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HOUSEHOLD DEMOGRAPHICS AND URBAN FORM IN TRAVEL BEHAVIOUR: THE EXAMPLE OF LAGOS METROPOLITAN AREA.

Taofiki Iyanda Salau [1], Adebukola Yewande Daramola [2] and Olufemi Ademola Adeniji [1]

[1] University of Lagos, Lagos, Nigeria.

[2] Nigeria Institute of Social and Economic Research, Ibadan, Nigeria.

ABSTRACT

Motivated by the need for a comprehensive explanation of travel behaviour towards the attainment of sustainable urban mobility in Lagos, Nigeria, data was obtained from a survey sample of 1,351 households across residential density types and subjected to descriptive and regression analysis. Four dimensions of travel behaviour were specified as dependent variables and explained using residential density and household demographics. High density residence was the strongest factor explaining variations in public transport use, while income had the highest effect strength in explaining variations in personal automobile use. Age was the strongest predictor of trip frequency while travel cost had the highest effect strength in explaining distance travelled.

Keywords: Travel Behaviour, Urban Form, Household Demographics, Sustainable Mobility, Household Travel Pattern, Lagos, Nigeria

INTRODUCTION

Individual and household travel patterns combine to form aggregate trip patterns in spatial units and thus impact on the day to day running of such units. Cities as spatial units are particularly influenced by a complex web of interactions spurred by households' travel behaviour patterns. Urban areas in Nigeria currently accommodate about half of the country's population and Lagos stands out as one of the most urbanized and most populous states in the country. The city of Lagos functions as the country's hub of commercial and economic activity, accounting for more than 60 per cent of Nigeria's industrial and commercial establishments. Consequently, the concentration of population, commercial enterprises as well as industries within the Lagos Metropolitan has serious implications for the provision of a sustainable urban transport system.

Lagos achieved the status of a megacity in 2010 when its population exceeded the 10 million mark. Hence, travel and transport are critical activities for continuous examination and analysis. This study therefore attempts to provide some explanation for variations in travel behaviour among Lagos households, by identifying significant predictors of same. Variations in travel behaviour have important consequences for public policy geared towards sustainability in mobility patterns, transport systems and land use management and planning, hence the rationale for this study.

Study Area

The Lagos Metropolitan area is the largest metropolitan area in Nigeria, located within latitudes $6^0$23'N and $6^0$41'N and longitude $3^0$9'E and $3^0$28'E. It constitutes less than 0.3 percent of Nigeria's total land area of 923,768km^2, but accounts for about nine percent of the country's urban population.

Estimates of transport demand in Metropolitan Lagos ranged from 7 million to 10 million passenger trips daily, of which over 95 percent were undertaken by road, primarily by private

cars, buses and taxis. Out Of these, between 80 to 85 percent were made by public transport according to Opeifa (2012).

Metropolitan Lagos is the fastest growing city in Africa (UN-Habitat, 2008), the seventh in the world, and the most populous conurbation in Nigeria. The Lagos state government household survey of 2010 showed that the commercial bus was the main mode of transport for over 70 percent of the household population in the state, while private cars were used by only 7 percent of households. Meanwhile, vehicle registration data pool (2001-2014) shows that commercial vehicles and private cars form 13 percent and 78 percent of the fleet respectively (Lagos State Government, 2015).

CONCEPTUAL ISSUES AND LITERATURE REVIEW

Conceptual Issues

Conceptually, travel behaviour is seen to be influenced by daily decisions bordering on activity participation (Jones et al., 1990; Axhausen and Gärling, 1992; McNally, 2000) and as such can be studied by focusing on individuals' or households' recurrent routine activities. Travel behaviour is also considered to be influenced by medium term decisions on locational behaviour. Authors (such as Levinson, 1997; Clark et al., 2003; Scheiner, 2006) have found for example

that mode use, travel distance and activity behaviour all change sequel to a relocation of residence. Residential locations are more often than not, the start off points in the analysis of travel activity.
In conceptualizing a hierarchy of travel needs, travel cost, along with other factors such as time, physical exertion, mental effort and unreliability are seen to constitute factors of disutility in travel activity (Singleton, 2015)

Other authors (Schwanen and Mokhtarian, 2005 Bhat and Guo, 2007; Cao et al., 2007; Pinjari et al., 2007; Chen et al., 2008; Mokhtarian and Cao, 2008) argue that the true determinants of travel patterns are found in peoples' attitudes and preferences and so individuals and households pre-select residential neighbourhoods which are consistent with their travel dispositions and preferences. A household with preference for public transport use will therefore locate in a neighbourhood where public transport services are easily accessible. In other words, travel patterns simply play out in spatial units such as residential neighbourhoods, but behaviours are in fact formed before the aggregation of individuals and households into these units. Therefore, travel dispositions and preferences may in fact be influenced by individuals' and households' socio-demographic characteristics with implications for sustainable travel behaviour.

The concepts of daily routine activity, medium term locational decisions, attitudes and travel preferences throw up insights into the interdependencies of travel and residential location choices. Our study does not however take account of these causal and reverse causality mechanisms. Rather we present a straight line of thought with travel behaviour as the outcome variable. We tried explaining different elements of this outcome using household demographics, urban form and modal characteristic factors. These factors have been observed in literature to influence travel behaviour.

Literature Review

In an UN-HABITAT report (UNCHS, 1993), travel activity was observed to vary by life cycle stages. Households with children of school age and those with adults in the working population age range had a propensity for more trips. A ten percent increase in household size was associated with six percent increase in household trip making. Age structure effect on travel activity was found critical largely in respect of the dependent population cohorts (children and the retired). Travel activity increased for households with young dependents but declined for the elderly dependents. The UNCHS report also shows that income effect was associated more with non-obligatory trips, and the effect of income on travel behaviour was often observed through the use of personal automobiles.
Studies on trip generation features in relation to different residential locations and income groups in developed countries have been undertaken by several authors including Mathies et al, 2002; Hunecke et al 2001; Stern, 2000; Kaiser et al, 1999 and Hanson and Hanson, 1981, In Nigeria, studies along these lines are mostly dated (Fadare, 2001; 1997; Ogunjumo, 1986 and Ayeni, 1981). Ayeni (1981) for instance examined the trip distribution pattern in Jos and noted that the number of trips per week was directly related to disposable income. The study showed that low income groups generated an average of 17 trips per week compared to the middle income and high-income groups who generated an average of 24 trips per week individually. Ogunjumo (1986) conducted a study on the pattern of trip generation in Ile-Ife, Nigeria and reported that the frequency of urban travel was influenced by the size of household, number of workers in a household and vehicle ownership. The author observed that households with cars had higher rates of travel than non-car owning groups.

Similarly, Fadare (1989, 1997) studied the travel behaviour of commuters in different residential density zones in Ibadan. Household size, number of employed family members, car ownership and income were the significant variables which sequentially explained the trip rates for various trip types in the study area. His study showed that there were different trip

rates for the various trip purposes in the different housing density types. Aloba (1998) cited in Okoko and Fasakin (2007) observed that commuters in households with personal and functional vehicles made more trips than those who depend on urban public transport. He identified other factors that could affect trip generation as age, income, education and occupational status. Aloba (1998) also observed that the pattern of trip generation at various hours of the day sometimes exhibit varying demographic and socio-economic characteristics. These studies reveal that an understanding of household travel behaviour and factors driving it is pivotal to the development of policy measures aimed at permanently shifting people's travel behaviour towards more sustainable mobility options.

Okoko and Fasakin (2007) in a study on Akure, Nigeria showed that travel time, trip mode, number of cars per household, house rent and trip distance in that order significantly affected trip generation in the city. The study revealed further that the mean trip rate values vary across the three residential density zones. However, the variation was not statistically significant. They conclude that residential density types in Akure do not significantly influence trip generation rates in the city.

Other studies have been conducted to examine socio-economic characteristics of individuals and households and their effects on travel behaviour. The most common households' socio-economic characteristics analysed in literature include household size, car ownership, income, age, gender, number of employed people in the family and occupation. (Fadare, 2010, Daramola and Adeniji, 2009; Asiyanbola, 2007; Fujiwara et al, 2005; Pucher and Renner, 2003).

Morikawa et al (2001) in a study on travel behaviour among residents of four Asian cities of Bangkok, Kuala Lumpur, Manila and Nagoya, discovered that travellers who were 18 years old or more preferred to use cars and motorcycles while the older ones from 65 years and above prefer bus travel due to the free transit passes offered to the aged people in Nagoya. In contrast, travellers who were above 45 years of age in Bangkok, Kuala Lumpur and Manila disliked bus transport, and rather preferred taxis or other para-transit modes. It was also noted that the rail was the preferred mode among school children.

Srinivasan (2005) opined that the number of vehicles in the household and the income level were significant socio-economic factors influencing travel behaviour in Chennai, India. In the US, income is regarded as the main determinant of car ownership and the higher the income the higher the number of vehicles per household (Pucher and Renne, 2003). In that clime, three-quarters of poorest households owned a car, with increase in number of car ownership per household observed to have minor additional impacts on travel behaviour.

Apart from socio-demographic characteristics, urban form is another factor established in literature as an explanatory variable in travel behaviour. Urban form elements include residential density, indicators of spatial allocation of land uses (such as land-use balance[1]), indicators of suburbanization (example- distance from the city centre) and indicators of road space development (such as road space per person). Singleton (2015) in his review notes that a common thread in literature leans to the belief that high-density and mixed-use neighbourhoods are associated with shorter trips and more non-motorized trips; hence, indicating that there exists a clear relationship between urban form and travel behaviour. He further notes that there is little consensus in the conclusions put forward in these studies. Some studies (e.g., Meurs and Haaijer, 2001) indicate that various aspects of the urban form are linked with travel behaviour, while others (e.g., Schwanen, 2002) state the opposite.

Recent studies on travel behaviour in Nigeria include Alade (2010) and EyinnayaEluwa et al (2012). Alade (2010) observed significant variations in trip frequency and mode of travel in households across the residential density areas in Lagos metropolis, while EyinnayaEluwa et al (2012) found significant variations in number of work trips and in trip distance across residential density types in Ibadan. Medium density suburban residents generated the most trips and recorded the highest mean distance.

Much of the empirical literature on travel behaviour in Nigeria dwells on the trip generation aspect. Additionally, cities mostly used as case studies do not have the megacity status of Lagos which Alade studied in 2010. Authors have attempted to explain travel behaviour aspects using either socio-economic characteristics or urban form. The authors, by this current study add to the pool of empirical studies on travel behaviour in Nigeria and present value addition by employing a more comprehensive definition of travel behaviour. Moreover, explanatory factors of travel behaviour are extended to include a mix of socio-demographic, urban form and modal characteristics.

RESEARCH DESIGN AND METHODOLOGY

Sampling and Data

The study sample is drawn from the Lagos metropolitan area. Metropolitan Lagos is made up of 16 urban local government areas (LGAs) out of the twenty LGAs in Lagos State. Using the National Population Commission's growth rate of 2.83 percent and the Commission's census figure for the metropolitan area (8,048,430), the area's population as at 2014 was estimated at 9,384.830. The number of households in the study area was estimated at 1,443,820, using an average household size of 6.5. These 1.4 million houses constitute our sampling frame.

Israel (2013) suggests a sample size of 1,111 for populations greater than 100,000 and with desired precision level of 3% (97% confidence level). In order to make provisions for non-

responses, we added on 240[2] to this number, to arrive at a sample of 1,351 households. The household formed our unit of analysis with household heads as the target respondents. Where heads of households were unavailable, spouses or an adult family member filled in as respondent.

Given our interest in different density types, the sample of 1,351 was stratified using residential density. Households included in the sample were therefore drawn from high, medium and low density areas using a proportionate to size principle. Samples drawn from high, medium and low residential density areas thus formed 58, 38 and 4 percent of the total sample respectively. Table 1 gives a breakdown of the Local Government Areas (LGAs) covered in the survey.

2Past experiences of administering questionnaire surveys have shown that about 1 in 5 completed questionnaires may be problematic. Hence, a rough calculation to arrive at 240 additional households to be included in the sample.

3

RESIDENTIAL DENSITY	Persons per hectare[3]	LGAs	SAMPLE PROPORTION
HIGH	2,160	Amuwo Odofin, Surulere, Ajeromi Ifelodun, Lagos Island, Mushin,Alimosho, Ifako Ijaye, Lagos Mainland, Kosofe, Shomolu, Agege, Ojo, Oshodi Isolo	58
MEDIUM	468	Amuwo Odofin, Ikeja, Ojo, Apapa, Kosofe,Alimosho,Lagos Mainland ,Eti-Osa, Mushin, Ifako Ijaye, Shomolu, Surulere	38
LOW	120	Amuwo Odofin, Ikeja, Eti-Osa, Apapa	4

Table 1: Sample Selection for Household Travel Survey
Source: based on survey methodology
Data were thus derived from household surveys using a semi-structured questionnaire.

Data Analysis and Model Specification

Data analysis was focused on explaining variations in travel behaviour (the dependent variable) using urban form and socio-economic factors of households as well as a modal factor (travel cost). Travel behaviour dimensions considered include average number of daily trips, mean daily distance, use of public transport and use of private car.

Indicators of urban form were restricted to residential density due mainly to issues of data availability. Moreover, residential densities were imputed as ordinal categorical variables given that actual residential density figures for each area were not available. The distance from city Centre, which could have been an indicator of suburbanization was not considered given the polycentric nature of the Lagos metropolitan area. Socio-economic variables used in data analysis include age of household head, household income, household size, employment status and gender of household head.

Preliminary descriptive statistics were used in illustrating patterns of travel behaviour among socio-economic and residential density groups. The one-way Analysis of Variance (ANOVA) was employed to explain significant variations in travel behaviour among socio-economic and residential density groups, while an unpaired two-sample t-test was used to test significant differences in means of travel behaviour variables between males and females.

Thereafter we conducted a regression analysis using urban form and socio-economic parameters and a modal characteristic parameter as explanatory variables for travel behaviour. Four models were estimated, one for each travel behaviour dimension. The predictor and response variables and their specifications in the model to be estimated are listed in Table 2.

Predictors	specification	Response	Specification
Travel cost	X1	Number of trips	Y1
Age of household head	X2	Distance travelled	Y2
Household income	X3	Use of Public transport	Y3
Household size	X4	Use of personal automobile	Y4
Informal employment	X5		
Formal employment	X6		
Unemployed	X7		
Low density residence	X8		
Medium density residence	X9		
High density residence	X10		

Table 2: variables for regression analysis

Employment status groups (informal/formal/unemployed) were coded as dummy variables, same for residential density groups (low/medium/high residence)

The empirical models to be used to explain travel behaviour in this study are:

$Y1 = \alpha+\beta_1x_1+\beta_2X_2+\beta_3X_3+\beta_4x4+ \beta_6X_{6+}\beta_7X_7+€$…… Equation 1

$Y2= \alpha+\beta_1x_1+\beta_8X_8+\beta_9X_9+€$……. Equation 2

$Y3= \alpha+\beta_1x_1+\beta_2X_2+\beta_3X_3+\beta_4x4+ \beta_5X_5+\beta_7X_7+\beta_8X_8+ \beta_{10}X_{10}+€$……... …… Equation 3

$Y4= \alpha+\beta_1x_1+\beta_2X_2+\beta_3X_3+\beta_4x4+\beta_5X_{5+}\beta_7X_7+€$…….Equation 4

α is a constant, β_1- β_{10} are coefficients to be estimated and € is an error term. We interpreted our results using a 95% confidence level.

RESULTS

Urban Form and Socio-Economic Parameters

All residential density types (low, medium and high) were covered in the survey as shown in Figure 1.

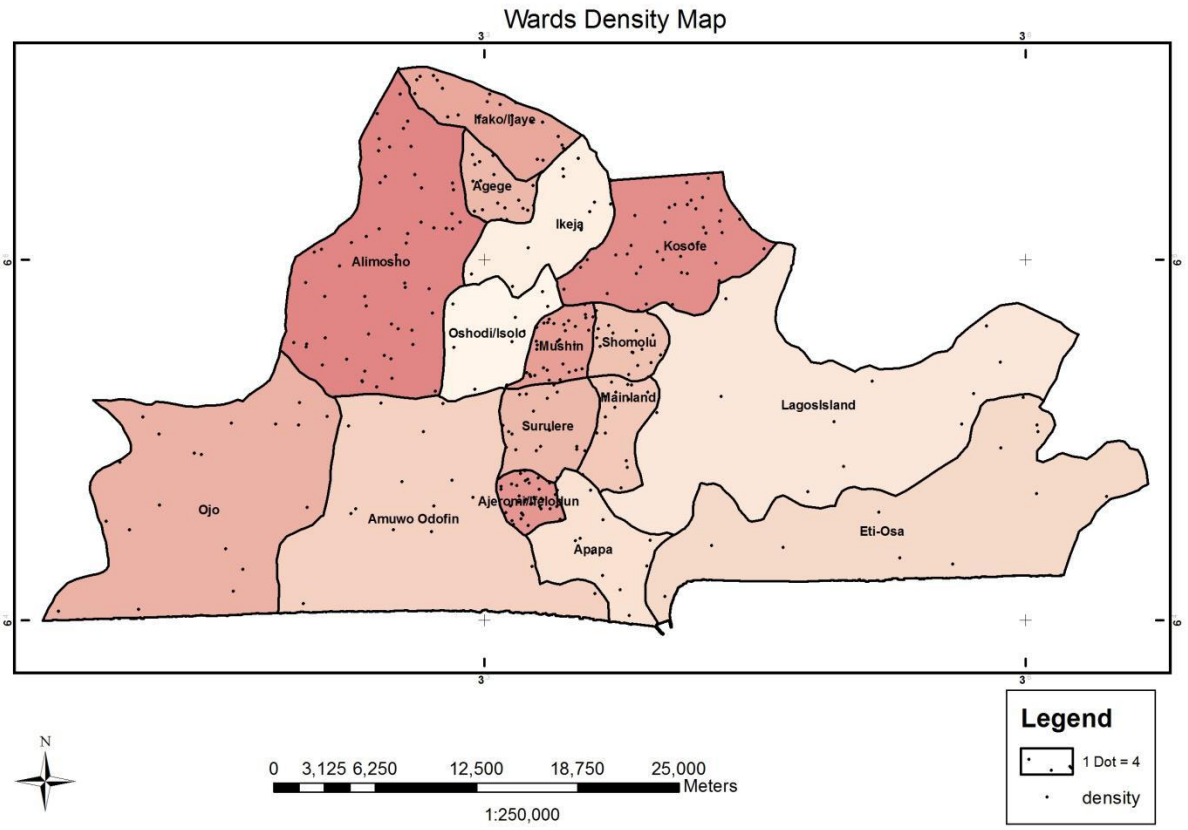

Figure 1: Residential density types in metropolitan Lagos.
Source: Salau (2017)

The high, medium and low-density areas in metropolitan Lagos roughly approximate the conventional low, medium and high-income class respectively. However, there are areas of overlaps and hybrids among residential areas. Consequently, we have some medium density areas inhabited by high income profile households. Moreover, given the fact that choice of residential areas often represents a sensitive trade-off between trip time to work and comfortable accommodation; high income households may be spread across residential density types in the area. Table 3 describes the socio-economic characteristics of respondents across urban forms.

Socio-economic characteristics	High Density	Medium Density	Low Density
Gender:			
Male	60.7	60.4	51.1
Female	39.3	39.6	48.9
Marital status:			
Single[4]	54.1	47.2	40.4
Married	45.9	52.8	59.6
Highest Level of Education:			
Primary	5.4	6	4.3
Secondary	39.4	38.6	17
Tertiary	47.4	48.5	72.3
Employment Status:			
Formal	33.5	39.8	61.7
Informal	38.1	35.7	17
Unemployed	6.7	4.9	2.1
Monthly Income (Naira):			
Min	2,500	8,000	20,000
Mean	52,795	59.429	108,000
Max	300,000	192,000	250,000
Household Size (number):			
Min	1	1	2
Mean	4.9	4.9	4.96
Max	24	17	12

Table 3: Socio-Economic Characteristics of Respondents by Density Types.
Source: Salau (2017)

The preliminary descriptive analysis contained in Table 3 enables us to appreciate interactions between the explanatory variables (household demographics and urban form) which will be used to explain travel behaviour in the study area. Since the sample size differed across residential density areas, socio-economic characteristics of respondents are described for each density type, taking each type to represent 100 percent.

Mean monthly income in medium density areas was higher than in high density areas by 13 percent. Low density residents had an even higher mean monthly income, more than double that of high-density residents. The pattern here shows that high, medium and low-density areas do approximate low, middle- and high-income groups to some extent. Low and

middle income in Lagos will of course be relative to high income groups in the city. Household size was more or less a flat line across the density areas, though marginally higher in low density areas. This may appear counter- intuitive; however, it could have been influenced by a few households with large numbers of live-in domestic staff.

Patterns of Travel Behaviour

On a general note, public transport is the most frequently used mode among 83.8 percent of survey respondents, only 10.1 percent of respondents use personal automobiles more frequently while 6.2 percent employ the use of bicycles and walking for daily travel. Public transport types available for use in the study area at the time of the survey include motorcycles, tricycles, taxis, minibuses, midi buses, bus rapid transit and boats. The most popular public transport types in use were motorcycles (61%) minibuses (59%), tricycles (31%) and taxis (12.2%). Residents' trips often involved combining more than one public transport mode, hence the various types are not mutually exclusive. The challenges of sustainable public transport usage associated with the existing mode by respondents include inefficiency, uncomfortable conditions of travel, time wasting, unreliability and traffic congestion. From a sustainability viewpoint, Singleton (2015) noted that these factors constitute disutility for travel activity. Traffic congestion was a sustainable mobility challenge which cut across both public and private transport users. With respect to motorcycles, safety was a major concern.

The average distance travelled daily by those who make use of public transport (of all types) is 25.8km, while those using private cars embark on a mean distance of 30.2km daily. Average daily travel cost for public transport users (N670) is much less than the cost for private car users (N2,442). The cost of private car usage can be linked to the relatively longer distances travelled using personal automobiles and the cost of fuelling private cars. At 145 naira per litre of petrol, the amount spent by private car users translates roughly to 17 litres per day. Travel cost for personal automobile and public transport users exhibit wide differentials indicating that much higher costs are involved in the use of automobiles. The average number of trips undertaken daily by all respondents is 1.5 (1.4 for public transport users and 1.1 for private car users). While private car is more flexible than public transport, the former involves higher cost of use. These general patterns of travel behaviour as highlighted above have severe implications for the economic sustainability of households. These general patterns of travel behaviour however conceal variations among socio-economic groups and among residential density types. These variations are explained in subsequent sections of the paper.

Travel Behaviour Variations among Socio-economic Groups

Socio-economic factors are useful in explaining travel behaviour. The factors included in this study are age of household head, gender of household head, household size, household income, and employment type.

Age and Travel Behaviour

The age of household head gives an indication of the stage of the family life cycle. All things equal, households headed by younger persons with dependent children (less than 18 years) may make more trips or make longer trips than those with children of adult age. The obvious reason is that trips to children's school are often added on to their obligatory work trips. Household heads in this younger age bracket will also have to oblige children on trips for leisure and recreation. Exceptions to school trips will occur where household heads subscribe to institutional arrangements such as a school bus. The presence/absence of dependents will equally influence modal choice. Table A (appendix I) contains a descriptive summary of travel behaviour among age groups.

Mean daily trips ranged from 1.37 (<25 years) to 1.60 (35-44 years). The average number of daily trips forms a 'n' shaped curve with increasing age cohorts. Number of trips increased up until 44 years and declined thereafter, indicating less trips with increasing age. Household heads in the less than 25 years category are mostly single (never married), living alone and often without dependents. Some do not have a steady job and so will not make trips often. Consequently, this group has the least number of daily trips as well as the least distance travelled.

The mean daily distance figure did not exhibit wide differentials across age groups (24.2-28.0km). The highest mean daily distance travelled (28km) was recorded for respondents in the 55-64-year bracket. This group represents those in a pre-retirement phase, albeit still economically active. The lowest mean daily distance travelled (24.2 km) was recorded for respondents less than 25 years and those over 64 years.

Modal choice of respondents (use of public transport and use of private car) refers to the most frequently used mode by respondents. The proportion of respondents who make use of public transport ranges from 71.4 percent (55-64 years cohort) to 90.7 percent (<25 years). Respondents in the 55-64 years age group have the lowest proportion of people making use of public transport. Given that public transport in metropolitan Lagos largely consists of unregulated, uncomfortable and reckless minibuses, the sizeable proportion of vulnerable groups which adopt the mode might not be unconnected with the unavailability of sustainable transport options. However, vulnerable groups such as the elderly will opt for a private transport alternative if they have a choice. Along this line, this same age group (55-64 years) has the highest proportion (21.4%) of those who make use of private cars.

Gender and Travel Behaviour

Literature suggests that some dimensions of travel behaviour may vary for males and females. Table B (appendix I) however shows marginal differences between male and female respondents with respect to most travel behaviour parameters. The exception here is in the case of public transport use.

While over 70 percent of females make use of public transport more frequently than any other mode, less than 65 percent of males are captive users. There is also a lower proportion of females (7%) using private cars. Mean number of daily trips and mean daily distance is roughly the same for men and women.

Household Size and Travel Behaviour

Households with larger sizes may have the propensity to make more trips than those with relatively smaller sizes. This is particularly so, when the household members are adults and are able to make trips independent of the household heads. Variations in journey destinations may also increase aggregate distance travelled. Results from the survey show that households with more than five members make more trips than those with fewer household members (Table C- appendix I). The average number of trips undertaken daily by households with a maximum of eight members and those with more than eight members was the same. This shows that number of trips will not necessarily increase proportionately with household size, as trips may well be shared among household members using private transport. This is in tandem with previous findings in literature such as in UNCHS, 1993.

The mean daily distance travelled showed some increase with increasing household size, while the use of public transport declined with increasing household size. We would expect that households with larger sizes will patronize public transport more, however, we must consider the options of non-motorized transport (such as bicycles) and walking were equally taken by a number of respondents. We reckon these other options were responsible for the trend in public transport use given

that private car usage clearly declined with increasing household sizes. Larger households are often synonymous with lower disposable income and so are often less able to afford a private car.

Household Income and Travel Behaviour

Relationships between income and travel behaviour may often be mediated by factors such as auto ownership (number of private automobiles). There was no consistent pattern in mean daily trips across income groups as seen in Table D (appendix I). The highest number of trips was recorded for the N60-80,000 group. Mean daily distance travelled however increased progressively from the N60-80,000 group upwards. The use of public transport shows a clear decline with increasing income groups, while private car usage mostly increased with higher income brackets.

Employment Status and Travel Behaviour

Formal and informal employments are two broad categories for grouping workers in Nigeria. Metropolitan Lagos has a large informal sector made up of traders, small manufacturers, service providers and artisans among others. Formal sector employment comprises government and organized private sector jobs. Work schedules and corresponding time allocations in the formal sector are often regimented, while those in the informal are mostly flexible though often with open-ended time allocation for work. These factors influence varied travel behaviour traits among workers in both sectors.

Table E (appendix I) shows that informal sector workers make more trips than those in the formal sector, while those in formal employment cover longer distances daily than those in the informal. Given that there is a higher proportion of formal sector respondents making use of private means of transport, distances travelled by this group may be positively influenced by that factor, while formal sector workers have a more structured routine (associated with predictable trip rates), trips for informal sector workers may be largely demand driven, including trips for market cultivation and product sourcing.

Informal sector workers make more use of public transport and less use of private cars, but the unemployed have the largest proportion (89%) of those who make use of public transport. Ironically, the unemployed group travel longer distances daily than those in formal and informal employment. This travel will probably be in search of jobs.

Analysis of Variations in Travel behaviour by Socio-Economic Factor

An analysis of variation in travel behaviour was conducted using parameters such as the socio-economic factors discussed above as explanatory variables. The results showing F values and corresponding significance are presented in Table F (appendix I).

The ANOVA results show that age of household head is the only significant variable which explains variations in average number of trips undertaken daily. This corroborates UNCHS (1993) that household life cycle does affect travel activity. Household income and employment status are significant factors in the explanation of variations in average distance travelled daily. Household size is the only socio-economic factor that does not significantly explain variations in public transport use. Age, household income and employment status are however significant factors in this regard. All four socio-economic factors included in the study are significant in explaining variations in private car use. This finding has implications for transport policies which seeks to shift mobility trip to more sustainable alternative public transport modes.

The gender variable was not included in the ANOVA test because there are only two categories indicated (male/female) and thus violates the requisite conditions for conducting a one-way ANOVA. Consequently, an unpaired two sample t-test was conducted with respect to the travel behaviour parameters between males and females. However, none of the F statistics generated for the four travel behaviour parameters were significant between males and females.

Travel Behaviour Variations among Urban Forms

The descriptive analyses of travel behaviour dimensions across residential density zones show that high density residents have the highest mean daily distance travelled as well as the highest proportion of public transport users (Table G-appendix I). The former finding on distance travelled negates the summary of findings put forward by Singleton (2015). In a review of various studies, Singleton notes that much of the studies put forward the basic idea is that high-density and mixed-use neighbourhoods gives rise to sustainable mobility which is associated with shorter trips and more non-motorized trips.

In Lagos, while there are some exclusive bus lanes (for Bus Rapid Transit), however, most public transport modes, (which are of the para-transit type) do not run on exclusive lanes, but are mixed with other traffic. Inefficient and unsustainable para-transit modes usually do not enjoy segregation or prioritization for minimization of distance or efficiency of time. Consequently, the main incentive for the existing public transport usage which is the reduced cost of transport is traded off in longer transit time, longer distance and much inconvenience to users. With respect to non-motorized transport use, a major disincentive is the lack of infrastructure support needed to operate such modes safely.

Medium density residents have a slightly higher number for mean daily trips (1.5) compared to high and low-density residents; this corroborates findings in Ibadan by EnyinnayaEluwa et al (2012). Personal automobile ownership as expected is highest (68,1%) among low density residents. Public transport use and personal automobile ownership are of course not exclusive of each other.

The ANOVA tests for travel behaviour in metropolitan Lagos using residential density as an explanatory factor shows that urban form (indicated by residential density) significantly explains travel behaviour dimensions except number of trips undertaken daily by the household (Table H-appendix I). This finding is at variance with EyinnayaEluwa et al's (2012) finding that residential density significantly explains variations in number of work trips. This finding was influenced by medium density residential zones which house large populations but are often significantly distant from city centres where work places are mostly located. Ibadan city is a much more spatially widespread area (more than twice the size of metropolitan Lagos), and so differences in physical distance travelled are likely to be greater; although transit time is undoubtedly longer in Lagos due to higher population and vehicle density.

The results imply that residents in high, medium and low-density neighbourhoods do not differ significantly with respect to the number of trips generated in the households. However, the distance travelled daily, the frequency of public transport use and the frequency of personal automobile use differ significantly across these urban forms.

Apart from socio-economic and urban form characteristics, travel cost, which is a modal characteristic, was found worthy of inclusion in explaining variations in travel behaviour. Responses from the survey showed that travel cost was

important in determining travel choices and travel behaviour patterns. Given the various results from the ANOVA tests, regression analysis is carried out for each of the travel behaviour dimensions using the explanatory variables specified in the tests and a modal characteristic variable (travel cost). Our objective is to determine the magnitude and direction of the effects of these explanatory variables on travel behaviour in metropolitan Lagos.

Determinants of Travel Behaviour

We experimented with several models for each of the travel behaviour dimensions, inputting socio-economic and urban form variables separately and jointly. In this section, we present models with the highest explanatory power for each dimension of travel behaviour. Table 4 gives an overview of significant predictors for the four travel behaviour parameters.

PREDICTOR	Travel Behaviour			
	Number of trips	Travel distance	Public transport use	Personal automobile use
Modal characteristic				
Travel cost		☐ (+)	☐ (-)	☐ (+)
Socio-economic				
Age of household head	☐ (+)			
Household income			☐ (-)	☐ (+)
Household size			☐ (+)	☐ (+)
Informal employment				☐ (-)
Formal employment	☐ (+)			
Unemployed				
Urban form				
Low density residence		☐ (-)		
Medium density residence				
High density residence				

Table 4: Summary of regression results (significant predictors ticked)

The summary table of regression results shows that socio-economic factors of households and travel cost come up more frequently as significant variables in explaining travel behaviour. Urban form, indicated in low density residence is significant only in the explanation of distance travelled.

The results of the ANOVA and regression imply that while travel behaviour varies significantly across urban forms, these variations may in fact be reflections of household demographics. Consequently, urban form parameters as defined here did not emerge as strong predictors of travel behaviour. Subsequent sections discuss the four regression models of travel behaviour in detail.

Number of Trips

The ANOVA tests conducted (Appendix I- Tables F and H) showed that household travel behaviour, with respect to number of trips did not vary significantly across urban forms, neither did it across many of the socio-economic groups (except across age groups). By the same token, the regression models for number of trips yielded very low coefficients of determination. The highest model yielded an adjusted R Square of 2.4% (Table I-appendix I)

Although the explanatory power of the model is really low, the model is statistically significant and reveals age of household head and formal employment as significant predictors of number of trips generated in the household. Age is however a stronger predictor; for every unit increase in age, number of trips generated in the household increase by 0.1. Our earlier descriptive analysis (Table A-appendix I) however shows that this positive change will happen up to a particular age bracket (35-44 years), beyond which we expect number of trips to decrease. The positive effect on number of trips with increasing age appears to feature in the early part of the economically active years. Formal employment status is equally a significant predictor but not as strong as age when we compare standardized coefficients. Households whose heads are engaged in the formal sector are higher by 0.1 points on number of trips generated compared to those with informal employment, and this difference, by the model is significant.

Distance Travelled

The predictors in the model- travel cost, low density residence and medium density residence explained 22 percent of the variance in distance travelled by households (Table J- appendix I).

Travel cost and low-density residence were the significant predictor variables in the model. A unit increase in travel cost expense is associated with a 0.007km increase in distance travelled

by households. Meanwhile, residents in low density areas account for a lower level (by 6.4 points) of the explained variance in distance travelled when compared to those in high density areas. This difference was found significant in the model.

Public Transport Use

Households without a private car resort to public transport to meet their mobility demands, and this category is where the bulk of respondents fall. The model predictors accounted for 52.3 percent of the variance in public transport use among households (Table K- appendix I).

Travel cost, household income and household size are significant predictors of public transport use. A standard deviation change in travel cost decreases public transport use by 0.16 units, while a unit increase in household income also diminishes public transport use by three units. A unit increase in household size increases public transport use significantly by less than one unit.

Personal Automobile (private car) Use

Personal automobiles are flexible and convenient, although more expensive to service than public transport. The inconvenience of public transport use (alluded to by many of the survey respondents) often compels the average resident in Lagos metropolis to purchase an automobile and so switch modes from public transport. Travel cost, household size, informal employment status, age and household income were all significant predictors of personal automobile use (Table L- appendix I).

The model accounts for 22.2 percent of the explained variance in public transport use. A standard deviation change in travel cost leads to a 0.2 unit increase in use of automobiles, while a unit increase in household size also leads to a 0.2 unit increase in automobile use. A unit increase in age decreases automobile use by 0.07 units, while one unit change in household income increases automobile use six-fold. Household income clearly has the highest strength of effect in explaining variance in personal automobile use.

CONCLUSIONS AND POLICY IMPLICATIONS

While travel behaviour varies significantly across household demographic groups and across urban forms, the former (household demographics) provides more explanation of travel behaviour parameters, particularly the modal choice aspect in metropolitan Lagos. Travel cost was equally significant in explaining several dimensions of travel behaviour. Given that data used for residential density was categorical in nature, it is possible that the predictive power of this variable in explaining travel behaviour could be stronger if continuous data relating to actual persons per square km in each area were used.

The conceptual premise that behaviours are in fact formed before the aggregation of households into spatial units seems a plausible explanation for the results obtained in this study- specifically, the fact that significant variations in travel behaviour exist across urban forms, yet urban forms provide minimal explanation of most travel behaviour parameters.

Clearly, public transport is the predominant mode of travel for residents in the Lagos metropolitan area. It is predominant in high density areas as well as among informal sector workers. Given that most African cities have large informal sectors, the implications of these findings for the sustainable use of public transport is relevant across the continent.

Public transport modes in Lagos are fraught with several challenges as noted by respondents. One obvious reason for the inefficiencies observed in its use is the fact that it is mostly of the para-transit type. Organized public transport in the form of Bus Rapid Transit (BRT) was in relatively short supply compared to mini buses (paratransit). The numbers have to change in favour of more sustainable public transport options and this will happen when the Lagos Bus Reform initiative is fully implemented and the BRT infrastructure is extended to the major traffic corridors in the metropolis as contained in the Lagos Strategic Transport Master Plan. In addition, exclusive use of BRT lanes by BRT vehicles must be enforced. The wider relevance of this finding from the Lagos case for other cities is the fact that public transport transcends the provision of vehicles for collective transport. The transport system must be such that prioritizes public transport and ensures reduced trip time using this mode. This organized transport system is the missing fundamental facility in the Lagos area.

Public transport users embark on shorter trips than personal automobile users. We can infer therefore that making public transport more decent and attractive, and incentivizing its use will enable us achieve reduced aggregate distances travelled. An efficient city arrangement is one which minimizes distance travelled, especially for obligatory trips; and minimized travel distances will help ease out traffic congestion. Moreover, public transport as High Occupancy Vehicles (HOVs) utilize less road space per person and so contributes less to traffic congestion situations. The fact that the cost associated with public transport use is much less than that associated with the use of personal automobiles is an economic incentive for modal switch in favour of public transport. However, the challenges of time wasting and lack of flexibility (including truncated trips and mode switching) associated with public transport use demeans whatever cost savings may be associated with it. Public transport users on the average embark on more trips (switching between modes) than private transport users, and this indicates the need for modal integration.

Findings regarding increased trip frequency with increasing age up to a particular cohort and declining trip frequencies at higher ages conform to observations by UNCHS, 1993. Given that private car usage declined with increasing household sizes, and that high-density residents had the highest proportion of households using public transport use, it is clear those larger households and high-density residents have the highest demand for public transport. Consequently, high density areas should be prioritized in the provision of organized public transport services. Origin-destination points for public

transport corridors must target high density areas and informal sector activity areas. The fact that residents in the different density types differ significantly with respect to most of the travel behaviour dimensions shows that residential land use planning might be a proper tool for influencing travel behaviour in Lagos and other such metropolitan areas.

The results show that increase in household income has a strong positive effect on personal automobile use. We expect therefore that as households go higher on the income scale, they will naturally acquire an automobile. No policy can reverse this predictable trend. However, by investing in organized, decent public transport modes, households, may choose to keep their automobiles for non-obligatory and leisure trips. This way, the objective of reduced mobility through car use would have been achieved in Lagos metropolis.

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ABOUT THE AUTHORS:

Taofiki Iyanda Salau, University of Lagos, Lagos, Nigeria

Adebukola Yewande Daramola, Senior Research Fellow, Nigeria Institute of Social and Economic Research, Ibadan, Nigeria

Olufemi Ademola Adeniji, University of Lagos, Lagos, Nigeria

APPENDIX I

Table A: Travel behaviour among age groups

Age group (years)	Mean daily trips (number)	Daily distance travelled (km) Min	Mean	Max	Use of public transport (%)	Use of private car (%)
<25	1.37	1.0	24.2	77.0	90.7	3.6
25-34	1.40	1.0	25.2	83.4	86.9	8.5
35-44	1.60	3.8	26.3	73.6	76.2	14.4
45-54	1.58	1.8	26.1	78.2	79.8	14.7
55-64	1.57	2.9	28.0	56.2	71.4	21.4
>64	1.56	4.7	24.2	50.0	83.3	16.7

Source, Field survey, (2014)

Table B: Travel behaviour between gender types

	Mean daily trips (number)	Mean daily distance	Use of public transport (%)	Use of private car (%)
Male	1.4	25.5	64.5	9
Female	1.5	25.4	71.3	7

Source, Field survey, (2014)

Table C: Travel behaviour among household sizes

Household size	Mean daily trips (number)	Mean daily distance (km)	Use of public transport (% of respondents)	Use of private car (% of respondents)
1-4	1.42	25.1	83.9	11
5-8	1.50	25.7	83.6	9.5
>8	1.50	26.4	82.4	5.9

Source, Field survey, (2014)

Table D: Travel behaviour among income groups

Household monthly income	Mean daily trips	Mean daily distance	Use of public transport (%)	Use of private car (%)
< 20,000	1.37	26.9	96.5	0.9
20,001-40,000	1.48	23.4	88.5	6.4
40,001-60,000	1.38	25.2	87.0	6.2
60,001-80,000	1.55	24.1	84.7	6.3
80,001-100,000	1.47	26.8	57.3	32.0
>100,000	1.51	32.8	54.9	37.8

Source, Field survey, (2014)

Table E: Travel behaviour among employment groups

Employment Status	Mean daily trips (number)	Mean daily distance (km)	Use of public transport (% of respondents)	Use of private transport (% of respondents)
Formal	1.45	26.8	80.5	14.4
Informal	1.55	24.6	83.9	8.5
Retired	1.33	24.2	85.2	14.8
Student/ Apprentice	1.40	24.6	88.5	4.6
Unemployed	1.30	28.8	89.2	1.5

Source: Survey results, (2014)

Table F: ANOVA results for socio-economic factors in travel behaviour.

Socio-economic variables	No of trips		Distance travelled		Frequency of public transport usage		Frequency of private car usage	
	F	Sig	F	Sig	F	Sig	F	Sig
Age	2.887	0.013	0.929	0.461	7.776	*0·000	4.365	*0·001
Household size	1.009	0.366	0.236	0.790	2.855	0.058	14.462	*0·000
Household income	0.658	0.708	4.719	*0·000	8.838	*0·000	22.687	*0·000
Employment status	1.568	0.180	2.905	*0·021	19.155	*0·000	11.537	*0·000

*Significant at 0.05 precision level (Larger F values represent greater dispersion of group means from the overall mean)

Table G: Travel Behaviour Parameters in Residential Density Zones

	Mean daily		% of respondents	
	Distance (km)	Trips (number)	Public transport	Personal auto
High Density	26.5	1.4	93.2	35
Medium Density	24.1	1.5	90.4	33.5
Low Density	22.4	1.3	57.4	68.1

Source: Survey results, (2014)

Table H: Travel behaviour variations among residential density groups

Travel behaviour characteristics	F	Sig
No of trips	0.808	0.446
Distance travelled	4.486	*0·011
Frequency of public transport use	7.819	*0·000
Frequency of Auto use	37.657	*0·000

*Significant at 0.05 precision level

Table I: Determinants of number of trips

n=
ANOVA: F – 3.415; Sig-0.003; Adj R-square=0.024, Coefficient of determination- 2.4%; DW[5]-1.5

Predictors	Unstandardized Coefficients (B)	Standardized coefficients (Beta)	T	Sig
Constant	1.003		6.893	0.000
Travel cost	-2.507E-5	-.027	-.651	.515
Unemployed group	-.135	-.022	-.523	.601
Household size	.020	.040	0.980	.327
Formal employment group	.179	.093	2.248	.025
Age of household head	.105	.105	2.477	.014
Household income	1.522E-6	.060	1.431	.153

[5] Durbin Watson test for auto-correlation. Values between 1.5-2.5 are generally acceptable to indicate no or minimal auto-correlation among predictor variables.

[6]Excluded variable: Informal employment group

Table J: Determinants of distance travelled

n= ANOVA: F – 108.065; Sig-0.000; Adj R-square=0 .220, Coefficient of determination- 22%; DW-1.915				
Predictors	Unstandardized Coefficients (B)	Standardized coefficients (Beta)	T	Sig
Constant	20.711		34.288	.000
Travel cost	.007	0.463	17.643	.000
Medium density residence	-1.440	-.046	-1.732	.084
Low density residence	-6.408	-.052	-1.982	.048

Excluded variable: high density residence

Table k: Determinants of public transport use

n= ANOVA: F – 100.238; Sig-0.000; Adj R-square= 0.523, Coefficient of determination- 52.3%; DW-1.622				
Predictors	Unstandardized Coefficients (B)	Standardized coefficients (Beta)	T	Sig
Constant	1.147		6.376	.000
Travel cost	.000	-.161	-6.173	.000
Unemployed group	-.269	-.024	-.901	.368
Household size	.643	0.712	27.279	.000
Informal employment group	.034	.010	.364	.716
Age of household head	.002	.001	.039	.969
Household income	-3.073E-6	-.064	-2.386	.017
Low density residence	-.310	-.019	-.740	.459
High density residence	.151	.042	1.603	.109

Excluded variables- formal employment group, medium density residence

Table L: Determinants of personal automobile use

n= ANOVA: F – 31.162; Sig-0.000; Adj R-square= 0.222, Coefficient of determination- 22%; DW-1.638				
Predictors	Unstandardized Coefficients (B)	Standardized coefficients (Beta)	T	Sig
Constant	-.065		-.543	.587
Travel cost	.000	.278	7.834	.000
Unemployed group	-.099	-.019	-.541	.588
Household size	.211	.135	3.806	.000
Informal employment group	-.241	-.144	-3.995	.000
Age of household head	-.077	-.091	-2.487	.013
usehold income	6.782E-6	0.307	8.543	.000

Excluded variables- formal employment group