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Trip Generation Modelling in Varying Residential Density Zones an Empirical Analysis for Akure, Nigeria

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Abstract: This study reports on the development of predictive trip rate models for three residential density zones in Akure town in Nigeria. The systematic sampling technique was used in selecting respondents from each of these zones and altogether, 2000 commuters were selected for the study. The responses that were collected from the respondents were subjected to statistical analysis and the variables that significantly influenced trip making in each of the residential density zones were identified using a stepwise regression technique. Predictive trip rate models were then developed for each of the residential density zones in Akure town. The study noted, among other things, that the mean trip rate values were not the same in the three residential density zones in Akure town. This observation was subjected to a statistical analysis and it was, however, found that the observed differential in trip rate values was not statistically significant. The study therefore posits that residential density types in Akure town do not significantly influence trip generation rates.

Key words: Trip, generation, modelling, residential, density, Akure, Nigeria

INTRODUCTION

Urban trip generation modeling usually involves an analysis of all the major typologies of trips in the urban transport system. The urban trip typology includes journey to work, journey to school, journey to recreational or social areas and shopping trips, among others. The journey to work (commuting) is probably the most important type of passenger transportation in cities. The journey to work accounts for a plurality of trips made in cities as workers travel from home to employment places and vice versa. The pattern of commuting trips is usually regular in time and space. Most workers commute on a fixed scheduled over a specific route, travel at the same time each workday and use the same roads or public transit lines[1,2].

The journey to shop, the second most frequent type of urban travel, varies in importance from season to season and from day to day during the week. The trip to shop is, on the average, shorter than trips to work[3]. Social and recreational trips are especially difficult to anticipate, but they usually have peak demand periods when demand for commuter travel is low e.g., on weekends, holidays and in the late evenings. Pupils and students in secondary and post secondary institutions mostly undertake the journey to school. The journey to school forms an important component of the pattern of urban spatial interaction. Urban spatial interaction is usually analyzed using the aggregate or disaggregate models. Aggregate models of trip generation are based on groupings of people and they are useful in predicting trip volumes e.g., the destination-constrained, entropy-maximized gravity models. Disaggregate models on the other hand are used in predicting the travel behaviour of individual commuters in the urban transport system. Disaggregate models are usually analyzed using such analytical techniques as category or cross-classification analysis and the multiple linear regression model.

Trip generation models are, therefore, a set of mathematical equations and processes that collectively relate travel patterns to landuse, residential density, socio-economic characteristics, demographic characteristics and other parameters of the transport system[3]. In the urban transport system, trip generation modeling involves two major approaches namely, an examination of some of the determinants of the propensity to generate trips at the household, individual or firm level, and also the capacity of the various land uses to generate and attract trips[4].

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The household level of trip generation is related to certain internal characteristics of the household. These characteristics include such variables as household income, the number of persons per household, the number of workers per household, the number of cars owned by each household and so on. The relationship between the household level of trip making and the socio-economic variables that influence trip making could be described by a multiple-variable linear equation[5,6].

Urban trip generation: The intensity of trip-generation in the urban transport system either at the household or individual level has been found to be a function of various socio-economic parameters such as household size, car ownership, income etc[7-9]. To accommodate more travel behaviour factors[10], employed the socio-demographic characteristics of the individual. According to them, social status is better measured by occupation, education and income, while social roles are determined by age, sex, marital status, socio-economic status and stage in the family life cycles.

Researchers at various times and over the years have identified some of the salient variables that influence urban trip generation. For example,[11,12] reported that people with higher occupational status make more automobile trips, less public transport trips and few non-motorized trips. In another study, found that household income and level of education had some relationship with specific aspects of travel. It has also been discovered that people with higher incomes make more vehicular trips, undertake more social trips, travel greater distances and visit more shopping areas in a weekday[12-14].

Studies have also revealed that residential density has a positive effect on the trip rate of households[15,11,16,17] used information from Reading to demonstrate the effect of residential location on the households' trip rates. The average weekday trip per household showed some sequential area variation. For example, the lowest household trip rates were obtained with respect to the inner sub-area (5.86 trips) while the middle sub-area had 6.57 trips and the outer suburb had 7.32 trips. Fawcett and Downes[18] showed further that when household size and car ownership variables are disaggregated for trip purposes and mode of travel, household location generally has little effect on trip rates in Reading. It was then concluded that the number of trips made by households is not influenced by the closeness of that household to areas of employment, shopping centres among other areas of weekday activities.

Studies on trip generation characteristics in contrasting residential locations and income groups in the developed countries are legion[2,10,17,19,20]. However, in the developing countries in general, and in Nigeria in particular such studies are scanty[4,6,21]. Ayeni[4] for example, studied the pattern of trip distribution in Jos and observed that the frequency of trips per week was a function of income. He noted that people in the low-income group generated an average of 17 trips per week, the middle income group 23 trips per week while the upper income group generated an average of 24 trips per week. He observed further that different households had different trip-generating capacities e.g., households headed by spinsters or bachelors generated only 16 trips per week while those headed by married people generated as many as 36 trips per week.

Ogunjumo[6] conducted a research in Ile-Ife, Nigeria, on the pattern of trip generation and discovered that there was a high level of correlation between the dependent variable (trip) and three independent variables namely household size, workers per household and the number of vehicles per household. He further observed that travel time, travel distance and education had negative signs in the regression model indicating that there was a decrease in the number of trips with a unit increase in the value of the variables.

Fadare[21,22] studied the travel behaviour of commuters in different residential density zones in Ibadan town. For example, Fadare[21] analyzed the factors that affected household trip generation in the residential areas of Ibadan. He discovered that household size, followed by the employed members of the family, car ownership and lastly income, were the significant variables, which sequentially explained the trip rates by the various trip types in the study area. He also discovered that there were different trip rates for the various trip purposes in the different housing density types.

Fadare and Hay[23] assessed the influence of housing densities and life styles of commuters on the frequency of intra-urban trips in Ibadan. He noticed marked differences between the three density zones and it was also noted that trip rates per head per day by purpose of travel vary significantly in the different residential density areas in Ibadan city. Fadare[22] also investigated urban sprawl and trip length characteristics in Ibadan and affirmed that trip lengths for some specific purposes of travel in the residential areas differ to some extent. For example, the low-density areas had longer distance trips than other density areas and work trip lengths were found to be longer in the high-density areas, followed by the medium and the low-density areas.

Aloba[24] observed that commuters in households with personal and functioning vehicles find it much easier to generate trips than those depending on foot, friends' cars, or urban transport. He further identified other factors that could affect trip generation as age, gender, income, education and occupational status. According to him, each of these demographic and socio-economic characteristics imposes some constraints or limitations on the volume of urban traffic. Aloba (op cit.) also noted that the pattern of trip generation at various hours of the day sometimes exhibits varying demographic and socio-economic characteristics. For instance, while the movement pattern in the early hours of the day and later in the afternoon usually show children and urban workers going to or returning from school and places of work, the pattern of movement in the evenings is largely composed of the elderly visiting recreational grounds, friends and relations. He, however, observed that most of these latter types of urban trips might be undertaken on weekends rather than weekdays.

This study reports the analysis of the factors that influence the propensity of commuters in the various residential density zones in Akure to generate all-purpose trips per week. All-purpose trips are the totality of all the identified trip-types generated by a commuter within a stated time period in each of the three residential density types in Akure town. These residential density types are: the high density; medium density; and low density. The factors that influence trip rates were identified using the stepwise regression analytical technique. The trip rate predictive models were developed using the multi-variable regression model. This model is usually abridged to take the form:

$$Y = a + \sum_{i=1}^{n} bixi + error \quad (1)$$

Where: Y = the criterion variable; a = the intercept value on the regression hyper plane; bi-bn = partial regression coefficients, xi-xn = predictor variables

MATERIALS AND METHODS

The study area for this research is Akure, the capital city of Ondo State in Nigeria. According to the 1991 National census, the population of Akure was given as 239,124. Akure is unarguably the most populous town in Ondo State. A transportation planning research work of this nature cannot possibly trace the travel pattern of every individual residing within the town. Consequently the pattern of trip making was determined by dividing the town into smaller travel analysis zones. Akure town was therefore divided into twenty traffic zones for the purpose of this study. Out of the 20 zones, 8 zones were in the low residential density zone, 7 in the medium residential density zone and 5 in the high residential density zone.

The twenty traffic zones are listed below:

(a) Low residential density zone (0-50 persons per hectare) .

- Ilesha road/Alaba layout traffic zone
- Okuta Elerinla traffic zone
- Akure High School traffic zone
- Ijapo Estate traffic zone
- Alagbaka Estate traffic zone
- Ala River traffic zone
- Federal Estate trafficzone
- Oba-Ile traffic zone

(b) Medium residential density zone (51-150 persons per hectare).

- Fanibi layout traffic zone
- Okegan/Eruoba traffic zone
- Oke-Aro/Oke-Aro Tutun zone
- Ayedun Quarters traffic zone
- Isikan/Ondo road traffic zone
- Oshinle Quarters traffic zone
- Ijoka/Sijuwade traffic zone

(C) High residential density zone (over 151 persons per hectare).

- Araromi/Isolo traffic zone
- Oke-Ijebu traffic zone.
- Idiagba/Ijemikin traffic zone
- Erekesan/Erekefa traffic zone
- Ijomu/Ilisa traffic zone

Systematic sampling technique was used in selecting respondents in the study area. In each traffic analysis zone, every 5th house along a street was selected for interview starting from the first dwelling. In each of the selected houses, only one household was interviewed AND the actual respondent in each case was the household head. One hundred respondents were equally but disproportionately chosen from each of the 20 traffic zones into which Akure town was divided. The approach was necessitated by the non-availability of broken down population figures for each of the traffic zones. One hundred respondents from each of the twenty traffic zones gave a sampling frame of 2000 cases.

A total of eleven significant predictor variables were employed in the analysis. The dependent variable in the model was the all-purpose trips per commuter per week. The all-purpose trip was an embodiment of all the typologies of trips embarked upon by the commuters covered in the survey. The eleven-predictor variables are:

- Educational background of respondents (Educas)
- Household size of commuters (Houses)

- Shifting in work place (Shifts)
- Residential density type (Resden)
- Distance from home to work place (Distan)
- Number of cars in the family of the commuter (Numcar)
- Travel time from home to work place (Tratim)
- Mode of travel to work (Tramod)
- Income of commuters (Income)
- Annual rent of commuters (Anrent)
- Departure time from home to work (Depart).

RESULTS AND DISCUSSION

Out of the eleven predictor variables that were fed into the model, only six had significant influences on trip generation in the low-density zones in Akure. These significant variables are: Shifts; Houses; Distan; Numcar; Tratim and Tramod. The criterion variable (Y) in the model is the All-Purpose Trip (ALLTRIP). A trip rate predictive model was developed for this zone using these significant variables. The model is given as:

$$Y = 2.546 + 0.190\ (\text{Tratim}) + 1.640\ (\text{Tramod}) + 1.405\ (\text{Numcar}) + 0.166\ (\text{Houses}) - 0.342\ (\text{Distan}) - 0.738\ (\text{Shifts}) \quad (2)$$

The model in Eq. 2 was developed using the partial regression coefficients of the significant variables and the slope intercept value on the regression hyperplane. Highlights of the model is that a change in the mode of transport from a public mode to a private mode will increase the trip rate of a commuter by 1.640 trips, holding the slope intercept value of 2.546 trips and the values of the partial regression coefficients of the other variables constant. A unit increase in the number of cars in the family of a commuter is predicted to bring about an increase in the trip rate by 1.405 trips, while an increase of one kilometer in the distance traveled will reduce the trip rate by 0.342 trip still holding all the regression parameters constant. The model also predicts that shifting in work places in this density zone will have a negative effect on trip rate i.e., where shifting is practiced, the trip rate per week will be reduced by 0.738 trip, holding all the regression parameters constant.

The overall significance of this model Eq. 2 was tested using the Analysis of Variance (ANOVA) test-statistic. The F value that was computed was significant at 0.01critical limit (Table 1).

The predictive ability of the model presented in Eq. 2 was tested using the mean values of the variables in the equation. The model correctly predicted the observed (empirical) mean trip rate of 14.02trips for the low-density zone. The efficacy of the model was measured using the coefficient of multiple determination (R^2). The R-squared value (0.791) explains the proportion of the variance of ALLTRIP accounted for by the joint variance of all the predictor variables in the model. In percentage form, this is expressed as 79.10%. This means that about 21% of the variance of ALLTRIP is accounted for by variables not included in the model.

Table 1: Analysis of Variance (ANOVA) for the low-density zone

Model	Sum of squares	d.f	Mean square	F-statistics	Sig.	R^2
Regression	22104.2	6	3684.035	501.322	0.0000	0.791
Residual	5627.468	793	7.349			
Total	27931.7	799				

Trip generation modeling for the medium density zone: Seven predictor variables significantly influenced trip generation in the medium density zone in Akure town. These significant variables are: Educas, Houses, Distan, Tratim, Tramod, Income and Anrent. The predictive trip rate model that was developed for this density zone was based on these variables. The model is given as:

$$Y = 6.997 + 2.774\ (\text{Anrent}) + .520\ (\text{Houses}) - 1.011\ (\text{Income}) + 1.268\ (\text{Tramod}) - .958\ (\text{Educas}) - .638\ (\text{Distan}) + .118\ (\text{Tratim}) \quad (3)$$

The highlight of the model in Eq. 3 is that people who pay higher rents make more trips than those who pay lower rents. Rent is usually highly correlated with income and it is axiomatic that those who pay higher rents are the high income earners and they are therefore expected to be able to make more trips because they are affluent. The model predicts that a unit increase in the annual rent of commuters will increase the trip rate of a commuter by 2.774 trips, holding all the other regression parameters and the slope intercept value on the regression hyperplane constant. The coefficients of all the other variables could be similarly explained but the specific effect of distance on interaction must be pointed out here. The partial regression coefficient for this variable is -.683 and this indicates a decrease in trip rate by this value vis-à-vis a unit increase in the distance traveled. In simple terms, the trip rate will decrease by .683 trip given a one km increase in the distance travelled. The trip-deterring effect of distance is well documented in the literature and this observation further confirms the effect of distance as trip impedance.

The overall significant regression using all the predictor variables in Eq. 3 was tested using the Analysis of Variance (ANOVA) technique. The F value of 501.322 that was btained as ignificant the .01 critical limit (Table 2).

Table 2: ANOVA for the medium density zone

Model	Sum of squares	d.f.	Mean squares	F-statistics	Sig.	R^2
Regression	16006.4	7	2286.629	53.34	0.0000	0.350
Residual	29664.5	692	42.868			
Total	45670.9	699				

Table 3: ANOVA for the high residential density zone

Model	Sum of squares	d.f.	Mean square	F-value	Sig.	R^2
Regression	18836.5	7	2690.933	1425.636	0.000	0.935
Residual	928.666	492	1.888			
Total	19765.2	499				

The level of performance of the model in Eq. 3 was tested by substituting the mean values of the significant variables for this zone into the equation. The model correctly predicted the empirical mean trip rate of 16.35 trips per week for this zone. However, the proportion of the variance of all-purpose trips (ALLTRIP) accounted for by the variance of all the other predictor variables was found to be very low (35.0%) as depicted by the R-squared value of .350. In spite of the low R-squared value, the overall regression was significant with an F value of 53.34 at 0.01 critical limit.

Trip generation modeling for the high residential density zone: Table 3 trip rate modeling for the high residential density zone was done using seven significant predictor variables selected on stepwise basis. These significant variables are: Educas, Shifts, Houses, Numcar, Tratim, Tramod, Anrent. A predictive trip rate model was equally developed for this residential density zone. The model is given in Eq. 4.

$$Y=6.597 + .503(TRATIM)-1.438 (EDUCAS) + .9998 (HOUSES)-.358(ANRENT) .525(TRAMOD) + .465 (SHIFTS) + .244(NUMCAR) \quad (4)$$

One major feature of this predictive model is that less educated people have higher propensities to make more trips than the educated ones. This observation is not surprising since this zone is a high-density residential zone occupied mostly by the less educated people. Another noticeable and significant feature of the model Eq. 4 is that a unit increase in the household size will bring about almost a unit increase in the number of trips (.998 trip) in this residential density zone. All the other partial regression coefficients of the variables in the equation could be used in a similar way to explain and predict trip rates for this zone.

The overall significant regression was tested using the analysis of variance technique. The Snedecor's F-Statistics from the analysis of variance test was 1425.636 AND this was significant at 1% confidence limit. The R-squared analysis indicated that 95.30% of the variations in all-purpose trips (ALLTRIP) in this residential density zone were accounted for by the seven predictor variables accommodated in the model.

Issues for policy formulation: The results presented in this study are mostly in form of statistical parameters and coefficients. This type of technical study is usually for the experts in the field to interpret and implement. However, efforts have been made in this study to present the results in a manner that a lay reader in the field can still comprehend. It is expected that policy makers in this field are quite conversant with the quantitative parameters and statistical results discussed in this study and will therefore have no difficulty in translating them to achievable policies.

This research has identified significant predictor variables that act as determinants of trip rates in the varying residential density areas in Akure town. Some of these variables were common to all the three zones and some were significant only in some zones. For example, it was discovered that household size (Houses), travel time (Tratim) and travel mode (Tramod) influenced trip generation in all the residential density zones.

Some other variables were unique only to some of the zones, for example distance from origin to destination (Distan) which one would have expected to have a significant influence in all the zones, was significant only in the low and medium density zones. Income of commuters (Income) is another variable that was expected to dominate in all the zones but it was only significant in the medium density zone. Shifting (Shifts) and number of cars per family (Numcar) were significant in the high and low density zones, while level of education (Educas) and annual rent (Anrent) were significant only in the medium and high density zones.

This observation draws attention to the fact that different residential density zones have specific and unique characteristics that distinguish them from others in terms of their propensity to generate trips. Policies on traffic and transportation planning in a medium-sized town like Akure must therefore recognize and take cognizance of these zone-to-zone peculiarities in the propensity to generate trips. Also the specific effects of these variables on trip generation rates in the various traffic zones must also be noted for policy formulation.

In both the low-density and medium density zones, distance (Distan) had a negative effect on interaction. This inverse relationship between distance and interaction calls for a policy framework to ensure that work places are located as close as possible to home places in Akure in order to reduce commuting time and cost. The effects of commuting longer distances to work are well known and there is need for a policy guideline to minimize some of the negative externalities of commuting. Some of these negative externalities of commuting include the emission of toxic gases like Carbon dioxide (CO_2) and Carbon monoxide (CO) into the ambient air. Carbon dioxide is injurious to the health of urban dwellers while CO_2 contributes to the global warming of the atmosphere through the greenhouse effect. A policy to put in place a design strategy that will make it m andatory for residential places and employment zones to be located in close proximity in an emergent urban center like Akure will surely be a bold step towards promoting environmental sustainability.

One of the significant variables in the high residential density zone is the mode of travel. This study reveals that public transport promotes interaction more than private transport in the high residential density zone in Akuretown, Nigeria. This observation can be explained in terms of the fact that the urban poor who do not have a ready access to private means of transport inhabit this zone. The policy implication of this is that there is a yawning need to put in place an efficient public transport system in the high residential density zones to cater for the transportation needs of the inhabitants of this zone. The existing system of public transport service in this zone is grossly inadequate, owing partly to the deplorable state of most urban roads. There is therefore the need for all urban roads in the town to be tarred to make them attractive to public transport operators.

The empirical mean all-purpose trip rate per week for the low-density zone was 14.02 trips and that of the medium density was 16.35 while the mean trip rate for the high-density zone was found to be 14.44. This observation was somehow unexpected. It is a truism that rich people generally inhabit the low-density zones. It is also true that they are capable of making many trips per time period than the people in other economic classes. The observation that this zone produced the least number of trips was therefore not expected. There is need for a result-oriented policy on economic empowerment of the populace to enable them purchase private cars.

The mean trip rate values for these three residential density zones were analyzed statistically to determine if the observed difference was significant. This comparison was done using the chi-squared (X^2) test statistic. The calculated chi-squared value was .2064 with a degree of freedom of 2. The null hypothesis that there is no significant difference between the mean trip rates in the three residential zones in Akure was accepted at 1% (0.01) confidence limit. The observed differential in trip rates in the various residential density zones in Akure is therefore not significant and it could therefore be concluded that residential density types in Akure do not significantly influence trip generation rates in the town.

CONCLUSION

The study has identified and highlighted the salient variables that influence the propensity to generate trips on a residential density basis in Akure town. It has also been shown that commuters in different residential density zones have different propensities to generate trips in Akure town. It remains to be added that the success of any public transport management and delivery hinges on a proper underst anding of the trip-generating ability of the different residential density zones in the town. When the traffic-generating ability of a zone is known in the present time and is also predictable for some future time, then adequate provision could be made to satisfy the public transport needs of commuters.

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