time increase. 33.7% of the service trips were made in less than 10 minutes while 0.2% were made between 80 -90 minutes. With respect to gasoline consumption, 1-50 litres of gasoline was consumed for 73% of the trips while 51-100 litres was consumed for 0.2% of the trips.

5.4.1 The Model

The hypothesis which states that gasoline consumption is significantly related to household's trip length is tested using correlation and multiple regression analysis. The multiple regression equation is given as :

$$Y= a +b_1X_1+b_2X_2+b_3X_3+b_4X_4 +e$$

where Y = gasoline consumption

a = intercept

b = beta weights

X1 = number of trips

X2 = travel time

X3 = distance

X4 = mode of travel

e = error term

5.4.2 Results and discussion

The zero-order correlation matrix of gasoline consumption for work trip and travel pattern of households is shown in table 5.10. The correlation coefficient of number of trips(0.545), travel time(0.161), distance(0.125) and mode of travel (0.174) are positive and significantly related to gasoline consumption at 0.01 level of significance. This suggests that the relationship between the dependent and independent variables is linear, that is, gasoline. consumption increases as number of trips, travel time, distance and use of vehicles for travel increase.

Results of the multiple regression analysis of gasoline consumption for work trip and travel characteristics in table 5.11 indicate that the multiple correlation coefficient R is 0.566 and multiple R is 0.321. This implies that the independent variables together account for 32 percent of the variation in gasoline consumption for work trip. Table 5.11 also shows the association between the volume of gasolineconsumed for work trip and the set of independent variables to be statistically significant at 0.0001 level of significance. The t values shows the individual contribution of the independent variables to the explanation of the variation in gasoline consumption. Number of trips made the highest contribution with a t value of 15.719 followed by mode of travel(2.544), distance(2.371) and travel time(2.027). Therefore, it is concluded that gasoline consumption is significantly related to travel characteristics of households. The hypothesis which states that gasoline consumption is significantly related to trip length is accepted for work trip.

Table 5.10: Correlation matrix of gasoline consumption for work trip and travel pattern

Variable	Y	X1	X2	X3	X4
Y Volume of gasoline(lit)	1	0.545	0.161	0.125	0.174
X1 Number of trips		1	0.132	0.028	0.132
X2 Travel time			1	0.214	0.075
X3 Distance				1	0.178
X4 Travel mode					1

Author's Analysis, 2008

Table 5.11 Results of regression analysis for work trip and travel pattern

Model		B	Standard Error of b	Beta	T	Level of significance	R	R^2	F	Level of significance
1	(Constant)	2.209	7.807		.283	.777	0.566	0.321	75.09	0.000
	No. of trips	.694	.044	.523	15.719	.000				
	Travel time	.006	.003	.068	2.027	.043				
	Distance	.143	.060	.081	2.371	.018				
	Mode of travel	20.852	8.198	.085	2.544	.011				

Author's Analysis, 2008

Table 5.12 shows the correlation matrix of gasoline consumption for school trip (dependent variable) and number of trips, travel time, distance and mode of travel(independent variables).The independent variables are positive and significantly related to the dependent variable at 0.005 level of significance. Mode of travel has the highest correlation coefficient of 0.307, followed by distance(0.166), number of trips(0.150) and travel time(0.098). This implies that gasoline consumption for school trip increases as number of trips, travel time, distance and use of vehicles increase. Hence, the hypothesis which states that gasoline consumption is significantly related to travel distance is accepted for school trip.

Table 5.13 shows the result of the regression analysis of gasoline consumption for school trip and household's travel characteristics. The multiple correlation coefficient R is 0.315 and multiple R is 0.099. This implies that the independent variables taken together account for 9 percent of the explanation of the variation in gasoline consumption for school trip. Also, the association between gasoline consumption and travel characteristics is significant at 0.0001 level of significance. We therefore conclude that gasoline consumption is significantly related to household travel characteristics for school trip.

Results of the correlation analysis of gasoline consumption for shopping trip is shown in table 5.14. Although the correlation coefficients of the independent variables are low they are positively related to gasoline consumption. This implies that gasoline consumption for shopping trip increases as number of trips, travel time, distance and use of vehicles increase. The relationship between gasoline consumption for shopping trip and travel time (0.331),distance(0.314) and mode of travel(0.138) is significant. Therefore, the hypothesis which states that gasoline consumption is significantly related to travel distance is accepted for shopping trip.

Table 5.12: Correlation matrix of gasoline consumption and travel pattern for school trip

Variable	Y	X1	X2	X3	X4
Y Volume of gasoline(lit)	1	0.158	0.098	0.166	0.307
X1 Number of trips		1	0.487	0.167	0.512
X2 Travel time			1	0.359	0.343
X3 Distance				1	0.339
X4 Mode of travel					1

Author's Analysis,2008.

Table 5.13: Result of multiple regression analysis of gasoline consumption and travel pattern for school trip.

Model		B	Standard Error of b	Beta	T	Level of significance	R	R2	F	Level of significance
1	(Constant)	.424	1.675		.253	.800	0.315	0.099	17.46	0.000
	No.of trips	.018	.229	.004	.077	.938				
	Travel time	-.008	.011	-.031	-.671	.503				
	Distance	.050	.027	.078	1.859	.063				
	Mode of travel	10.292	1.676	.289	6.141	.000				

Author's Analysis,2008

Table 5.14: Correlation matrix of gasoline consumption and travel pattern for shopping trip

Variables	Y	X1	X2	X3	X4
Y Volume of gasoline(litre)	1	0.075	0.331	0.314	0.138
X1 Number.of trips		1	0.561	0.207	-0.060
X2 Travel time			1	0.618	0.016
X3 Distance				1	0.064
X4 Mode of travel					1

Author's Analysis,2008.

Result of the multiple regression analysis of gasoline consumption for shopping trip (dependent variable) and number of trips, travel time, distance and mode of travel (independent variables) in table 5.15 shows that the association between the dependent and independent variables is significant at 0.0001 level of significance. The independent variables contribute 45 percent of the explanation of the variation in gasoline consumption for shopping trip since the multiple correlation coefficient R is 0.454 and multiple R is 0.393.In addition, the contribution of distance and mode of travel to gasoline consumption is significant at 0.005 significance level. Thus, gasoline consumption for shopping trip is significantly related to number of trips, travel time, distance and mode of travel.

With respect to service/recreational trips, table 5.16 show the zero-order correlation coefficient matrix of gasoline consumption for service/recreational trip and number of trips, travel time, distance and mode of travel. The independent variables are positive and significantly related to gasoline consumption at 0.05 significance level. The correlation coefficients are generally low, but, distance has the highest value with 0.476, followed by travel time (0.371),number of trips(0.327),and mode of travel(0.062). Gasoline consumption increases as the independent variables increase. Therefore, the hypothesis which states that gasoline consumption is significantly related to travel distance is accepted.

Table 5.15: Result of multiple regression analysis of gasoline consumption and travel pattern for shopping trip

		B	Standard. Error of b	Beta	T	Level of significance	R	R2	F	Level of significance
1	(Constant)	1.376	.582		2.366	.018	0.393	0.154	28.92	0.000
	No. of trips	-.366	.137	-.121	-2.677	.008				
	Travel time	.057	.010	.311	5.537	.000				
	Distance	.108	.037	.140	2.940	.003				
	Mode of travel	1.644	.516	.117	3.184	.002				

Author's Analysis,2008.

Table 5.16: Correlation matrix of gasoline consumption and travel pattern for service/recreational trip

	Y	X1	X2	X3	X4
Y Volume of gasoline (lit)	1	0327	0371	0.476	0.062
X1 Number of trips		1	0.613	0.492	0.115
X2 Travel time			1	0.656	0.058
X3 Distance				1	0.056
X4 Mode of travel					1

Author's Analysis,2008.

Table 5.17 shows the result of regression analysis of gasoline consumption for service/recreational trip (dependent variable) and number of trips, travel time, distance and mode of travel (independent variables).The multiple correlation coefficient R is 0.490 and multiple R is 0.240. This implies that the independent variables contribute 24 percent to the explanation of the variation in gasoline consumption. Furthermore, the association between the dependent and independent variables is significant at 0.001 level of significance. The individual contribution of the independent variables, that is, t value, in table 5.17 show that distance made the highest contribution with a t value of 8.438 followed by number of trips (2.254), travel time (1.005), and mode of travel (0.728).We conclude therefore that gasoline consumption for service/recreational trips is significantly related to household travel characteristics.

In this section the relationship between gasoline consumption and travel pattern for work, school, shopping and recreational trips is examined. Gasoline consumption is significantly related to travel distance for work, school, shopping and service trips.

5.5 Increase in price of gasoline and travel pattern

This section examines how households respond to increase in the price of gasoline over time. 848 households (63.9percent) responded that they took various actions to reduce their level of gasoline consumption while 479 (36.1) did not take any action. Due to the nature of household travel characteristics, some households responded to increase in the price of gasoline by taking one or several actions to reduce gasoline consumption or cost of travel. From table 5.18, major actions taken by households are (i) use of telephone (41%), (ii) making fewer shopping trips(31%) and (iii)choosing social and recreational activities closer to home(30%). Others include use of public transport to work(17%),combining shopping and non-work activities(16%), use of public transport more often for non-work activities(14%) and carpooling to work(13%). Therefore, the hypothesis which states that. households respond to increase in price of gasoline by combining shopping trips, reducing the number of trips, shifting to fuel efficient cars and the use of public transport is accepted.

Table 5.17: Result of multiple regression analysis of gasoline consumption and travel pattern for service/recreational trip

Model		B	Standard Error of b	Beta	T	Level of significance	R	R2	F	Level of significance
1	(Constant)	1.577	.510		3.095	.002	0.490	0.240	50.04	0.000
	Number.of trips	.411	.182	.100	2.254	.025				
	Travel time	.010	.010	.051	1.005	.315				
	Distance	.328	.039	.391	8.438	.000				
	Mode of travel	.038	.052	.025	.728	.467				

Author's Analysis,2008

Table 5.18: Actions taken by households to reduce gasoline consumption due to price increase

Actions taken	Yes	Percent	No	Percent
Carpool to work	168	12.7	1159	87.3
Take public transport to work	226	17	1101	83
Walk to work	68	5.1	1259	94.9
Take a bicycle to work	16	1.2	1311	98.8
Walk to non-work activities	110	8.3	1217	91.7
Take a bicycle to non-work activities	16	1.2	1311	98.8
Move closer to work	40	3	1287	97
Get job closer to home	138	10.4	1189	89.6
Shop on the way home from work	166	12.5	1161	87.5
Make fewer shopping trips	414	31.2	913	68.8
Combine shopping and non-work activities	207	15.6	1120	84.4
Shop closer to home	132	9.9	1195	90.1
Take public transport more often for non-work activities	182	13.7	1145	86.3
Use a telephone	544	41.0	783	59
Replace a car with a more fuel efficient one	48	3.6	1279	96.4
Sell car do not replace	14	1.1	1313	98.9
Share rides to non-work activities	19	1.4	1308	98.6
Choose social and recreational activities closer to home	397	29.9	930	70.1

Author's Analysis, 2008

The low percentage of households that replaced their car(s) with a more fuel efficient one (4%) and households that take public transport to work (17%) indicate that gasoline consumption will continue to rise despite the increase in the price of gasoline. Although Adenikinju (1995) noted that appropriate energy pricing of petroleum products will foster efficiency and reduction in demand, recent trends of gasoline consumption shows that demand has increased tremendously despite increase in the price of gasoline overtime. Hence, the introduction of other measures such as car purchase and ownership tax, development of more compact land use pattern and efficient public transport system will make the automobile less attractive, thereby reducing gasoline consumption and environmental pollution in the long run.

CHAPTER SIX

SUMMARY AND CONCLUSION

6.1 Summary of major findings

Transport is that part of economic activity which is concerned with increasing human satisfaction by changing the geographic location and pattern of goods and people. Energy use in the transport sector is dominated by petroleum products specifically gasoline, diesel and jet fuel. Current transport energy supply is finite and replacement with renewable energy resources will not match current consumption levels. Therefore, transport systems will be subject to supply shortage and increasing constraints.

Spatial patterns and activity systems combine to produce the transport –energy requirements of a region. The structure of cities-type and density of housing and their geographical constraints influence the length and frequency of trips and transport energy demand. Traffic volumes and energy consumption from the transport sector continue to rise, yet the potential role of urban planning in contributing to reduced transport energy consumption continues to be largely underplayed.

This study focused on the spatio-temporal pattern of gasoline consumption in Nigeria. In addition the relationships between household gasoline consumption for intra-urban travel and household travel characteristics, socio-economic characteristics and land use pattern in Ibadan metropolis are examined. The consumption of gasoline in Nigeria displays three distinct trends. There was a rapid growth between 1971 and 1983, followed by fluctuation with rises and falls between 1984 and 1998. After this period, gasoline demand increased steadily to a peak in 2003 and stabilized between 2004 and 2005. The study also shows that gasoline consumption varied significantly amongst the thirty-six states. The spatial pattern of consumption indicates that the largest consumption centres are in the South West and South South zones. Lagos State has the highest consumption level followed by Oyo, Ogun, Kaduna, Edo, Rivers, Delta, Kano, Abuja and Imo states. In comparison with the work of Ikporupko (1978), four additional major consumption centres have emerged since 1978, namely, Ogun, Delta, Imo tates and Abuja (FCT). Other centres similarly identified in this study are Lagos, Oyo, Kaduna, Edo, Rivers and Kano states. Although Ikporupko's study was based on towns, the major consumption centres (towns) are the state capitals of the states identified in this study. The towns constitute centres of population, commercial and industrial concentration in the states.

Futhermore, the spatial distribution of gasoline consumption is significantly explained by new registration of gasoline using vehicles, number of industries and per capita income. Indeed, the number of newly registered gasoline using vehicles in the states is the most significant explanatory variable.

The spatial pattern of gasoline consumption for work, school, shopping and service/recreational trips among the eleven local government areas in Ibadan metropolis shows that Ibadan North has the highest level of gasoline consumption for work, school, shopping and service /recreational trips. This is because Ibadan north has the highest concentration of households that have vehicles and a high percentage of the land use variables. Thus, a lot of vehicular traffic is generated within the area. Ido has the highest level of gasoline consumption for shopping trip. This high level of consumption may be attributed to the fact that major markets in the metropolis are located far from Ido LGA, and as a result, households travel a long distance for shopping. Hence, the volume of gasoline consumption is high.

The study shows that the land use variable which significantly explained the variation in gasoline consumption are number of industries and recreational facilities. Household socio-economic characteristics that account for the variation in gasoline consumption for work trip are number of buses, gender and educational level. Gasoline consumption for school trip is significantly determined by the number of cars and age of household head.

Annual income, number of cars, household size and number of relatives significantly explain the variation in the volume of gasoline consumption for shopping trip. In addition, gasoline consumption for service/ recreational trip is significantly explained by annual income, number of cars and gender. The regression analysis results show that land use variables explain more of the variation in energy consumption for intra-urban travel than socio-economic variables.

The relationship between gasoline consumption and travel pattern for work, school, shopping and recreational trips is examined. Gasoline consumption is significantly related to number of trips, travel time, distance and use of vehicles for work, school, shopping and service trips.

6.2 Implications of findings.

This study has attempted to determine the spatio-temporal pattern of gasoline consumption in the country and the relationships between energy use in the journey to work, school, shopping and service/recreational trips and a list of land use, socio-economic and travel characteristics of households at the metropolitan level. The research findings have implications for planning and research.

6.2.1 Theoretical Implications

The theories of urban spatial structure describe and explain the pattern of land use and the distribution of population groups within cities. Although the situation in Ibadan (mix of residential, commercial and cottage industrial activities at the centre of the metropolis), is slightly different from the land use patterns described in the theories, the location of land use activities influence travel pattern and energy consumption. Since the location of public facilities is determined by population size, educational facilities, health centres and markets are located in all the local government areas while large industrial establishments are concentrated in few locations- oluyole estate, oyo- Ibadan road, Ibadan-Lagos road and Ibadan Abeokuta road. Similarly, recreational facilities are clustered in and around the central business district. The location of industries and recreational facilities implies that households travel over a long distance to these locations, thus, high volume of gasoline is consumed.

Besides, the influence of urban structure, household travel pattern is also theoretically meaningful. Urban interaction refers to the flows of people, goods and information among different locations in the city. Movement of people within an urban centre is based on the principle of complementarity, intervening opportunity, and transferability. The high positive relationship between gasoline consumption and distance confirms the basic principles of Ullman. Transferability relates to distance in terms of transfer and time costs. If the distance or time required to make a journey is too great and the cost is too high, transferability will not take place. The decrease in the number of trips with increasing distance for all trips is related to the cost of gasoline. However, journey purpose influence the maximum distance which household are willing to travel. Households travel up to 20km for work trips and 10km for other purposes. This is as expected since journey to work is the most important journey purpose for anyone in regular employment and the location of workplaces are fixed. Therefore, cost is an important consideration in household trips.

In addition, certain conclusions of this study pose considerable challenges to previous research in transport geography. The findings of this work have shown that urban land use pattern is a more important factor than socio-economic characteristics of urban residents in the explanation of travel pattern and energy consumption. Researcher's therefore need to be more critical in using socio-economic characteristics of households alone as measures of determinants of household travel.

6.2.2 Policy Implications

The rapid increase in gasoline consumption in the country implies an increase in the contribution of the transport sector to atmospheric pollution through the emission of pollutants such as carbon monoxide, unburnt hydrocarbons, nitrogen oxides, tetra-ethyl lead, carbon dust particles and aldehydes. Hence, decrease in gasoline consumption will lead to a reduction in atmospheric pollution.

Strategies for reducing gasoline consumption include fuel pricing, development of fuel efficient vehicles, reduction in congestion through transport management and the development of alternative sources of energy for the automobile. Potential alternatives to gasoline are classified into various groups, namely, conventional fuel equivalents-broad cut and synthetically derived diesel fuel: gaseous-compressed natural gas, liquefied natural gas, hydrogen, propane, butane: alcohols such as ethanol, methanol, alcohol-gasoline blends, alcohol-diesel fuel blend: electric hybrid vehicles and vegetable oil. Although the government has initiated the production of ethanol as an alternative to gasoline, for this fuel to be used in current vehicles would require significant changes to (i) engine design through the use of glow or spark mechanism (ii) fuel storage and delivery (both from the vehicle storage tank to the engine and from the facility storage area to the vehicle and (iii) engine parts.

Among the available options, urban structure will almost certainly have to play some role. Urban structure can be influenced overtime and urban planning at the strategic and local levels is a very important tool in seeking to reduce energy consumption arising from travel. The layout of land use, densities and connections within an urban area have been identified as components to consider when taking a more comprehensive approach to urban planning in the search for reduced car dependence and transport energy consumption. Urban planning will aid reduction in traffic congestion, thereby reducing pollution.

Community energy management programmes which incorporate land use and transportation planning, site planning, and the infrastructure that serves the communities has been adopted in some cities, for example, California and San Diego. Community energy management strategies typically focus on land use planning, transportation planning, site and building design and energy supply and transmission systems. Land use planning as it relates to community energy management strategies seek to maintain existing and plan new development and land uses that reduce travel needs.

Community energy management plans can be accomplished through a variety of urban planning tools, zoning regulations and transportation planning. Energy requirements may be woven into the comprehensive plan used to guide and manage the growth of an area, built into the zoning regulations that identify characteristics such as provisions for sidewalks and parking allowances, integrated into transportation planning and provide the basis for development programs. The integration of transportation planning into urban planning should emphasize non-vehicular methods of travel, including the encouragement of pedestrian and bicycle travel, the use of mass transit, ride sharing programs and development along transportation corridors (transit-oriented development). Transit-oriented development is defined as compact, mixed-use development near new or existing public transportation infrastructure that serves housing, transportation and neighbourhood goals. Its pedestrian- oriented design and mixed-use zoning around transit stops encourages residents and workers to drive their cars less and walk or ride mass transit more, thereby reducing transport energy consumption.

6.3 Future research areas

Some future research areas arise from this study. There is urgent need for transportation surveys in major cities of Nigeria so as to determine household travel pattern, vehicle characteristics and energy consumption for various trips. The data obtained will be useful for academic, planning and development control. There is need for research on urban land use planning and design strategies that will incorporate transport energy requirements, that will also reduce traffic congestion in the cities and thereby drastically reduce the extent of emission of atmospheric pollutants. Finally, future research may be carried out to determine the volume of gasoline saved from the development of compact land use and reduced household travel distance.

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APPENDIX 1

DEPARTMENT OF GEOGRAPHY
FACULTY OF TNE SOCIAL SCIENCES
UNIVERSITY OF IBADAN

Questionnaire Survey on Demand for Gasoline for Intra- urban Travel in Ibadan Metropolis

Dear Respondent,

This questionnaire survey is designed to collect information on the above topic for a postgraduate thesis. Your response will be used for academic purpose only. Thank you for your anticipated cooperation.

Section A: Socio-economic Characteristics of Respondents

1. Location of respondent:

   Street.................. Ward.......................... LGA...

2. Lenght of stay in LGA..........................years.
3. Gender (i) Male (ii) Female
4. Household head (i)Male (ii)Female
5. Age......................years
6. Educational status

   (i) None (ii)Primary (iii) Modern /Secondary (iv)NCE/Diploma

   (v) HND/Bachelors Degree (vi) Postgraduate Degree

7. Employment

   (i) Government employed (ii) Privately employed (iii) Retired

   (iv) Unemployed

8. Occupation

   (i) Farming (ii) Industry/Manufacturing (iii) Commerce/ Trading

   (iv) Adminstration (v) Construction (vi) Teaching (vii)Schooling (viii)Road transport worker (ix) Others.......................................

9. Marital status

   (i) Married (ii) Single (iii) Divorced (iv)Widowed

10. Place of work...................................

11. Annual income...

12. Household size..

13. How many children are schooling..

14. How many children are working..

15. Number of relatives staying with you..................................

16. Number of relatives schooling..

17. Number of relatives working...

18. Mode of transport of children to school

Private vehicle (i) Drive alone (ii) carpooled

Public vehicle (iii) Bus (iv) Taxi (v) Motorcycle (vi) Walk

19. Number of male adults in your household........................

20. Number of female adults in your household..........................

21. Number of vehicle belonging to your household

(i)Car............... (ii) Bus................ (iii)Motocycle............. (iv)None

22. How many litres of gasoline is used in your vehicle(s) in a week?

(i) vehicle 1....................(ii)vehicle 2............ (iii)vehicle 3............. (iv)vehicle 4.................. (iv)vehicle 5.........................

23. Did you take any action to reduce vehicle gasoline consumption due to price increase?

(i) Yes (ii) No

24. If yes, indicate the action(s) taken

(i) Carpool to work

(ii) Take a public transport to work

(iii)Walk to work

(iv) Take a bicycle to work

(v)Walk to non-work activities

(vi) Take a bicycle to non work activities

(vii)Move closer to work

(viii) Get job closer to home

(ix) Shop on the way home from work

(x) Make fewer shopping trips

(xi) Combine shopping and other non work activities

(xii) Shop closer to home

(xiii) Take public transport more often for non work trips

(xiv) Use a telephone

(xv) Replace a car with a more fuel efficient one

(xvi) Sell car do not replace

(xvii) Share rides to non work activities

(xviii) Choose social and recreational activities closer to home

RECORD OF HOUSEHOLD TRIPS

Please record on the table provided the details of all trips made within Ibadan during the week.

Work Trips

	Travel origin	Destination	Mode of travel e.g car	No. of trips	Distance(km)	Duration of travel(mins)	Vehicle occupancy	Qty of gasoline (lits)	Cost of gasoline	Vehicle ownership	Cost of travel
Monday											
Tuesday											
Wednesday											
Thursday											
Friday											
Saturday											
Sunday											

Shopping Trips

	Travel origin	Destination	Mode of travel e.g car	No. of trips	Distance(km)	Duration of travel(mins)	Vehicle occupancy	Qty of gasoline (lits)	Cost of gasoline	Vehicle ownership	Cost of travel
Monday											
Tuesday											
Wednesday											
Thursday											
Friday											
Saturday											
Sunday											

School Trips

	Travel origin	Destination	Mode of travel e.g car	No. of trips	Distance(km)	Duration of travel(mins)	Vehicle occupancy	Qty of gasoline (lits)	Cost of gasoline	Vehicle ownership	Cost of travel
Monday											

Tuesday											
Wednesday											
Thursday											
Friday											
Saturday											
Sunday											

Service/recreational Trips

	Travel origin	Destination	Mode of travel e.g car	No. of trips	Distance(km)	Duration of travel(mins)	Vehicle occupancy	Qty of gasoline (lits)	Cost of gasoline	Vehicle ownership	Cost of travel
Monday											
Tuesday											
Wednesday											
Thursday											
Friday											
Saturday											
Sunday											

APPENDIX 2

Summary of household socio-economic variables and gasoline consumption

Socio-economic Variables		Frequency	Percentage
Gender	Male	449	70.2
	Female	191	29.8
Household Head	Male	601	93.6
	Female	39	6.1
Age of Household Head	20-30	44	6.9
	31-40	185	28.9
	41-50	278	43.4
	51-60	103	16.1
	61-70	28	4.4
	Above 70	2	0.3
Educational Status	None	17	2.7
	Primary	63	9.8
	Sec Cert	150	23.4
	NCE,HND,B.Sc	313	48.9
	PGD	97	15.2
Marital Status	Married	583	91.1
	Single	20	3.1
	Divorced	15	2.3
	Widowed	22	3.4
Occupation	Farming	17	2.7
	Industry	64	10.0
	Trading	113	17.7
	Administration	144	22.5
	Construction	40	6.3
	Teaching	98	15.3
	Schooling	6	0.9
	Road transport Worker	113	17.7
	Others	45	7.0
Annual Income	1-50000	58	9.1
	50001-100000	96	15
	100001-150000	89	13.9
	150001-200000	110	17.2
	200001-250000	79	12.3
	250001-300000	39	6.1

	300001-350000	8	1.3
	350001-400000	36	5.6
	400001-450000	10	1.6
	450001-500000	35	5.5
	Above 500000	80	12.5
Household Size	1-3	83	13
	4-6	460	71.9
	7-10	94	14.7
	Above 11	3	0.46
Number of children schooling	0	81	12.7
	1-3	478	74.7
	4-6	79	12.4
	Above 6	2	0.3
Number of children Working	0	389	60.8
	1-3	233	36.4
	4-6	17	3.7
	Above 6	1	0.2
Number of cars	0	148	23.1
	1	383	59.8
	2	83	13
	3	17	2.7
	4	8	1.3
	5	1	0.2
Number of buses	0	527	82.3
	1	111	17.3
	2	2	0.3
Number of motorcycles	0	590	92.2
	1	50	7.8
Total gasoline consumed(litres)	0	11	1.7
	1-50	334	52.2
	51-100	197	30.8
	101-150	65	10.2
	151-200	15	2.3
	201-250	5	0.8
	251-300	6	0.9
	301-350	4	0.6
	351-400	3	0.5

APPENDIX 3

Summary of step-wise regression analysis for work trip and socio-economic variables

Model		B	Standard Error	t	Level of Significance	R	R^2	F	Level of Significance
1	(Constant)	35.320	2.096	16.849	0.000				
	No.of buses	58.882	4.837	12.172	0.000	0.434	0.189	148.2	0.000
2	(Constant)	23.442	3.493	6.710	0.000				
	No. of buses	57.183	4.792	11.933	0.000	0.459	0.211	84.93	0.000
	Gender	17.382	4.119	4.220	0.000				
3	(Constant)	55.625	11.797	4.715	0.000				
	No. of buses	57.427	4.766	12.050	0.000				
	Gender	17.712	4.098	4.323	0.000	0.470	0.221	59.98	0.000
	No. of male adults	-15.737	5.513	-2.855	0.004				
4	(Constant)	69.690	13.025	5.350	0.000				
	No. of buses	53.869	4.955	10.872	0.000	0.478	0.228	46.92	0.000
	Gender	16.650	4.103	4.058	0.000				
	No. of male adults	-15.608	5.490	-2.843	0.005				
	Education	-14.792	5.915	-2.501	0.013				
5	(Constant)	52.994	14.879	3.562	0.000				
	No. of buses	52.235	4.989	10.469	0.000	0.485	0.235	38.84	0.000
	Gender	16.565	4.089	4.051	0.000				
	No. of male adults	-13.690	5.535	-2.473	0.014				
	Education	-15.269	5.899	-2.589	0.010				
	Occupation	14.914	6.494	2.296	0.022				
6	(Constant)	49.788	14.910	3.339	0.001				
	No. of buses	56.570	5.366	10.543	0.000	0.490	0.240	33.33	0.000
	Gender	16.761	4.078	4.110	0.000				
	No. of male adults	-14.388	5.529	-2.602	0.009				
	Education	-18.272	6.044	-3.023	0.003				
	Occupation	15.400	6.480	2.377	0.018				
	No. of cars	5.918	2.744	2.157	0.031				

APPENDIX 4

Summary of step-wise regression of gasoline consumption for school trip and socio-economic variables

		B	Standard Error	Beta	T	Level of significance	R	R^2	F	Level of significance
1	(Constant)	3.547	1.056		3.358	0.001				
	Number of cars	4.041	0.836	0.188	4.833	0.000	0.188	0.035	23.361	0.000
2	(Constant)	12.872	3.181		4.046	0.000				
	Number of cars	4.689	0.856	0.218	5.477	0.000	0.223	0.050	16.660	0.000
	Age	-0.228	0.073	-0.124	-3.105	0.002				
3	(Constant)	12.530	3.176		3.945	0.000				
	Number of cars	4.451	0.861	0.207	5.169	0.000	0.238	0.057	12.695	0.000
	Age	-0.225	0.073	-0.123	-3.085	0.002				
	Number of relatives at school	2.212	1.034	0.083	2.139	0.033				
4	(Constant)	6.153	4.318		1.425	0.155				
	Number of cars	4.578	0.861	0.213	5.320	0.000	0.252	0.064	10.757	0.000
	Age	-0.265	0.075	-0.144	-3.529	0.000				
	Number of relatives at school	2.288	1.032	0.086	2.218	0.027				
	Marital status	8.229	3.787	0.086	2.173	0.030				
5	(Constant)	4.178	4.398		0.950	0.342				
	Number of cars	4.741	0.861	.221	5.505	0.000	0.266	0.071	9.620	0.000
	Age	-.277	0.075	-0.151	-3.689	0.000				
	Number of relatives at school	2.388	1.030	0.090	2.319	0.021				
	Marital status	8.392	3.777	0.088	2.222	0.027				
	Gender	3.074	1.401	0.085	2.194	0.029				

APPENDIX 5

Summary of step-wise regression of gasoline consumption for shopping trip and socio-economic variables

Model		B	Standard. Error	Beta	T	Level of significance	R	R^2	F	Level of significance
1	(Constant)	3.145	0.303		10.392	0.000	0.247	0.061	41.318	0.000
	Annual income	3.09E-006	0.000	0.247	6.428	0.000				
2	(Constant)	1.847	0.419		4.405	0.000	0.298	0.089	30.954	0.000
	Annual income	2.26E-006	0.000	0.181	4.433	0.000				
	Number of cars	1.568	0.356	0.179	4.404	0.000				
3	(Constant)	4.782	0.830		5.759	0.000	0.335	0.112	26.687	0.000
	Annual income	2.31E-006	0.000	0.185	4.588	0.000				
	Number of cars	1.712	0.353	0.196	4.844	0.000				
	Household size	-0.609	0.149	-0.154	-4.078	0.000 0.000				
4	(Constant)	5.856	0.902		6.490	0.000	0.352	0.124	22.428	0.000
	Annual income	2.33E-006	0.000	0.186	4.650	0.000				
	Number of cars	1.596	0.354	0.183	4.515	0.000				
	Household size	-0.892	0.177	-0.225	-5.045	0.000				
	Number of relatives	1.034	0.351	0.132	2.946	0.003				

APPENDIX 6

Summary of step-wise regression of gasoline consumption for service trip and socio-economic variables

Model		B	Standard. Error	Beta	T	Level of significance	R	R^2	F	Level of significance
1	(Constant)	4.179	0.302		13.828	0.000				
	Annual income	2.87E-006	0.000	0.230	5.972	0.000	0.230	0.053	35.661	0 .000
2	(Constant)	6.076	0.518		11.733	0.000				
	Annual income	2.88E-006	0.000	0.231	6.087	0.000	0.286	0.082	28.387	0.000
	Number of children schooling	-0.913	0.204	-0.170	-4.477	0.000				
3	(Constant)	5.035	0.607		8.299	0.000				
	Annual income	2.27E-006	0.000	0.183	4.498	0.000	0.311	0.097	22.691	0.000
	Number of children schooling	-0.867	0.203	-0.162	-4.274	0.000				
	Number of cars	1.143	0.354	0.132	3.233	0.001				
4	(Constant)	3.850	0.720		5.347	0.000				
	Annual income	2.13E-006	0.000	0.171	4.228	0.000	0.331	0.110	19.502	0.000
	Number of children schooling	-0.892	0.202	-0.166	-4.419	0.000				
	Number of cars	1.253	0.353	0.144	3.546	0.000				
	Gender	1.673	0.555	0.114	3.012	0.003				
5	(Constant)	5.425	0.919		5.905	0.000				
	Annual income	2.15E-006	0.000	0.173	4.280	0.000				
	Number of children schooling	-.524	0.242	-0.098	-2.166	0.031	0.346	0.120	17.252	0.000
	Number of cars	1.411	0.356	0.162	3.961	0.000				
	Gender	1.638	0.553	0.111	2.964	0.003				
	Household size	-0.488	0.178	-0.124	-2.739	0.006				

APPENDIX 7

Summary of multiple regression results of gasoline consumption for all trips and socio-economic variables.

Model		B	Standard Error	Beta	T	Level of significance	R	R^2	F	Level of significance
1	(Constant)	54.181	2.453		22.083	0.000	0.317	0.100	70.95	0.000
	Number of buses	47.687	5.662	0.317	8.423	0.000				
2	(Constant)	38.965	4.077		9.557	0.000	0.360	0.130	47.34	0.000
	Number of buses	45.510	5.593	0.302	8.138	0.000				
	Gender	22.268	4.807	0.172	4.632	0.000				
3	(Constant)	26.563	5.528		4.805	0.000				
	Number of buses	54.394	6.171	0.361	8.814	0.000	0.380	0.144	35.66	0.000
	Gender	22.959	4.775	0.177	4.808	0.000				
	Number of cars	10.320	3.135	0.135	3.292	0.001				
4	(Constant)	65.007	13.959		4.657	0.000				
	Number of buses	55.214	6.139	0.367	8.994	0.000				
	Gender	23.401	4.748	0.181	4.929	0.000	0.395	0.156	29.33	0.000
	Number of cars	10.927	3.122	0.143	3.500	0.000				
	Number of male adults	-19.155	6.394	-0.110	-2.996	0.003				
5	(Constant)	46.028	16.443		2.799	0.005				
	Number of buses	53.696	6.161	0.356	8.716	0.000				
	Gender	23.357	4.734	0.180	4.934	0.000	0.403	0.162	24.54	0.000
	Number of cars	11.100	3.114	0.145	3.565	0.000				
	Number of male adults	-17.078	6.447	-0.098	-2.649	0.008				
	Occupation	16.365	7.549	0.081	2.168	0.031				
6	(Constant)	44.807	16.410		2.730	0.007				
	Number of buses	52.756	6.161	0.350	8.563	0.000				
	Gender	22.448	4.742	0.173	4.734	0.000				
	Number of cars	8.520	3.342	0.111	2.549	0.011	0.410	0.168	21.28	0.000
	Number of male adults	-16.378	6.439	-0.094	-2.544	0.011				
	Occupation	16.643	7.530	0.082	2.210	0.027				
	Annual income	9.02E-006	0.000	0.082	2.089	0.037				
7	(Constant)	56.212	17.303		3.249	0.001				
	Number of buses	50.522	6.243	0.335	8.092	0.000				
	Gender	21.503	4.753	0.166	4.524	0.000				
	Number of cars	9.946	3.407	0.130	2.919	0.004	0.417			
	Number of male adults	-16.352	6.423	-0.094	-2.546	0.011				
	Occupation	17.297	7.519	0.085	2.300	0.022				
	Annual income	9.25E-006	0.000	0.084	2.146	0.032				
	Education	-14.267	7.014	-0.080	-2.034	0.042				

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APPENDIX 8

Summary of Household Trips and Gasoline Consumption

Work Trip						Shopping Trip			School trip			Service/Recreational		
		Week total	Average	%		Week Total	Averag e	%	Week total	Average	%	Week total	Averag e	%
Mode	Car	2541	363	73.7	Car	585	83.6	52.6	1373	274.6	49.2	709	101.3	70.4
	Bus	622	88.9	18	Bus	266	38	23.9	711	142.2	25.5	162	23.1	16.1
	Motorcyc le	262	37.4	7.6	Motorcycle	46	6.6	4.1	100	20	3.6	60	8.6	6
	Walk	22	3.1	0.6	Walk	214	30.6	19.3	605	121	21.7	73	12.2	7.2
	Bicycle	2	0.3	0.06	Bicycle	-	-	-	--	-	-	3	1.5	0.3
	Total	3449		100	Total	1111		100	2789		100	1007		100
Numb er of trips	1-5	2723	389	79	1	3	1.5	0.3	29	5.8	1	3	1	0.3
	6-10	249	35.6	7.2	2	1107	158.1	99.6	2724	544.8	97.7	999	142.7	99.2
	11-15	192	27.4	5.6	3	-	-	-	-	-	-	-	-	-
	16-20	173	24.7	5.0	4	1	1	0.09	35	7	1.3	5	0.7	0.5
	21-25	26	3.7	0.8	Total	1111		100	2789		100	1007	-	100
	26-30	80	11.4	2.3										
	46-50	6	1	0.2										
	Total	3449		100										
Veh.O wners hip	Public	162	23.1	4.7	Public	283	40.4	25.5	753	150.4	27	122	17.4	12.2
	Personal	3278	468.3	95	Personal	614	87.7	55.3	1269	253.8	45.5	802	114.6	79.6
	Carpool	9	1.5	0.3	Walk	214	30.5	19.3	605	121	21.7	73	10.4	7.2

	Official	-	-	-	Carpool	-	-		162-	32.4-	5.8	10	1.4	1
Total		3449		100	Total	1111		100	2789	-	100	1007		
Est Distance	0	422	60.3	12.2	0	410	58.6	36.9	1091	218.2	39.1	318	45.4	31.6
	0.1-5	1455	207.9	42.2	0.1-5	364	52	32.8	1038	207.6	37.2	405	57.9	40.2
	5.1-10	982	140.3	28.5	5.1-10	196	28	17.6	459	91.8	16.5	202	28.9	20.1
	10.1-15	380	54.3	11.0	10.1-15	86	12.3	37.7	155	31	5.6	57	8.1	5.7
	15.1-20	162	23.1	4.7	15.1-20	47	6.7	4.2	36	7.2	1.3	19	6.3	1.9
	20.1-25	22	3.1	0.6	20.1-25	3	1.5	0.3	5	1	0.2	6	1.2	0.6
	25.1-30	-	-		25.1-30	3	1	0.3	-		-	-	-	-
	30.1-35	21	3	0.6	30.1-35	2	1	0.2	-		-	-	-	-
	35.1-40	5	1	0.2	Total	1111		100	2789		100	1007		100
	Total	3449		100										
Travel time	1-10	544	77.7	15.8	1-10	388	55.4	34.9	664	132.8	23.8	339	48.4	33.7
	11-20	850	121.4	24.6	11-20	296	42.3	26.6	1104	220.8	39.5	337	48.1	33.5
	21-30	978	139.7	28.4	21-30	213	30.4	19.2	634	126.8	22.7	200	28.6	19.9
	31-40	384	54.9	11.1	31-40	97	32.3	8.7	220	44	7.9	69	9.9	6.9
	41-50	336	48	9.7	41-50	44	6.3	4	86	17.2	3.1	26	4.3	2.6
	51-60	213	30.4	6.2	51-60	36	5.1	3.2	60	12	22	22	4.4	2.2
	61-70	25	3.6	0.7	61-70	9	1.5	0.8	5	1	0.2	6	1.5	0.6
	71-80	21	3	0.6	71-80	13	3.3	1.2	10	2	0.4	1	1	0.1
	81-90	40	5.7	1.2	81-90	14	2.3	1.3	5	1	0.2	2	1	0.2
	91-100	10	1.4	0.3	91-100	1	1	0.1	-	-	-	1	1	0.1
	>100	48	6.8	1.4	>100	-	-	-	-	-	-	4	2	0.4
Total		3449		100	Total	1111		100	1111	-	100	1007		100
Gas. Cons	0	199	28.4	5.8	0	574	82	51.7	1719	343.8	61.6	270	38.5	26.8
	1-50	3204	457.7	92.8	1-50	535	76.4	48.2	1068	213.6	38.3	735	105	73

	51-100	45	6.4	6.4	51-100	2	0.3	0.2	2	0.2	0.07	2	0.3	0.2
	101-150	-			101-150	-	-		-	-	-	-	-	-
	151-200	-			151-200	-	-		--	-	-	-	-	-
	201-250	--			201-250	-	-		-	-	-	-	-	-
	251-300	1	0.1	0.03	251-300	-	-		--	-	-	-	-	-
	Total	3449		100	Total	1111		100	2789		100	1007	-	100