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ORIGINAL RESEARCH PAPER

The socio-demographic determinants of urban household demand for road travel in urban areas

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ABSTRACT

BACKGROUND AND OBJECTIVES: The demand for travel is increasing along with the development of the urban city. Since its establishment in 1890, the same situation has been replicated in Uganda, particularly in Kampala, the capital city. The city has grown tremendously, and this has spilled over to neighboring towns. Road transport carries 99 percent of the traffic in Kampala Capital City, causing massive congestion on city roads. Increased traffic could result from residents of the city or visitors from other parts of the country. Thus, understanding societal travel behaviours of city dwellers is necessary for better planning and policy guidance. This study examines the socio-demographic determinants of urban household demand for road travel in Kampala City.

METHODS: Data from the Kampala Capital City Authority's transport and household travel habits survey were used in this study. A sampling plan developed by the Greater Kampala Metropolitan Area Transport Master Plan Project was followed. Households were drawn from parishes stratified by residential typology using a simple random sampling method. Based on the social economic groupings, a proportional sample of 1906 households was drawn. Data on household characteristics, personal attributes of the household head and travel habits data were obtained. Given the observed over dispersion, a Negative Binomial Regression was estimated.

FINDINGS: The results show that household daily demand for travel increase with the size, age, and education level of the head. Compared to households with 1-3 members, results indicate a significant increase in the difference between the logs of the daily trips taken by 0.329 and 0.587 for households with 4-6 and above 6 members, respectively; the older the household head, the higher the difference between the logs of expected number of trips, compared to households with heads aged 15-24 years, those whose heads are aged 25-34, 35-44, 45-54 and above 54 years, the difference of the logs of the expected number of trips taken increases significantly by 0.0769, 0.149, 0.163 and 0.212 trips, respectively; household heads working in the private sector reduces the difference in the logs of daily travel by 0.0659 trips when compared to the public sector; the more educated the household head, the more trips taken daily. Households with a private car make fewer trips than those without.

CONCLUSION: Sensitization programmes for reducing unnecessary and avoidable travel and family size are required. Uptake of distribution and or redistribution polices for development activities and investments to other urban centers and regions.

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INTRODUCTION

Travel demand rise concurrently with economic development (Coutinho *et al*., 2020; Ignacio, 2019). This has been the case in Uganda, particularly in the Kampala Capital City Authority (KCCA), since its founding in 1890. One of the major causes of traffic congestion has been identified as high demand for travel. Ccongestion is a problem for all large and growing urban areas, not just in developed countries, but also in medium and small cities in developing countries, particularly those with less developed road infrastructure. Cities and road traffic congestion have coexisted since the dawn of large human settlements (Organization for Economic Co-operation and Development (OECD/ ECMT, 2007; Mirzapour *et al.,* 2017). This is because of increased movements caused by increased rural-urban migration and the need for travel (Kampouri *et al*., 2021; *Ortega et al.,* green). Although traffic congestion is caused by an imbalance between supply and demand for road infrastructure, understanding societal travel behaviour is important. In Uganda, Kampala, as the capital city and thus the major business center where most important government ministries' offices are located, has drawn the desire and the need for people to frequently move to the city. Overtime, Kampala has experienced massive congestion on the city roads, which has worsened by extending into late hours in the night and almost every day of the week. Congestion is a negative externality that comes with a number of high economic costs or time losses. Traffic congestion also raises air pollution levels, which is dangerous and goes against the principles of the Green Deal (Sharifi *et al*., 2021; Stilwell, 2021; Beaudoin *et al*., 2015). Congestion has a knock-on effect in that events that cause congestion may also cause other events. According to Alinange (2010) and Kiggundu (2007), the traffic jam in Kampala is caused by the city's structure, which is single-centred and poorly planned, disorganised and outdated, with an expensive transportation system. Despite the congestion, road transport remains the most popular mode of transportation, carrying over 90%of all transit and traffic in the country and 99% of all traffic in Kampala (Azad and Chakraborty, 2021; KCCA), 2011). It transports approximately 95% of the country's goods and 99% of its passengers (Sanya, 2011; O'Donnell *et al*., 2011). Given the importance of Kampala city to the country's economic growth, traffic to the city is expected to increase at a much faster rate. The labor force participation rate in Kampala is increasing at a faster rate than in other cities such as Mbarara in the western region, Mbale in the eastern region and Gulu in the northern region of the country. Nonetheless, all of these urban centres have a high day-time population, which includes people who work in the city but do not live there (UBOS, 2014). According to the Greater Kampala Metropolitan Area study, there are approximately 3 million people who travel to and from the city centre every day. By 2024, the day population is expected to double (KCCA, 2012). As the population grows, so will the number of people who travel to cities. Despite the increased congestion, only 38% of Kampala's total road network is paved, and 89% of gravel roads are in poor condition (KCCA, 2010). KCCA and the Ugandan government have devised traffic management strategies. These include road rehabilitation, the creation of new parks to relieve congestion the city centre's taxi and bus parks, the recruitment of traffic wardens and police at congested intersections, the construction of outer ring roads, the prohibition of street businesses the introduction of buses on major arterials, and the reorganisation of traffic flow on some city roads. The heavy traffic congestion on Kampala roads has drawn the attention of city authorities and the Ugandan government, who have tried and are still trying to find solutions to manage this problem. Despite these efforts, traffic congestion remains severe. Recent studies emphasise the importance of sustainable travel demand management policies in situations of limited road infrastructure supply and for long-term solutions (Lozzi and Monachino, 2021; Sarkar, 2019; Stanford, 2017; Malayath and Verma, 2013). Since good road infrastructure may instead cause congestion, supply side solutions may have short-term advantages. Since congestion is an excess demand for road space, other approaches to managing and/reducing excess demand for road travel are required. Understanding the relationship between societal dynamics and mobility has been identified as critical in achieving sustainable mobility and travel demand management policies (Himanen *et al*. 2005). Studies on congestion have focused on identifying causes and potential solutions without taking into account household

travel demand behaviour and characteristics as an important factor in planning (Troy, 2017; Kaine and Brigden, 2015). This is demonstrated by the supply side solutions offered. Further, increased traffic may result from residents of the city or visitors from geographical locations. Thus, understanding societal travel behaviors of the city dwellers in necessary for better planning and policy guidance. The purpose of this study is to evaluate the socio-demographic determinants of urban household demand for road travel in order to provide a link between societal dynamics and mobility in Kampala City. The specific objectives of this study are: to investigate the social drivers of the level of household urban road travel demand; and to investigate the demographic drivers of the level of household urban road travel demand. The paper is organised as follows: after the introduction in section one, the second section of the paper reviews relevant theoretical and empirical literature. The study's data is discussed in the third section on methods and materials, which includes data sources, descriptive statistics, and multicollinearity and heteroscedasticity tests. Section four presents the estimation method, and section five presents and discusses the results. Section six concludes the paper by discussing some policy implications, areas for further research and limitations of the study

Theoretical and empirical literature

According to the words of Golob, *et al.* (1981); Niedercorn and Bechdolt (1969), the utility theory-travel demand has been the most elaborative and appealing for urban travel demand studies thus far (Winkler, 2015). The former asserts that travel is derived demand while the later considers it to be direct demand. According to Golob *et al.* (1981), an individual chooses a travel option that maximises his/her utility based on the activities to be engaged in, implying that travel is an induced demand rather than a need in and of itself. The consumer is constrained by both money and time, and thus spends money on a variety of consumption goods, including travel and leisure. As a result, the consumer maximises utility (u) subject to the two budget constraints as stated in (Eq. 1). Thus,

$$\max u(x,c,t) \quad s.t \qquad (1)$$

$$p_x x + p_c c \le Y$$

$$t_x x + t + t_c c \le \hat{T}$$

Where,

x is the amount of travel, c is the consumption of non-travel goods and services and t is leisure time. Among the assumptions, u is expected to be monotonically increasing and quasi-concave in the domains of goods and services. Y and T are the money and time budget constraints respectively. p_x and p_c are price indices for travel and general consumption respectively. t_x and t_c are given time per unit distance travelled and time for general consumption respectively. According to this approach, travel is expected to increase as income, available time and speed increases and decrease as costs increase, emphasising that the demand curve for travel is always downward sloping. Of course, this is only true if travel is assumed to be a normal good, but it may not be obvious if travel demand exhibits characteristics of other types of goods. For example, if we consider travel to work, where individuals have no choice but have to travel for work, we can conclude that travel is a necessity. The elasticity of demand for travel to cost of travel may then be positive rather than negative. All of the preceding is consistent with neoclassical theory of consumer behaviour, which ignores the fact that consumption (activities) cannot be fulfilled without incurring travel costs. Travel, on the other hand, can explicitly be treated as a resource-constrained activity subject to both financial and time constraints (Sultan and Khan, 2012). This is consistent with the gravity approach of utility maximisation proposed by Niedercorn and Bechdolt (1969), who contend that demand for travel is direct demand based on the individual trips taken regardless of the desire to fulfil certain activities. Trip planning is viewed as some kind of resource allocation behaviour in which both monetary and travel time budgets act as constraints in deciding how much travel should be consumed (Niedercorn and Bechdolt, 1969). This implies that travel is a need in and of itself and thus is a direct demand. The gravity model of trip distribution is used to estimate travel demand in this. This method is based on origin–destination (O-D) characteristics, with an individual in the

originating zone travelling to a specific destination. This person is assumed to derive a positive amount of utility from repeated trips. The utility derived is constrained by monetary constraints. The cost of a trip, income and distance are all factors to consider when making a decision. Impedance factors include distance and cost. As a results, the total number of trips taken is inversely proportional to the total distance travelled and cost of travel, but positively related to income the traveller's willingness to spend money on travel. Bierlaire (1995) cites gravity model theory derived from Casey Jr's (1955) analogy with Newton's gravitational law. Travel demand is determined by impedance factors such as travel time and/or cost of travel between zones, as well as the number of trips made in both the origin and destination zone, and the socio-economic factors. Impedance factor represents the generalized cost of travel between two zones. The basic component is travel time that represents impedance. Travel can be quantified using aggregate mathematical models such as the gravity model. Adjustments are made in this model using a friction factor. A friction factor fails individuals to make their desired trips which could be the cost of travel (time/money) from one zone to another. This implies that as travel costs rise, the likelihood of traveler's taking trips of the expected length decreases. The number of trips T_{ij} between origin *i* and destination *j* is proportional to the number of people leaving *i* (O_i), to the number of people arriving at j (D_j), and inversely proportional to the square of the (generalized) cost C_{ij} of travelling between zones *i* and *j* as indicated in (Eqs. 2, 3 and 4);

$$T_{ij} = \alpha \frac{O_i D_j}{C_{ij}^2} \tag{2}$$

C_{ij} being the deterrence/impedance factor

Based on the deterrence function $f(C_{ij})$, equation (2) can be used;

$$T_{ij} = \alpha O_i D_j f(C_{ij}) \tag{3}$$

The typical form of a gravity model for travel demand is given as;

$$T_{ij}^p = P_i^p \left[\frac{A_j^p * F(t_{ij}) * K_{ij}}{\sum_{j=zones} A_j^p * F(t_{ij}) * K_{ij}} \right] \tag{4}$$

Where;

T_{ij}^p =Total trips taken from zone *i* to zone *j*

P_i = Total trips taken from zone *i* for purpose *p*

A_j = Total trip destined to zone *j* for purpose *p*

$F(t_{ij}) = \frac{C}{t_{ij}^n}$ = Friction factor, a function of travel cost and travel distance between zone *i* and zone *j*

t_{ij} = Distance between the zone *i* and *j*

K_{ij} = Effects of other variables on travel demand other than travel distance

C = Cost of travel between the zones

n = Number of zones

Regardless of the controversy, both theories measure travel in terms of total distance travelled or the total number of trips taken by the traveller. These are observed over time rather than based on responses to hypothetical questions. For empirical studies, this argument could thus presuppose Samuelson's (1947) concept of revealed preference. According to the two theories, a consumer only chooses a bundle of goods, including travel that maximises the utility based on income, travel cost, and time. The two theories focus on economic factors while ignoring the importance of societal dynamics. Nonetheless, utility maximisation theory is advocated (Becker et al., 2017). In the study of the driving factors of passenger transport, Belzer and Sedo, (2018); De Jong and Van de Riet (2008); Kansky (1967); Doubleday (1977); Goeverden and Hilbers (2001) identify passenger demand parameters in terms of number of trips and trip length or distance among others. Trip volumes and distance travelled are regarded as good indicators of urban dwellers' travel habits (De Bok *et al*., 2021). Findings from a pooled sample Ordinary Least Squares (OLS) and generalised least squares in Limited Dependent (LIMDEP) of unbalanced panel of 22 countries, including developed and developing countries, show that car ownership with a positive elasticity, is one of the significant factors influencing mobility. This implies that car-owning households are more likely to travel than non-car-owning households. Household size, age, and education are all likely to increase travel demand for. However, due to the

socialising effect, age has an ambiguous effect on travel demand in some studies. It is expected to rise with more social activities but to fall with other activities. Furthermore, demand for transportation requires a time investment on the part of the traveller or the provider of transportation services to invest time (Guo *et al.*, 2020; Lindsey *et al.*, 2011). Empirical evidence from Giuliano and Dargay's (2006) study of car ownership, travel and land use compared the United States and Great Britain by modelling daily travel conditional upon car ownership. Using a pooled sample for both countries, a model excluding car ownership was estimated, and results revealed that demographic factors and car ownership were the most significant factors influencing travel demand. Travel is regarded as a positive function of employment, with females travelling more than males. It does, however, decrease with age, implying that older people travel less than younger people. Travel also decreases as the number of adults in a household increases. This study, however, ignores the employment sectors. However, while emphasising the important determinants of travel, Litman (2021) contends that the majority of these factors do not work in unison. Demographic factors, for example, may influence the mode of transportation chosen and thus the frequency of travel, whereas automobile travel may also be a supplement to vehicle parking and a substitute for transit travel. The majority of studies discussed above were conducted in the developed world, with a few exceptions from Latin America, South and East Asia. A few African studies have also emphasised the importance of socio-demographic factors in analysing travel behaviour. There may be some socio-demographic factors influencing household urban travel in developed countries that do not affect travel in developing countries' urban centres. Similarly, the magnitude and direction of these influences may differ, rendering the existing studies inconclusive. A study on urban travel in Ogun State, Nigeria, using a multiple regression model discovered that social factors, particularly trip generation by households have a significant influence on intra-urban travel (Olayiwola, 2014). It should be noted, however, that the influence varies between urban centres based on their level of development. Some factors are more pronounced in some urban areas than others. However, in the same model, this study examines travel as a function of mode choice and car ownership. Such estimates are vulnerable to endogeneity, which has a significant impact on model robustness, particularly when multiple regression is used. The current study have been carried out in Kampala, Uganda's capital city in 2021.

MATERIALS AND METHODS

Study area and data source

This study makes use of secondary data from the KCCA transport and household travel habits survey. A sampling plan of 3000 households based on zonal system created by the Greater Kampala Metropolitan Area (GKMA) Transport Master Plan Project was used from a population of 418,787 households in Kampala city. Three super-zones were defined from the 22 identified super zones, and seven major corridors were and several representative transportation zones were chosen for the super-zones. The zones and corridors selected were all in Kampala. Households were drawn at random from parishes stratified by residential typology, and these were further sub-divided into three socioeconomic groups based primarily on education levels as proxies. However, because half of the population is low-income and tends to exhibit similar travel behavior, the sampling rate for this category was considerably reduced, and only 1906 households were sampled. Data on socio-demographic characteristics as well as travel habits data were obtained. The information gathered included household and personal characteristics as well as daily trips made by each household member. To reduce data errors and ensure data quality, the Global Positioning System (GPS) was used where each household head was receiving a GPS logger for 24 hours. Every three seconds, the coordinates of each individual were collected. The GPS trip data was compared to reported trips to allow for any necessary correction. Fig. 1 shows the map of Uganda including the location of the study area of Kampala city and other major urban centres. Kampala city is located 0 19 N, 32 33 E.

Description of study variables

Dependent variable

Trip Volume

The daily household trip volume is used as a

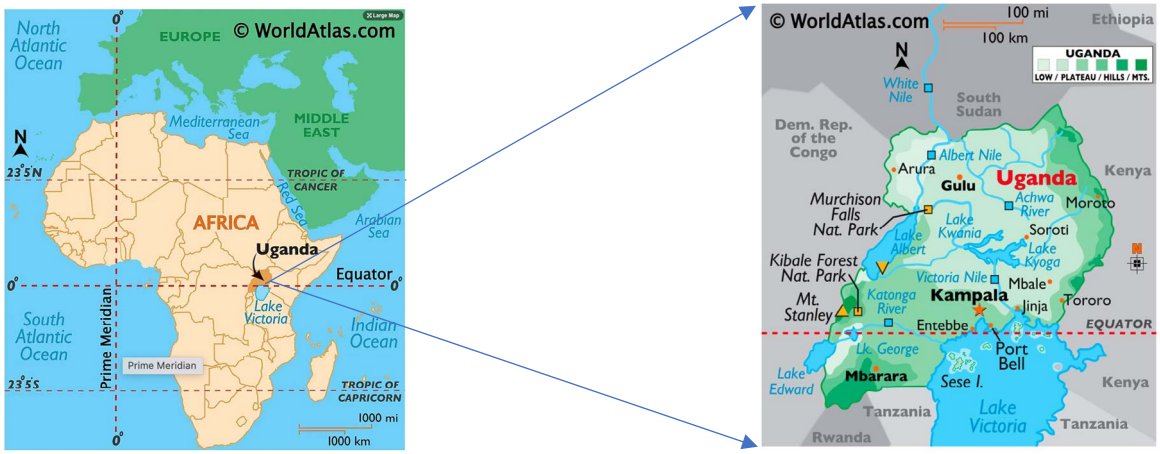

Fig. 1: Geographical location of study area (a) Uganda (b) Kampala City

proxy for urban road travel demand. According to both theoretical and empirical literature, travel demand can be estimated in terms of trip volumes taken by an individual or household over a given time period. It is a discrete count variable. The average daily number of trips taken by a household is taken into account in this study. Since the average daily trips taken by individuals in a household are obtained in the questionnaire, the average daily trip volume for a household is calculated by summing the average number of trips taken by all members on a daily basis.

Independent Variables

Household Size (hhsize)

Household size is an important factor to consider when estimating urban travel demand. The size of the household is related to the amount of travel that a household makes each day. According to UBOS (2012); UBOS and ICF (2018), household size in Uganda refers to the number of usual members in a household, with usual members defined as those who have lived in the household for at least 6 months in the previous 12 months, including persons who may have spent less than 6 months in the previous 12 months but have joined the household with the intention of living there permanently or for an extended period of time. Since it is a discrete variable, it is first used in its original form before being classified into three groups. The categories are; 1-3, 4-6 and above 6, with 1-3 members serving as the base category. The three categories reflect households with few members, which is less than the average urban household size, within the average range and above the average size, implying larger households respectively.

Vehicle/Car Ownership

Vehicle ownership must be considered when estimating urban travel demand. Vehicle ownership in this study refers to private car ownership for personal use. Private car ownership is associated with household's daily amount of travel. It is defined as 0 for households that do not own a private vehicle and 1 for those that own a personal vehicle.

Age

Another important factor in determining urban travel demand is age. Since the unit of analysis is a household, such individual characteristics are taken into account for the household head. As a result, in this study, the age of the household head is used. This variable is used in its original form before being categorized into five groups. The age groups are as follows: 15-24, 25-34, 35-44, and 45-54 and above 54. The age group 15-24 years old is the base category. These categories distinguish teenagers, youths, adult youths and those nearing retirement as pensioners and retirees.

Gender

Gender is another important factor to consider when estimating urban travel demand. The gender of the household head is related to the amount of

travel taken by that household the daily basis. This variable is used in its original form, with values 0 for female and 1 for male. Female = 0 is used as a base category. Therefore, the terms female-headed and male-headed households are used in the discussion of results.

Education Level

Another factor to consider when estimating urban travel demand is education level. The education level of the household head is used in the same way that age and gender are. The education level of the household head is related to the amount of travel taken by that household on a daily basis. There are four levels to this variable; no education, primary, secondary and tertiary education levels. Post-secondary education is referred to as tertiary education

Employment Sector

This is another important factor when estimating urban travel demand. The employment sector of the household head is used the same way that age, gender and education level are used. The employment sector of the household head is related to the amount of travel that a household takes on a daily basis. This variable is categorized into three sectors; public, private, and other sectors. The private sector includes the formal and informal sector while others include manufacturing, building and construction, transportation, agriculture, unemployed/job seeking, domestic service, pensioners and those not in labor force.

Model Specification

The estimation of travel demand is adopted from Golob *et al.* (1981), but with a focus on household socio-demographic variables as proposed by Giuliano and Dargay (2006), Souche (2010); Litman (2021). The model takes into account household size (*hhsize*), car ownership (*vown*), age, gender, education level (*edlevel*) and employment sector (*esect*). Borrowing from Niedercorn and Bechdolt (1969), and focusing on household socio-demographic factors, travel demand (dt_i) is therefore given as (Eq. 5).

$$d_t = \beta_0 + \beta_1 hhsize_i + \beta_2 vown_i + \beta_3 age_i + \beta_4 gender_i + \beta_5 edlevel_i + \beta_6 esect_i + e_i \quad (5)$$

Where, $\beta_1, \beta_2 > 0; \beta_3, \beta_4, \beta_5, \beta_6 >< 0$ as derived from literature.

e_i = error term

Where,

hhsize is household size, *vown* is private vehicle/ car ownership, *edlevel* is the level of education, and *esect* is employment sector.

Method of estimation

Urban demand for travel can be measured in terms of the number of trips taken (Giuliano and Dargay (2006); Bacon (1995); Gordon and Richardson (2000); and Anas, (2007).This study takes into account the average number of trips made by a household level. The main methodological issue with using cross-sectional data in this study is that of unobserved heterogeneity which is best solved with longitudinal studies. However, the only available data set is cross sectional. As a result, just as in developed countries, it may be difficult to capture the complex inter-relationships among factors in our urban systems in order to allow detailed and sophisticated analyses of the urban phenomenon. This is one of the limitations of estimating demand models in developing countries. A Negative Binomial Regression (NBR) is estimated using the average number of trips as a measure of a household's daily travel demand.

Negative Binomial Regression (NBR)

Although the Poisson model is commonly used in estimations involving count data, the NBR is preferred in this study due to the observed over dispersion. The number of trips taken is the dependent variable which is a count variable with a variance of 15.21 and the mean of 9.7. The variance is 57% greater than the mean, indicating over dispersion and justifies the use of the NBR. In order to estimate the NBR model, the maximum likelihood approach. The superiority of the NBR over other estimation methods for count data stems from its disturbance term composition and ability to account for over dispersion. To avoid biased standard error, the assumptions of conditional normality, homoscedasticity of the errors and independence must be met. One problem with count data is conditional normality and homoscedasticity of the error term can be difficult to achieve. This is due to the fact that such data frequently exhibits increasing

conditional variance with increasing predictor value and has positively skewed distributions (Gardner *et al*., 1995; and Long, 1997). This could affect the convergence of the model being estimated. However, after 9 iterations the estimated NBR model converged. Furthermore, the NBR was chosen over a Poisson regression because the Poisson regression model does not account for individual heterogeneity (Coxe *et al*., 2009). The Poisson distribution is based on assumption that the conditional mean and conditional variance are the same. The Negative binomial, on the other accounts for over dispersion by assuming the existence of unexplained variability among individuals with the same predicted value. This may result in larger variation but has no effect on the mean (Hilbe, 2011 and 2007; Neisiani *et al.,* 2016; Coxe *et al.,* 2009; Greene, 2006; Long, 1997; Land *et al.,* 1996; Gardner *et al.,* 1995). Greene (2006); Hilbe (2011); Zwilling (2013) advocate for use of the log-likelihood NBR function.

RESULTS AND DISCUSSION

Descriptive and summary statistics

The primary purpose of travel in Kampala has been categorized into three categories. The purpose for the household head's first trip taken on a daily basis is captured in this case as per Table 1.

Approximately 81% of the first journey made by the household head is for the primary purpose of going to work, while 14% are for social services such as education, shopping, health and sports, only 5% are for the primary purpose of returning home. This finding may imply that some people work at night since their first trip of the day is to get going home. However, it also suggests that the majority of travels to Kampala city are primarily for work purposes. Since the cost of living is expected to be higher in terms of housing and food, as one moves closer to the city center, larger households that require more space and food are expected to stay farther from the city center. However, the situation in Kampala is quite different as shown in Table 2.

Larger households prefer to live closer to the city center. Fewer and larger households stay far from the city center. Among these households, 28% own private vehicles for personal use. Approximately 49% household heads have a tertiary education, 37% have a secondary education, 12% have a primary education and 2% have no education. This is not surprising given that household heads in Kampala have a literacy rate of more than 90%. Approximately 59% of the respondents work in the private sector employment, with 40% in formal employment and 19% informal employment. Approximately 21% of those in the private sector have a tertiary education while 16% have a secondary education. In the private informal sector, approximately 10% have a secondary education and 6% have a primary education. Only 19% work in public sector, with approximately 16% having a tertiary education. The average household size is approximately 4 people, which is the same as the national average for urban areas (UBOS and ICF, 2018). The largest household can accommodate up to 15 people. A household's

Table 1: Distribution of the primary purpose of travel

Purpose of travel	Frequency	Percent	Cumulative Frequency
Work	1,545	81	81
Social	260	14	95
Home	101	5	100
Total	1,906	100	

Table 2: Distribution of Household Size by Proximity to the City Centre

Proximity to Kampala city center	Grouped household size (number of people)				
(Kilometers)	1 - 3'	4 -6'	7 - 9'	Above 9	Total
0.00-3.0km	134	219	25	7	385
3.01-6.0km	311	492	72	8	883
6.01-9.0km	148	261	32	3	444
Above 9.0km	73	113	7	1	194
Total	666	1,085	136	19	1,906

Table 3: Summary Statistics of the Selected Variables (in levels)

Variable	Mean	Standard deviation	Minimum	Maximum	Skewness	Kurtosis
Average daily trips taken	9.7	3.9	2	32	0.87	4.28
Age	38	11.2	19	90	0.97	3.97
Household size	4.2	1.6	1	15	1.09	5.76

average number of daily trips is approximately 10. The average age of respondents is 38 years, with the youngest and oldest being 19 and 90 years old as shown by Table 3:

Multicollinearity and Heteroscedasticity Tests

Survey data is notorious for having collinearity and non-constant variance of the error term, so testing for the two is essential. If collinearity is high and the error term exhibits heteroscedasticity, this must be corrected prior to model estimation to improve the model's robustness. In order to identify such variables, the Collin test that provided a Variance Inflation Factor (VIF) as well as the tolerance level and other tests is used (Ender, 2010). The rule of thumb is that any individual variable with a VIF greater than 10 should be checked (Wang *et al*., 2019; Tridico and Paternesi, 2018; Marquardt, 1970). Similarly, when all variables are combined, an average VIF greater than 5 indicates that the variables may exhibit collinearity in the error term. Therefore, the use of groupings and or other models other than the Ordinary Least Squares (OLS) may be recommended. Continuous variables exhibited multicollinearity in their original form and where thus log transformed. The average VIF was 1.62 with no individual covariate having a VIF of greater than 10. This implies that if continuous variables are log-transformed before being used in model estimation, there is no significant multicollinearity in the error term. Tolerance was greater than 0.1 for all the covariates, indicating non-collinearity. As a result of these findings, each covariate is regarded as a non-linear combination of other independent variables in the model. Therefore, the estimated empirical model does not exhibit significant multicollinearity. Following preliminary estimation of the variables in their original form, additional tests show that heteroscedasticity of the error term exists, as indicated by the Breusch-Pagan test, which yields the Prob > chi2=0.000. As a result of these findings, the null hypothesis that the error term is homoscedastic is rejected. Logarithmic transformation of the continuous covariates is expected to reduce this risk in order to solve the heteroscedasticity problem (Greene, 2006; Maddala, 2008). Thus, the natural logarithm of all continuous variables is used to transform them. In addition, a robust model was estimated using the NBR regression to ensure that the standard errors from the estimated models are consistent with the heteroscedasticity assumption.

Model estimation and discussion of findings

An assessment of the individual influence of socio-demographic factors on travel demand was performed during the estimation process. Individual characteristics of the household head are used where individual characteristics are important because the household head is considered to be the decision maker for the entire household. The McFadden Pseudo R-square (0.063 and 0.054, in Tables 4 and 5 respectively) with a significant probability of the Chi2 (Prob>Chi2=0.000) indicate a good fit for the Negative binomial regression. According to the NBR estimations shown in Table 4, household size, vehicle ownership, education level, and age and employment sector of the household head all play a significant role in the variations in daily travel demand for households in Kampala. These factors affect the frequency with which people travel to the city center on the daily basis.

Socio-demographic factors

According to the estimates in Table 4, almost all the social factors, with the exception of gender, have a significant effect on household travel demand. While household size, age, and level of education have a positive effect on travel demand, car ownership and employment sector have a negative effect on travel demand. Notably, households travel more as their heads grow older, and those who own cars take fewer trips than those who do not own cars, people with education attainment travel more than those who have no education, those employed

Table 4: Results for the Negative Binomial Regression.

Variable	Coefficients -
Household size	0.112***
	(0.006)
Age	0.003***
	(0.001)
Gender	0.010
	(0.022)
Vehicle ownership	-0.056***
	(0.018)
Education level	Base = No education
Primary	0.112**
	(0.052)
Secondary	0.116**
	(0.050)
Tertiary	0.116**
	(0.049)
Employment sector	Base = Public sector
Private	-0.047**
	(0.023)
Others	-0.054**
	(0.025)
Constant	1.575***
	(0.063)
lnalpha	-4.675***
	(0.374)
N	1906
pseudo R^2	0.063
Walds Chi2(3;9;12)	613.45
Prob > Chi2	0.000

*Standard errors are in parentheses; * p < 0.10, ** p < 0.05, *** p < 0.01; Dependent Variable is the household average daily number of trips taken.*

in the private and other sectors take fewer trips than those employed in the public sector. Table 4 shows that, household size has a significant positive effect on travel demand. This means that adding a member to a household increases the difference in the logs of the expected household daily demand for travel by 0.112 trips at 1% level of significance holding other covariates constant. While holding other covariates constant, the age of the household head significantly increase the difference of the logs of the expected household daily demand for travel by 0.001 trips at 1% level of significance. Furthermore, vehicle ownership by a household reduces the difference of the logs of the expected household daily demand for travel by 0.056 trips at 1% level of significance, holding other covariates constant. Holding other covariates constant, households whose heads have completed primary, secondary and tertiary education have a significant increase in the difference of the logs of the expected household daily demand for travel by 0.112, 0.116 and 0.116 trips, respectively, at 5% level of significance. Holding other covariates constant, households with heads employed in the private and other sectors of the economy, experience a significant decrease in the difference of the logs of the expected household daily demand for travel by 0.047 and 0.054 trips respectively at 5% level of significance. The results in Table 4 are supported by those in Table 5 which group household size and age.

Table 5 shows that, when compared to households with 1-3 members, there is a significant increase in the difference of the logs of the expected household daily demand for travel by 0.329 and 0.587 for the household size of 4-6 and above 6 members respectively at 1% level of significance, holding other covariates constant. Thus, the greater the number of people in a household, the greater the number of daily trips taken, as well as the rate of change. Given the urban nature of a typical African

Table 5: Negative binomial regression results of travel demand using trip volume as a measure with categorized household size and age of the household head

Variables	Coefficients
Household size	Base = 1 - 3
4 - 6	0.329***
	(0.018)
Above 6	0.587***
	(0.065)
Age (in years)	Base = 15 - 24years
25 - 34	0.0769**
	(0.033)
35 - 44	0.149***
	(0.035)
45 - 54	0.163***
	(0.037)
Above 54	0.212***
	(0.042)
Gender	0.021
	(0.022)
Car ownership	-0.0580***
	(0.018)
Education level	Base = No education
Primary	0.111**
	(0.050)
Secondary	0.111**
	(0.048)
Tertiary	0.102**
	(0.048)
Employment sector	Base = Public
Private	-0.0659***
	(0.0229)
Others	-0.060**
	(0.026)
Constant	1.960***
	(0.058)
lnalpha	-4.313***
	(0.281)
N	1906
pseudo R^2	0.054

*Standard errors are in parentheses; * p < 0.10, ** p < 0.05, *** p < 0.01; Dependent Variable is the household average daily number of trips taken.*

society, where an average household is expected to have a spouse, a child and a household helper, travel demand is likely to increase particularly if the household has school-aged children and both spouses are employed. Regardless of car ownership, even if all members of a household use the same mode of transportation, the number of travels will still be higher with the exception of cases where they all travel to the same destination. The age of the household head is another significant factor identified as having a significant positive effect on household daily demand for travel in Kampala, which is consistent with the findings by Belzer and Sedo, (2018), Metz (2011, 2012) but differs from the findings of Giuliano and Dargay, (2006), who found that household demand for travel decreases with aging populations. Holding other covariates constant, the result implies that the older the household head, the greater the difference in the logs of the expected household daily demand for travel, with an increase of 0.003 trips. Thus, the number of daily trips taken by a household increases with the age of the household head. This result is supported by the estimates in Table 5 which categorizes age. Table 5

shows that households with older heads take more trips than those with younger heads. Compared to households whose heads are 15-24 years old, those with older heads who are in the age groups of 25-34, 35-44, 45-54 and above 54 years, see a significant increase in the expected household daily demand for travel of 0.077, 0.149, 0.163 and 0.212, respectively. These findings are significant at 1 percent level of significance for all age groups except for age group 25-34 that is significant at 5%. To affirm the results, descriptive statistics, show that the majority of the household heads are between the ages of 25 and 54. In a typical African setting, these are expected to work and have families resulting into increased household demand for urban travel. The household head's employment sector has a significant impact on the volume of trips taken by the household. Households with heads who work in the private and other sectors travel less than those in the public sector. The results in Table 5 show that working in the private sector reduces the difference in the logs of travel by 0.066 trips per household as compared to working in the public sector, holding other covariates constant. When compared to working in the public sector, working in other employment sectors reduces the difference in the logs of travel by 0.060 per day. Manufacturing, building and construction, transportation, agriculture, domestic, voluntary employees, as well as job seekers and students, all fall under the purview of the private sector. Households with heads who work in the public sector may have more commuter travels because government workers are required to report to work and are mostly salaried, whereas those in the private sector and other sectors may not be required to report to work. According to findings in Tables 4 and 5, the gender of the household head has an insignificant influence on household travel demand. The results contrast with those of Giuliano and Dargay, (2006), who found that females travel more than males. Even when comparing male headed to female headed households in Kampala, gender is an insignificant factor. The findings also show that household size has a significant effect on urban travel demand. This is intuitively true because having more people in a household means more trips. This implies that the number of people in a given household increases the demand for travel. Car ownership reduces the number of trips taken, implying car owners take fewer trips. These findings contradict those of Sharifi *et al*., (2021); Olayiwola (2014); Souche (2010); Metz (2011, 2012) who found a positive relationship between car ownership and household travel demand. Other factors such as high fuel costs may make it difficult for car owners to drive frequently. The majority of them drive, park and use other modes of transportation to get around the city. They are also more likely to own houses. Most car owners in Uganda have average income and may live further away from the city center because land ownership closer to the city center may be difficult for such earners. These people usually buy land on the outskirts of the town. The level of Education has a significant positive effect on trip volume. This means that highly educated people take more trips than the less educated. Such a situation may arise when highly educated people are employed or looking for work and must commute as a result. Some choose to live closer to the city center so that they can commute more often as needed. Therefore, using the Negative Binomial regression a log-likelihood model, fits well data with over-dispersion.

CONCLUSION

Estimated NBR results confirm the influence of household socio-demographic factors on urban households travel demand. Trip volumes rise in direct proportion to household size, age, and education level of the household head. However, the daily number of trips taken by households in Kampala City decreases with car ownership, as does the number of trips taken by household whose heads work in the private sector and other sectors of the economy, as opposed to those employed in the public sector. The findings are consistent with theory and empirical literature, implying that they should be heavily emphasized in policy making. Finally, the majority of the obtained coefficients have economically and intuitively correct signs.

Policy implications

The study findings are informative of households' travel behaviors in Kampala City and should thus guide policy in regulating the frequency of urban travel. Sensitization programmes aimed at reducing unnecessary and avoidable travels are required. This should be combined with planning for future

urban travel demand. Given that 60% of Uganda's population is young, the significant positive effect of household size and age of household head implies that future demand for travel is bound to grow at a much faster rate, particularly in Kampala. Household size can be reduced through population reduction policies. The findings also show that households with heads employed in the private and other sectors travel less than those employed in the public sector, implying that policymakers must distribute and/or redistribute government development activities and private investments to other urban centres and regions in order to reduce rural-urban migration towards Kampala city and thus divert traffic to other urban centres. The significance of the socio-demographic determinants on households' demand for road travel suggest that travel demand theories should not neglect this influence and thus incorporate them in theory development.

Limitations of the study and areas for further research

The main limitation in this study is the cross sectional set, which makes it impossible to trace the consistency in the travel behaviour of urban households. Nonetheless, a household's daily number of trips was provided and used in the study. Further, detailed information about the purpose of all these trips was lacking. Travel demand is derived demand, and thus trip purpose would provide a better understanding behavior of Kampala city residents' travel behaviour for better policy guidance. Given how travel demand is derived, a study that focuses on purpose of travel would improve the understanding of the travel behaviour of households in Kampala city. Further, a panel data research approach would also reveal the consistency in urban households' travel behaviour

AUTHOR CONTRIBUTIONS

S. Watundu conducted the literature review, collected data, analyzed and interpreted data, prepared and edited the manuscript and is the corresponding author. B. Kalinda Mkenda was the supervisor, reviewed literature, interpreted the data, prepared the manuscript and edited the manuscript. N. Mwelu was involved in data collection, preparing the manuscript and edited the manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

ABBREVIATIONS (NOMENCLATURE)

AERC	African Economic Research Consortium
ECMT	European Conference of Ministers of Transport

GKMA	Greater Kampala Metropolitan Area
ICF	Inner City Fund
KCCA	Kampala Capital City Authority
NBR	Negative Binomial Regression
OLS	Ordinary Least Squares
OECD	Organization for Economic Co-operation and Development
UBOS	Uganda Bureau of Statistics

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