Addis Ababa University
Addis Ababa Institute of Technology
School of Civil & Environmental Engineering

Road and Transport Engineering

Developing Trip Generation Model for Suburb Area of a City: Case of Kolfe Keranio Sub City, Addis Ababa

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This is to certify that the thesis prepared by Hana Nega, entitled "Developing Trip Generation Model for Suburb Area of a City: Case of Kolfe Keranio Sub City, Addis Ababa" and submitted in partial fulfilment of the requirements for the Degree of Master of Science in Road and Transport Engineering, complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

The first important step of transportation planning process is trip generation modelling and followed by trip distribution, modal choice and trip assignment. It is essential for forecasting travel demand pattern by planning transportation system. Travel pattern modelling in suburban is different from urban areas because of fast population growth. This research develops a trip production model for Kolfe Keranio sub city to predict the future travel demand. The objective of research is to develop a home based trip production model for the study area using multiple linear regression and multiple classification analysis methods, then compare the performances of the methods to choice the best technique. The primary data collected using simple random sampling for 421 samples household through household interview survey from total population for model estimation and calibration within 15 travel analysis zones and analysed through SPSS software. The results of the research show that MLR and MCA used 11 and 9 significant independent variables respectively with 5 dependent variables for model estimation. Some of the significant independent variables; household size, number of employed, household income, vehicle ownership and number of student are strongly affecting trip production. From the comparison of R^2 value, MLR is comparatively better for modelling total, work and school trip with R^2 value 0.524, 0.735 and 0.772 respectively also MCA is comparatively better for modelling shopping and other trips with R^2 value 0.49 and 0.429 respectively. As a conclusion multiple regression method is comparatively better for trip production modelling and the research helps transport planner to use as an initial model for further development of transport planning models to forecast the travel demand for study area in the future.

Key words: Trip Production, Multiple Linear Regression, Multiple Classification Analysis, Suburb, Kolfe Keranio sub city.

DECLARATION

I declare that the thesis work entitled "Developing Trip Generation Model for Suburb Area of a City: Case of Kolfe Keranio Sub City, Addis Ababa" has been my original work. This work has not been presented to any other University for a degree or diploma; and all materials from other source have been properly acknowledged.

Hana Nega

Addis Ababa

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LIST OF ABBRIVIATIONS

AA	Addis Ababa
ANN	Artificial Neural Networks
ANOVA	Analysis of Variance
CCA	Cross Classification Analysis
CSA	Central Statistics Agency
FHWA	Federal Highway Administration
FL	Fuzzy Logic
HB	Home Based
HBO	Home Based Other
HBS	Home Based Shopping
HBSCH	Home Based School
HBW	Home Based Work
HH	Household
HIS	Household Interview Survey
HS	Household Survey
KKSC	Kolfe Keranio Sub City
MCA	Multiple Classification Analysis
MLR	Multiple Linear Regression
NHB	Non Home Based
NPTS	Nationwide Personal Transportation Survey
RMSE	Root Mean Square Error
SPSS	Statistical Package for Social Sciences
TAZ	Travel Analysis Zone
TG	Trip Generation
TP	Trip Production
USA	United States of America
UTMS	Urban Transportation Modelling System
VIF	Variance Inflation Factor

1. INTRODUCTION

1.1 Back Ground

Transportation is the movement of people, goods and service from one place to another under a desirable condition (Oyedepo and Makinde, 2009) and its contribution to the gross domestic product of many developed countries is more than 26% while, in developing countries it is 5% (Temesgen, 2006).Transportation modeling was well-known in 1990. Transportation modeling is not transport planning rather support planning and play important role in the process. Planning change the world but modeling can assist (Ortuzar and Willumsen, 2011).The travel demand modelling have been based on the traditional four inter connected modules: trip generation, trip distribution, mode choice and traffic assignment (Chang *et al*., 2014).

Trip generation (TG) is the first step in the conventional four-step transportation planning process, widely used forecasting travel demands and its defines the frequency of origins or destinations of trips in each zone by trip purpose (like trip to work, school, shopping, medical center etc.), as a function of land uses, household demographics and other socio economic factors such as population, educational qualification, income and auto ownership rates. Trip generation rates also affected by distance from the city (urban or sub urban), which forms the base for assessing traffic impacts and regional planning (Kadiyali, 2009; Zenina and Borisov, 2013).

Trip production and trip attraction are the two requirements of trip generation. Trip is either produced from traffic zone or attracted to the traffic zone (Zenina and Borisov, 2013). All trips have two ends, the first part is determining how many trips originate in a zone and the second part is how many trips are destined for a zone. The reliability of trip generation forecasting results influences the other models such as; trip distribution, mode choice and traffic assignment (Jadranka and Vladimir, 2010).

The study area Kolfe Keranio sub city (KKSC) is one of the suburb areas of Addis Ababa, Ethiopia with higher population number and, there is a strong need to develop a travel demand forecasting process on this area to understand travel characteristic pattern and to determine the performance of its transportation infrastructure. The aim of the study is to determine trip generation model for KKSC. The total number of trips generated from the area has a significant impact on the overall transport system of the sub city. In this study the model for the first step which is trip generation is developing.

1.2 Statement of the Problem

This research attempts to advance the travel demand trip generation model for suburb area of a city to improve the transportation level there are various types of transport problem generators related to movement of vehicles that make transportation planning inevitable. Developing cities use trip generation models that are developed by the developed countries. These models are not suitable to be used as the original form because of the different conditions in developing countries. Especially Kolfe Keranio sub city is a sub urban area of Addis Ababa city and has larger area of land; because of this most of the people who come from country side of Ethiopia to AA prefer to settle in this sub city, so the number of population and Household (HH) increase continuously, similarly number of trip generated from the household will be growth (Bamlaku, 2009). This make transportation problem expected. And the transport problem that comes due to movements of vehicles that's traffic congestion, crash, delay, parking difficulties and over loading of vehicles etc. followed inflexibility in formulating a new plan to improve the level of service for transportation make the problem critical. In order to improve the precision of forecasting, sound trip generation models are required to consider local situations rather than importing models developed for other countries (Golob, 2000).Therefore, there is a need to develop a trip generation model for the sub city in order to help in predicting the future demand and adopting the suitable transport policies to solve the transportation problem. This study limited to at a sub-city level because of large population, time and for better data collection.

1.3 Research Question

The research questions of this study can be summarized as follows:

- What are the existing characteristic of the travel (O – D) patterns?
- What are the existing appropriate alternative techniques for trip generation model?
- What is the importance's of comparing alternative techniques performance?
- What are the significant independent variables?
- What are the household travel characteristics patterns?

1.4 Objective

1.4.1 General Objective

The general objective of the study is to develop a home based trip generation model for Kolfe Keranio sub city using a simple and suitable technique for suburb area to determine the household travel characteristics pattern and to determine the most efficient options for policy makers.

1.4.2 Specific Objectives

The specific objectives of this study are to:

- Identify appropriate alternative techniques of home based trip generation models for KKSC;
- Develop the models with available socio-economic data collected from the sub city;
- Compare the multiple regression and cross-classification approaches performance; and
- Determine the household travel characteristics pattern in the study area.

1.5 Significance of the Study

The proposed study will make significant contributions, both in understanding and quantifying of travel demand forecasting for the study area by developing an appropriate trip generation model for home based trips that is suitable to the study area according to land use, social and economic aspects. As mention above in statement of problem number of trip generated from this sub city has growth continues so need to forecast the travel behavior and pattern for the households to the efficiency of the transport system. The result from this research will guide the government authority (sub city administrative) or transport planner to complete transport modeling by giving accurate travel characteristics and demand data of households in study area. It’s also plays a significant role to the households by limiting the loss of cost to time delay on the transportation and to other researches give base line to develop trip distribution, modal choice and trip assignment model in this area.

1.6 Scope of the Study

The research has been carried out in Addis Ababa; limited to Kolfe Keranio sub city which is located in western sub urban area of the city. The sub city has 61.25 sq.km and trip rate presented only one-way home based trip production. The research main focus is developing suitable trip generation mode according to study area characteristics.

1.7 Limitation of the Study

- The investigation is limited to production of home based trips.
- The study uses minimum sample size and random sampling method.
- This study did not answer the trip attraction of the study area
- The study did not cover all conventional transportation models.

1.8 Research Methodology

The analysis in this research for the study area which is located in western Addis Ababa, occupies approximately 61.25 square kilometers (KK archived, 2013). According to the most recent city government of Addis Ababa, the population of the study area in 2013 was 456,219 living in 87,734 households.

For primary field survey data collection the representative simple random sampling process has been adopting and samples households extrapolate from the population have been taken from the field through direct personal home interview or questionnaire process.To forecasting travel demand the study area is divided into travel analysis zone (TAZ) and household interview data collected representatively in each zone.

In general, two methods of data analysis will be used; namely qualitative and quantitative. Qualitative data analysis is a search for general statements about relationships among categories of data, whereas quantitative methods use procedures and techniques to analyze data numerically. The description of the data will be compiled, analyzed and presented using tables, figures, charts, and graphs after organizing and checking completeness of the data enter in computer.

After completing organization of data, Trip Production (TP) is performed by using Multiple Linear Regression model (MLR) and multiple classification analysis (MCA) through analysis of variance (ANOVA) in software of SPSS for selecting the most significant independent variables from any given set of variables.

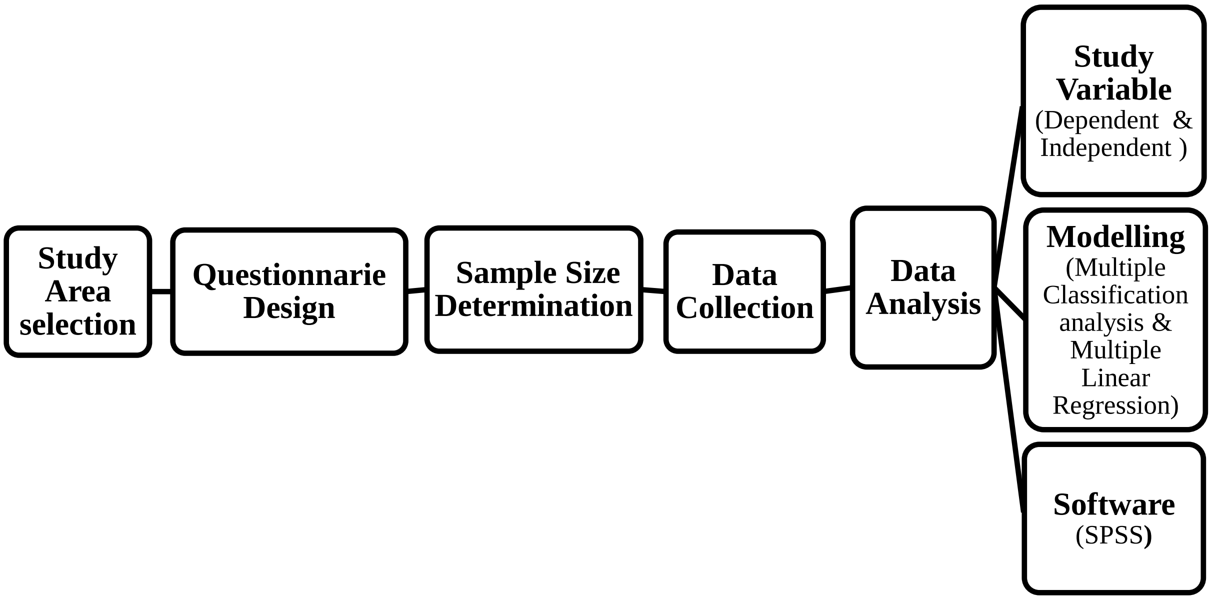

Figure 1.1: Over view of methodology

1.9 Organization of the Paper

This thesis is contains five chapters. Chapter one is the introduction of the thesis contains back ground, statement of the problem, research question, general and specific objective, significance of the study, scope of the study and limitation of the study.

Chapter two is literature review which contains transport planning and trip generation introduction, trip generation modelling, factor influencing trip generation, aggregate and disaggregate model, modelling techniques such as category analysis, multiple classification analysis and multiple regression and also review of previous studies related to trip generation in developed and developing countries.

Chapter three is research methodology. Research material part contains introduction, study area, zoning system, sample size determination, sampling method, questionnaire design, method of Survey and data analysis software. Also research methodology part contains model estimation with statistical tests for multiple regressions and cross classification methods, model calibration and model validation.

Chapter four is the result and discussion parts of the thesis. This contains trip production by both multiple linear regressions (MLR) and multiple classification analysis (MCA) with selecting significant variable, model estimation, model calibration and also model validation. Also contain descriptive statistics form the data of household survey. Lastly compare the model and the independent variables performance.

Chapter five and the final part are conclusion and recommendation. This chapter presents the results of the research and finalized objective with recommendation.

2. LITERATURE REVIEW

2.1 Transport Planning

Transportation is well-known to be the movement of people, goods and service from place to place under a desirable condition. Transportation planning is focused on the development plan of population to improve positive goals and accommodate the need for mobility in order to provide efficient access to various activities that satisfy human needs with respect to the social, economic and environmental impacts (Oyedepo and Makinde, 2009).

Transportation modelling is the most commonly used tool to estimate the upcoming performance of the current or developed transportation system. During 1950s in U.S the basics of transportation modelling principles were developed, and it became an important element of transportation planning, investment and policy development internationally (Martens, 2006).

Urban transportation planning is the process which represents the combination of many relating characteristics of the urban environment. It is a process of forecasting travel demand for future time with the help of explanatory models which take information of current travel behaviour mechanisms, growth potentials and changing socio-economic conditions (Owolabi, 2009). Forecast of demand for the system at the several levels of facility provision considered is one of the basic elements of long-term transportation planning. Travel demand forecasting mainly consists of the traditional transportation planning models that is based on the Urban Transportation Modelling System (UTMS) or as it is more widely known as the classical four major steps; (Owolabi, 2009). And this System is still the standard practice for most strategic transport planning, although advanced approaches explore more accurate representations of travel behaviour in transport modelling (Chang *et al*., 2014).

1. Trip Generation: is the process to estimate where urban activities are transferred into numbers of trips from given origins and destinations.

2. Trip Distribution: is a procedure to determine where destination for each trips produced in each zone and how they will be divided among other zones.

3. Mode Choice: is determining the choices regarding to mode of travel (automobile, minibus, bus, train, etc.) for each trip.

4. Route Assignment: is the procedure to determine where the specific paths (routes) for each trip will take.

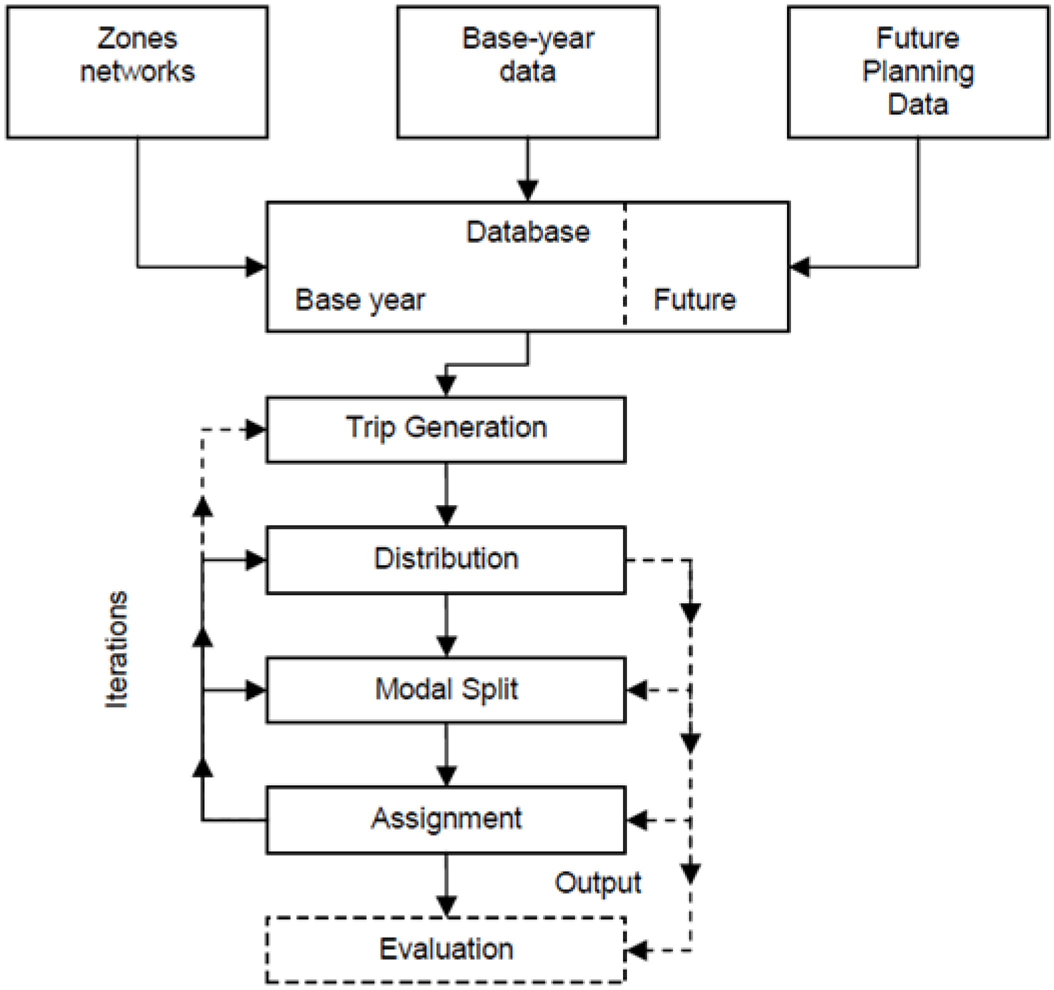

Figure 2.1: The classic four stage transport model
(Source: (Ortúzar and Willumsen, 2011).

In developing countries the growing capacity and difficulty of urban travel should be a major concern to transportation planners, service sponsors, and policy makers. In reality of most developing countries travel demand analysis looks to have been ignored or taken for granted in the planning of cities. And this modelling approach is resource-intensive to apply and has limited its application in data scarce developing countries cities. So, efforts to apply urban transport planning models in developing countries have been of varying degree from country to country as many countries lack quality data and capabilities (McDonald *et al.*, 2002).

There is no systematic analysis of established relationships between various forms of land use and attitudes of trip makers to guide planning of major developments and activity centres.

This deficiency limits the effectiveness of transportation policies and activities in meeting the desires of increasing urban populations in the developing world. In contrast, travel demand analysis has been a major component of transportation planning in the developed world for many years (Kassoff *et al*., 1969).

2.2 Trip Generation

Transportation planning plays a vital role in the development of the transportation system and its key components is travel demand forecasting. Trip generation is the first and most important phase in the classic four-step model broadly used in real-world transport planning applications (Ortuzar and Willumsen, 2011).This phase serves many purposes, mainly the estimation of the number of trips attracted to and produced by land uses (traffic analysis zones) in a study area (Chang *et al*., 2014). Trip generation defines the frequency of origins or destinations of trips in each zone by trip purpose, as a function of land uses and household demographics, and other socio-economic factors (Zenina and Borisov, 2013). Trip generation according to (O'Flaherty, 1997) is concerned with the estimation of the number of trips into and out of various traffic zones, while described trip as the basic unit of movement.

The reliability of forecasting an outcome influences the other phases such as trip distribution, mode choice and traffic assignment. In describing the travel behaviour or the demand for transportation facilities, travel estimation building helps in determining both present and future travel patterns with respect to trip generation, trip distribution, modal choice and traffic assignment (O'Flaherty, 1997).

The aim of trip generation is to forecast the number of various purpose trips that will begin from and end at each travel analysis zone bounded in the area of study as a function of the socioeconomic, locational, and land-use characteristics of the section. (Oyedepo and Makinde, 2009).

For trip generation purposes, travel is considered in terms of number of trips, it does not consider the other characteristics such as direction, length, or duration of trips. Trips considered are usually those generated for a regular weekday ,but they may also be for weekend travel, particularly trip purpose, mode of travel, and/or other stratification required for a specific analysis or forecasting purposes (FHWA,1975).

Trip generation usually answers the question: How many trips originate at each zone? And there are two types of trip generation models: trip production models and trip attraction models. Trip is either produced from traffic zone or attracted to the traffic zone. A production model predicts the direction and number of home-based trips origin and destination on the place where trip makers live and land use of traffic zone defines the attraction of the trip (kadiyali, 2009; Zenina and Borisov, 2013).

Land use is a major consideration in the generation of trips with common socio-economic factors considered for trip generation analysis such as population, educational qualification, family income and auto ownership rates (kadiyali, 2009; Zenina and Borisov, 2013). while O'Flaherty attitude that trips are based on the principle that land use causes trips and that the number and types of trips are influenced by location variables such as population density, socio-economic variables such as car availability or ownership, household income and size, household composition, occupational status and public transport accessibility variables.

Zonal based trip production models were developed as a function of such zonal socioeconomic variables as land use, characteristics of households as well as individual characteristics such as employment, profession, car ownership, and median family income (Chang *et al*., 2014). Household-based trip generation models are more common in current practice, even though they require an additional process of obtaining zonal-level totals (Papacostas and Prevedouros, 2001).

2.3 Trip Generation Modelling

2.3.1 Trip purpose

According to (Ortuzar and willumsun, 2011) trips can be classified by trip purpose, trip time of the day, and person type, also they identify different trip purposes and model separately to get better trip generation models.

Home – based (HB) Trip: is where the home of the trip maker is either the origin or destination of the trip.

Non- home – based (NHB) Trip: is where neither end of the trip is home of the trip maker.

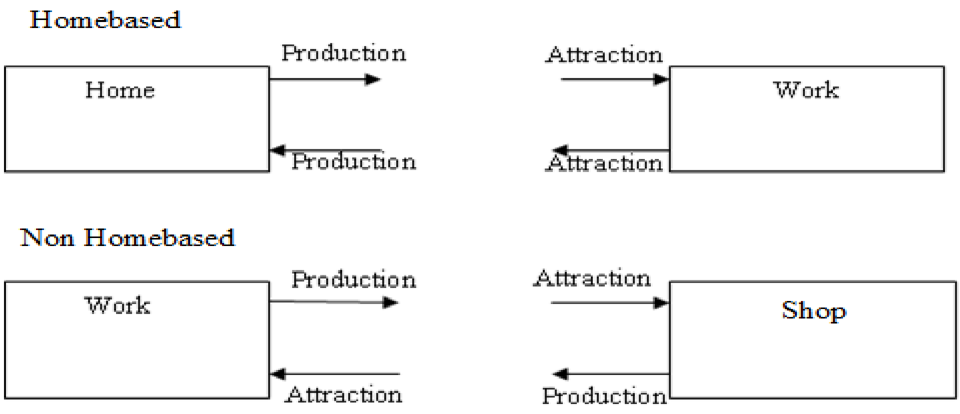

Figure 2.2: Trip productions and trip attractions
(Source: (Ortúzar and Willumsen, 2011).

In the case of home based trips, five categories are distinguished (Ortúzar and Willumsen, 2011).

1. **Home-based Work (HBW)** is a trip maker made a home activity at one end and a work activity at the other end of a trip. There are two types of HBW trips such as: Direct (trips go home to work without transitional stops) and Strategic (trips go home to work with numerous transitional stops).
2. **Home-based School (HBSCH)** is a trip maker made a home activity at one end and kindergarten through college/university education activity at the other end of a trip.
3. **Home-based Shopping (HBS)** is a trip maker made a home activity at one end and a shopping activity at the other end of a trip.
4. **Home-based Social-recreational** is a trip maker made a home activity at one end and a visiting or recreational activity at the other end of a trip.
5. **Home-based Other (HBO)** is a trip maker made all other home-based activity at one end of a trip that are not included in above mentioned home-based trips categories.

Usually the first two are called essential trips and the others are optional trips, among which work trips can be regular, during peak hours. Most workers travel on a fixed scheduled over a specific path, travel at the same time each workday and use the same roads or public transit lines. Home based trips typically constitute about 80 to 85 percent of trips and non-home based trips were often not separated because they only take 15 to 20 percent of all trips (Ortúzar and Willumsen, 2011)

2.3.2 Factor Influencing Trip Generation

Trip generation is affected by production factors and attraction factors, Production factors are often based on household demographics and other socio economic factors whereas attraction factors express something about land use (Ortúzar and Willumsen, 2011).The main factors affecting personal trip production include income, car ownership, household structure and family size. In addition factors like value of land, residential density and accessibility are also considered for modelling at zonal levels. The personal trip attraction, on the other hand, is influenced by factors such as space available for industrial, commercial and other services. At the zonal level zonal employment and accessibility are also used (Mathew and Krishna, 2007).

Some of independent variables that affect trip generation listed below according to different studies described.

Household Size, Employment

Increase in household size, household income, employment and mobility tools (e.g. vehicle ownership, driver license and transit accessibility) has a positive influence on the total trip frequency for all purpose (Badoes and Chen, 2004), work trips (Chang *et al*., 2014; Huntsinger et al., 2013; Páez et al., 2006) and non-work trips (Huntsinger et al., 2013).Household income and mobility tools reflects the degree of economic activity and accessibility of a household respectively.

Income

Based on the data of Nationwide Personal Transportation Survey (NPTS) in 1995 the low income people make lower mobility and travel less kilometres (less trips) than the high income people. Low income people mostly depend on public transport, foot and bicycle to fulfil their mobility desires. Conversely high income people make more autos trips, less public transport trips and few non-motorized trips and take on more social trips, travel greater distances (lower mobility) and visit more shopping place in a weekday.

Gender

Previous studies show gender has impact on trip generation; males have a positive influence on total trips (Badoe, 2007) whereas females usually in a multi person family have a positive influence on shopping and social trips in. Similarly according to Transportation Research Board (TRB) research in 2001 the gender difference in travel patterns is connected to employment status, household structure and child care. From the research results for single families the travel patterns of men and women are very similar. However, for multi person family without children, differences in the travel behaviour of men and women are noticed. These differences become very obvious when considering multi-person family with children.

Age

From many researchers investigation the relationship between age and trip generation is nonlinear. For example, a study by (Badoe, 2007) of age on total trip frequency shows that young people (11-17 years) are more possibly involve in more trips, and the number of produced trips decreases as age increases, the lowest trips produced by elder. Lastly, (Páez *et al*., 2006) highlights that for work trips, trip rate is somewhat low for the young age group (< 20 years), and increases with age reaching a peak for the employed age group (34-50 years). The impact of age decreases for the preretirement and elder age groups. The number of produced trips decreases quickly for persons in the preretirement and elder age groups.

2.3.3 Aggregate and Disaggregate Model

There are numerous alternative structures for identifying trip generation models generally analysed using the aggregate or disaggregate models approaches. The difference on these two techniques is mainly the data efficiency.

1. Aggregate Model

Aggregate models are aggregated at zonal level to give an appropriate trip generation modelling using regression analysis and growth factor analysis based on household interview trip origin and destination data. Aggregate models are cost-effective in terms of data collection, calibration and operation. There is vagueness in aggregate approach on defining the criteria of group because of the generalization of the model (Cubukcu, 2001).

2. Disaggregate Model

Disaggregate models are based on large samples of household types and forecasting travel behaviours, and uses household or individual levels data directly in urban transport system. This model has non-linear relationships and easily understood. Disaggregate models are usually analysed using such analytical techniques such as multiple linear regression (MLR), cross classification, discrete choice (Probit, Logit and ordered Probit models), simulations methods (smash, amos & starchild system), fuzzy-logic (FL), artificial neural networks (ANN) and rough set theory (Arabani and Amani, 2007).

The Disaggregate approaches are nonlinear and have description power with more accurate estimation on trip rate; also groupings are independent of zone structure and have a diverse form of relationship. Transferability of Trip generation model is developed to provide well estimation of variable at a more disaggregate levels (Ashenagar, 2010).

Beside the advantages there are some limitation, disaggregate models for wide areas will demand long period, high cost, and several peoples. Household or individual based disaggregate approaches need a significant quantity of data for model calibration and testing (Cotrus *et al.*, 2003).

2.4 Modelling Technique

Trip generation models are a set of mathematical equations and procedures that collectively relate travel patterns to land use, residential density, socio-economic characteristics, demographic characteristics and other parameters of the transport system. Many methods for modelling trip generation are done in the travel demand modelling studies. These include multiple linear regression (Cotrus *et al.* 2003) cross-classification analysis, growth factors methods, discrete choice models (Zhao, 2000), Tobit, Poisson, ordered logit, (Chang *et al*, 2014) fuzzy logic models, and artificial neural networks (Huisken, 2006). However, of these methods, growth factors methods, regression methods and category analyses (cross-classification analysis (CCA)) have been widely applied in practice (Chang et al., 2014; Ortúzar and Willumsen, 2011).

Trip generation models are divided into three levels: strategic, tactical and operational ones. Regression is a statistical technique to determine the relationship between different variables. The variables are classified as dependent variables and independent variables. Cross-classification models or category analysis are used for trip generation calculations at the strategic and tactical levels (Zenina and Borisov, 2013).

A number of methods have been developed over the years to study trip generation. These include the use of simple or multiple linear regression analysis at the aggregate level, at the household level (Badoe and Chen, 2004). Models of this type are used to identify variables that very relate with the number of trips originating at the unit of analysis, based on variables that can be either of policy significance (such as land uses) or of predictive interest (such as household structure, age).

2.4.1 Growth Factor Analysis

Growth factor method tries to forecast the number of trips produced or attracted by a household or zone as a linear function of explanatory variables (Mathew and Krishna, 2007). This model characterizes future trips by a factor of magnitude in relation to current trips. Its basic equation is :(Ortuzar and Wilumsen, 2011)

$$T_i = F_i t_i \tag{2.1}$$

Where T_i and t_i are respectively future and current trips in zone *i* and F_i is a growth factor.

This method is considered to be very crude, so a refinement can be made with a Multiplicative formulation of growth factors: normally the factor is related to variables such as population (P), income (I) and car ownership (C), in a function. *d*

$$F_i = \frac{f(p_i^d, I_i^d, C_i^d)}{f(P_i^c, I_i^c, C_i^c)} \tag{2.2}$$

Where *f* can even be a direct multiplicative function with no parameters, and the superscripts *d* and *c* denote the design and current years respectively.

2.4.2 Category Analysis

Category Analysis (Cross Classification Method) was developed in late 1960s in United Kingdom for further disaggregation in trip frequency analysis as an alternative to regression analysis modelling of trip generation (Ortúzar and Willumsen, 2011). Similarly Federal Highway Administration, 1975, p.2 supposed the need to practice aggregated zonal analysis (regression approach) move to a disaggregated household analysis (cross-classification approach). Cross Classification models have been more widely used for long range residential trip generation analysis to overcome some of the inherent problems with regression analysis.

Cross-classification analysis involves the use of trip rates as trips per person or trips per household to compute regional travel demand. Distinguishing the heterogeneity in populations first divides the population into relatively homogeneous groups based on two or three household characteristics and estimates a trip production rate for each group which is assumed to remain constant over time. Then, a trip rate is calculated for each relatively homogeneous group. This method is nonparametric; it does not assume any probabilistic distributional association between the dependent and explanatory variables. The multidimensional matrix in which each dimension is represented by one of the independent variables is constructed to form different group. After that, mean value of the dependent variable is calculated for each group. (Ortúzar and Willumsen, 2011). Also, the method makes use of the raw data obtained from a household travel behaviour survey directly, and its simplicity has made it attractive to practitioners (Rengaraju and Satyakumar, 1994).

(Ortúzar and Willumsen, 2011) supposes a cross-classification based on household sizes and income groups. Then, the number of household categories will be m x n. As categories are defined, households are assigned to each cell. For each cell, the observed trips of the households that fall in that category are aggregated. Lastly, the total number of trips in each cell is divided by the number of households in it to give the trip rate.

Mathematically, trips produced by the individuals of the household are given by: (Ortúzar and Willumsen, 2011)

$$t(h) = {T(h)}/{H(h)} \qquad (2.3)$$

Where,

$t(h)$= the number of trips for purpose p made by the household members of type h

$T(h)$ = total number of trips produced by the households of type h for purpose p

$H(h)$ = total number of households in category h

The main advantages of the cross-classification model over regression method from different researcher's perspective are: (Takyi, 1990; Rengaraju and Satyakumar, 1994; Ortúzar and Willumsen, 2011; Chang, Jung *et al*, 2014)

- Raw data obtained from home interviews may be used directly It does not require a definite relationship (linear or monotonic) among the variables that affect the trip making
- The effects of socioeconomic characteristics of trip makers are directly reflected.
- No assumptions need to be made about the distribution of the error terms between the trip rate and explanatory variable.
- The model allows a more comprehensive analysis of trip making by showing the differences in relationships among different classes.
- Human behaviour is simulated more realistically at the household level.

- Generate an acceptable level of performance from the viewpoint of transport planning.

In spite of having several advantageous on regression method, cross-classification has some disadvantages (Ortúzar and Willumsen, 2011).

- Lacks statistical goodness-of-fit measures to test the significance of the various explanatory variables that influence the dependent variables so the calibration cannot be verified.
- There is no effective way to select independent variables and their strata for classification (requires trial and error).
- The increasing number of explanatory variables to be measured, where the variables are stratified increases the demands made on data collected.
- The cell by cell calculation reduces the reliability of cell values.
- The uncertainty increases when there are cells with small samples and/or large variances.
- Requires large sample sizes, which acquires much cost and time.

2.4.3 Multiple Classification Analysis

Multiple Classification Analysis (MCA) method is an alternative approach to overcome the disadvantages toward a simple category analysis model for person trips and freight movements (Stopher and McDonald, 1983). MCA is like to multiple regression analysis with dummy variables. The method is applicable where the dependent variable is quantitative and the explanatory variables are categorical.

The method is basically a simple extension of analysis of variance (ANOVA), it is a powerful statistical method that can be used to identify the most appropriate variables of households for the cross classification models based on analysis of variance (ANOVA). The cell value is estimated by the grand and the group means (Stopher and McDonald, 1983). Likewise MCA with two categorical variables relate to two-way ANOVA. Stopher and McDonald (1983) is the former to apply the method in trip generation analysis. Then, several researchers (applied the method. The overall mathematical equation of the MCA model is expressed as:

Household Trip Rates

$$t(m,n) = T(m,n) / H(m,n)$$

$$t(m,n) = G_{\mu} + \alpha_m + \beta_n + \boldsymbol{\varepsilon}_{mn} \qquad (2.4)$$

Where

$t(m, n)$= the trip rate for a cell in a cross-classification matrix with household attribute values

$T(m, n)$ = total numbers of trips produced by the households attribute values

$H(m, n)$ = total number of households in category (m,n)

G_μ= the grand mean of trips made by the households in the dataset

α_m = the column-effect for column m of a cross-classification matrix

β_n = the row-effect for row n of a cross-classification matrix

$\boldsymbol{\varepsilon}_{mn}$ = error term

For comparison purposes investigates three MCA models designated as MCA1, MCA2, and MCA3. The first, MCA1, takes the following equation.

$$t(m, n) = G_\mu + \alpha_m + \beta_n \qquad \forall\, m \in M, \forall\, n \in N, \tag{2.5}$$

Where

$$G_\mu = \frac{\sum_{h=1}^{H} T(h)}{H(h)} \tag{2.6}$$

$$\alpha_m = \frac{\sum_{n\in N} T(m,n)}{\sum_{n\in N} H(m,n)} - G_\mu \tag{2.7}$$

$$\beta_n = \frac{\sum_{m\in M} T(m,n)}{\sum_{m\in M} H(m,n)} - G_\mu \tag{2.8}$$

Where

N, M = the respective number of classes for the two stratification variables
n, m = the values of two household attributes used in defining homogeneous groups (cells)

The second, MCA2, takes the same mathematical equation as the first one except the row and column effects are calculated as weighted means, takes into consideration the unequal number of observations in the cells of the cross-classification matrix (Stopher and McDonald, 1983).

$$\alpha_m = \left(\sum_{n\in N} W_{mn}\, t(m, n) / \sum_{n\in N} W_{mn}\right) - G_\mu \tag{2.9}$$

$$\beta_n = (\sum_{m\in M} W_{mn}\, t(m,n) / \sum_{m\in M} W_{mn}) - G_\mu \qquad (2.10)$$

Where

W_{mn} = weighting factor for cell *mn*

The third, MCA3, is from MCA regression of household trips on all classification variables. However, the model is somewhat different from ordinary least squares when calculating the marginal effect of an explanatory variable; the other explanatory variables are held constant at their mean values in the entire sample (Retherford and Choe, 1993). The model's mathematical equation is;

$$t(m,n) = a + \sum_{n\in N} \beta_n x_n + \sum_{m\in M} \alpha_m x_m \qquad (2.11)$$

Where

x_n, x_m = 1 if the *n*th or m^{th} element of X is observed, and equals a zero otherwise.

n and *m* are initial classes that are considered as reference classes, hence a constant '*a*' to be estimated is added.

2.4.4 Multiple Regressions

Regression methods were widely used in late 1950's to generate equations relating urban trip rates to socioeconomic characteristics (Federal Highway Administration, 1975, p.2).There are two types of linear regression such as simple linear regression and multiple linear regressions. Simple linear regression analysis is done if the relationship between the dependent variable and one independent variable is investigated and multiple linear regression analysis is done if the relationship between the dependent variable and several independent variables is investigated.

The regression modelling is the statistical technique that used to calculate the generated trips. Also to generate a model relate two or more variables that predicts one variable most significant to a data from the others (Al-Hasani, 2010). The data used to develop a regression equations are collected from the field survey. As a data collection changes in the filed it is obvious to varies the coefficient of independent variables. Different conditions are used for the selection of explanatory variables in regression method (Zenina and Borisov, 2013).

Regression model investigate linear or non-linear relationships between a dependent variable y to the independent (explanatory) variables x1, x2, x3... xn, as they describe the variations in the value of y (Pas 1974, p.19). Multiple regressions analysis is standard statistical technique trip generation modelling works when more than one independent variable is considered. The goal of multiple linear regressions is to develop the best model at a selected confidence level that satisfying the basic assumptions of regression analysis (Al-Hasani, 2010). For trip generation model dependent variable as number of trips produced by the individual, household or zone and independent variable such as size of the household, number of vehicles, household income etc. set by the equation: (Pas 1974, p.19).

$$Y_O = a + b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_nx_n + \varepsilon \qquad (2.12)$$

Where,

Y_O = Dependent variable

$x_1, x_2, x_3, \dots, x_n$= independent variables

a = Coefficient to be estimated (Y intercept)

$b_1, b_2, b_3, \dots, b_n$ = regression plane of independent variables,

ε = error (disturbance) terms or residual

The multiple linear regression involve in the following assumptions: (Ortuzar and willumsen, 2011).

- Can be used with continuous variables for independent variables.
- Can be applied when independent variables are correlated or uncorrelated.
- The error terms has zero mean and covariance value.
- The error terms has constant variance and normal distribution.
- The explanatory variables are not correlated with each other.

Multiple linear regression analysis has advantages on the modelling of trip generation such as (Ortuzar and willumsen, 2011):

- Properties and characteristics are well implicit as a mature technique.
- Improved well prediction from multiple variables
- Not only depend on a single variable.
- Avoid weak relation of variables.
- Allow more advanced research hypotheses than using simple correlations.

- Gives a connection between the various correlation and ANOVA models.
- Regression equation provides better-than-chance prediction (R^2).

Beyond the above multiple linear Regression analysis advantages there is some drawbacks according to different researchers' investigation such as: (Badoe 2007; Ortuzar and willumsen, 2011)

- Sample size must be large enough (N> 50 + 8(m), N=sample size, m=number of independent variables).
- Linearity, Multicollinearity.
- Error variance remains constant (frequently violated).
- Outliers must be considered.
- Normal distribution (the dependent variables take the negative values rather to set zero)
- Homoscedasticity of Residuals (exaggerate the model accuracy) Independent variables insertion should direct by theory (not by data).
- Trips number consider as a continuous random variable (while it is a discrete variable).

2.5 Review of Previous Studies Related to Trip Generation

The modelling of trip generation different from develop to developing countries because of the changing characteristics of land use and trip making activity that changes the transport demand. The section below reviews some researches done before in developing and develops countries.

2.5.1 Review in the Developing Countries

The trip generation studies by using different modelling techniques in developing countries results by some researchers discussed in this section.

Fillone *et al.* (2003) developed multiple regression models that estimate the number of person trips and vehicles attracted to 30 randomly selected condominiums in Metro Manila, Philippines and their characteristics such as residential floor area, parking slots, commercial floor area, occupancy rates and so on were gathered by conducting morning to afternoon hourly counting of people and vehicles in condominium. The result showed that the residential floor area was strongly related with the peak vehicular attraction and number of people entering the condominium. This study used to determine the sufficient number of parking facilities and also to minimize the traffic congestion in condominium.

Abdel-Aal (2004) developed a trip production model using Multiple Classification Analysis (MCA) for the city of Alexandria, Egypt. The two-dimensional MCA model showed the model sensitivity to reflect the effect of changes in socioeconomic household attributes on trip rates in the future. More significantly, the motorized trips had largely increased while walk trips had decreased.

Al-Taei & Amal (2006) use cross-classification technique to forecast trip production rate between 20 traffic analysis zones in Dohuk city, Iraq residential area. To define disaggregated trip rates, total vehicle and private trips use cross-classification matrices with two and three level. The main factor affecting trip production in this research was car ownership related to other variables and also, family size and workers number were the most effective independent variables.

Okoko & Fasakin (2007) the development of trip rate models for three residential density zones in Akure Town in Nigeria. On the technique of systematic sampling total 2000 commuters selected from each of these zones. The study resulted that the main trip rate values were not the same in the three residential density zones in town. Therefore the study concluded that residential density types do not significantly influence trip generation rates in Akure Town.

Oyedepo & Makinde (2009) developed a regression model of household trip Generation of Ado-Ekiti Town in Nigeria through household interviews. The results were analysed using Statistical Package for Social Sciences (SPSS) it showed that people with higher income and more automobile availability make more trip than people with low income and less automobile availability. Also, home based other trip purpose took the 52% which is a largest of all trips while non home based and home based work took 31% and 17% respectively. For result of the regression analysis average value of R and R^2 are 63.5% and 40.45% respectively for dependent variable against to other variables such as age, income, family size and car ownership.

Priyanto & Friandi (2010) develop a trip generation model using multiple linear regressions to predict the number of public transport passenger in Yogyakarta city, Indonesia. The resulted model showed that number of public transport trips made by people decrease as income, the number of motorcycles, and car owned increase, and also the number of public transport trips increases as family size increases.

Ashengar (2010) compares and contrasted trip rates modelled by multiple linear regression and category analysis in Skudai town in state of Johor in Malaysia. And also to decide the technique used for traveling collect origin and destination interview surveys. For predicting the future travel using regression model looks much better and simple than category analysis by having a fixed formula. Furthermore, household regression approach has advantages as a model building procedure and makes better use of sample data.

Urquiza *et al.* (**2010)** developed a trip generation model based on household based trip through crossed classification technique in the city of Palmira, Colombia. The number of total trip produced on each travel analyses zone were calculated by collected data. The researchers found that the technique of crossed classification shown some trouble on the integration and interrelation of anew variables, limits the accuracy of estimation of future demands but the stability of hypothetical relations was satisfactory.

Sarsam and Al Hassani (2011) developed using multiple regression techniques to forecast number of trip in Ai Karkh side of Baghdad city, Iraq. The study area was divided in to 10 segments and each segment was divided in to a number of zones. A questionnaire and interviews were made for data collection, after that the data has been enter to the SPSS software. The results show coefficient of determination equals to 0.90 and home based education trip are strongly related to the number of students in the household.

Sofia et al. (2012) developed a relationship between the daily household trips and socio economic characteristics of Al Diwaniyah city, Iraq by using multiple linear regressions after the collected data had been inter to the SPSS software. Household questionnaire forms were distributed through 70 zones of a city that cover an area of 52 km^2. From the result the trip generation model mainly depends on family size, number of workers, and number of students in the family.

Moussa (2013) developed a trip generation model for Gaza City, Palestine to determine the household travel characteristics pattern and compare trip rates modelling by the conventional cross classification (CCA) and multiple cross classification (MCA) method. Also, the researcher developed a trip attraction model using multiple linear regression technique (MLR).Household interview survey was conducted to 425 households in different zones of city. From the result of the research main factors that affected trip production are vehicle ownership, household size, income level and the number of licenced drivers in the household.

Furthermore, the results showed that for expression of trip rates on trip production multiple cross classification (MCA) models are more effective than the conventional cross classification (CCA) models.

2.5.2 Review in the Developed Countries

The trip generation studies by using different modelling techniques in developed countries results by some researchers discussed in this section.

Stopher & Mcdonald (1983) conducted a trip generation analysis on the data from Midwest, USA using multiple classification analysis (MCA) in contrast to linear regression analysis. The household structure variable was tested using both analysis of variance (ANOVA) and MCA to determine how well the variable performs in various model structures when compared with other variables. The variables tested were the number of vehicles available to in household, household size, housing type, household income, total number of employed persons and total number of licenced drivers. The analysis concluded that the household structure variable did not perform significantly better than other variables tested.

Goulias, Pendyala et al. (1990) developed trip generation and trip chaining model based on a data from Detroit Metropolitan Area. Six trip groupings i.e. work, education, shopping, social, personal business and serving passengers' trip groupings were considered in the study. Education trip generation model was the best performing model with R^2 value of 0.545 followed by work trips which yielded R^2 value of 0.313. Similarly, trip generation model for shopping trips yielded R^2 value of 0.079 and social trips yielded 0.087. The R^2 value of the remaining personal business and serve-passenger trip generation models were 0.114 and 0.05 respectively.

Prevedouros and Schofer (1991) Use linear regression to study factors affecting all trips, work trips and non-work trips per person by analysing trip characteristics and travel patterns of suburban residents in Chicago based on 1989 mail back survey to knowing the causes of variations in traffic congestion. The estimate of the all trips generation model yielded R^2 value of 0.08 which is very low. Similarly, R^2 values yielded by non-work and work trip generation models were 0.28 and 0.33 respectively.

Purvis *et al.* (1996) Average home based work trip duration is used in home based shop and home based social/recreation models for the San Francisco Bay Area. Work trip duration and home based non work trip rate shows inverse relation in survey data and models. Trip generation models using multiple regression techniques, cross classified by employees and vehicles in household level, are estimated using data from the 1981 and 1990 household travel surveys. This study helps to include workplace accessibility in regional travel demand model to provide a better understanding of the connection between congestion and trip rate selection behaviour.

Hu (2010) developed trip generation model for work trips per household using National Travel Survey data its covering residents of Great Britain. In addition, the researcher developed trip generation model for shopping trips per person using Edinburgh Household Survey (HS) data results shows parking prices reflecting the impact of transport policies and other attributes. For both studies employed linear regression and logistic analysis. The linear regression trip generation model of work and shopping trips yielded R^2 value of 0.326 and 0.135 respectively, which is very low for shopping trips.

Chang, Jung et al. (2014) studied home based work trips per household in Seoul metropolitan area using six models regression, tobit, Poisson, ordered logit, category, and multiple classifications and compared the results. The Regression model gave R^2 value of 0.4. Category model is superior in contrast of all six models by calculating the difference between observed value and model value based on RMSE and NRMSE.

3. RESEARCH METHODOLOGY

3.1 Study Area

The study area Kolfe Keranio or Kolfe is one of the ten sub cities established under Addis Ababa City Administration in 2003. It is located at the western part of Addis Ababa, between the road to Jimma and Ambo towns. According to the most recent city government of Addis Ababa, the population of the KKSC in 2013 was 456,219 separated into 220,859 Male (48.4 %) and 235,360 Female (51.6 %) with 87,734 households with an average household size of 5.2 persons. It covers an approximate area of 61.25 square kilometres of Addis Ababa's land (KK archived, 2013). According to a report from the city Administration the sub city it is one of the rapidly growing sub cities of Addis Ababa ,currently its population densities is 7448.5 population per sq. m (this value is a result of dividing population of 456,219 to the area 61.25 km^2) with the annual growth rate about 2.1 percent. The study area was classified into 15 districts (woredas).

The geographical position of the sub city is located on longitude 38° 42' 21" East and latitude 09° 0' 49.75" North with an elevation of 2400-2500 meters above sea level. The study area is suburban area of the city, near to Gefersa reservoir and it's about 9.6 kilo meters away from center of the city and, shares boundary with Lideta and Addis Ketema sub city in the east, Nefas Silk Lafto sub city in the south east, Gulele sub city in the north east and Oromia regional state in the west.

The study area presently has poor road network and transport planning and it cause the area congested constantly. The gravel road takes the higher percentage; among asphalt roads the ring road covers the largest part of the sub city road. The people buying housing land from farmers at lower price and construct informal houses in the sloppy land, its cause a rapid land use change. The increase of migration from the countryside in the working age group, lack of land for the housing of lower and middle class, increasing rate of the rent house indicate the rapid population growth rate. Know the sub city is in critical problem of transport planning (CSA, 2007).

In the study area a number of residential areas, retail shops, shopping complex, industries, religious place and schools are located. Therefore, there is a need to develop a trip generation model for the sub city in order to help in predicting the future demand and adopting the suitable transport policies to solve the transportation problem. Figures below shows geographical location of Kolfe Keranio sub city and the traffic analysis zones or administrative districts.

Figure 3.1: Map of Kolfe Keranio Sub City in Addis Ababa
(Source: Addis Ababa city mayor office website, 2020)

Figure 3.2: Areal map of Kolfe Keranio Sub City
(Source: Google Earth, 2020)

Table 3.1: Addis Ababa sub cities population and area 2011

No.	Sub City	Population		Total	Area (km^2)	Density (pop/area)
		Male	Female			
1	Addis Ketema	132,825	138,819	271,644	7.41	36,659.10
2	Akaki Kaliti	95,558	99,715	195,273	118.08	1,653.70
3	Arada	105,963	120,036	225,999	9.91	22,805.10
4	Bole	154,542	174,358	328,900	122.08	2,694.10
5	Gullele	137,690	147,175	284,865	30.18	9,438.90
6	Kirkos	110,069	125,372	235,441	14.62	16,104
7	Kolfe Keranio	220,859	235,360	456,219	61.25	7,448.50
8	Lideta	102,513	112,283	214,769	9.18	23,000
9	Nifas Silk-Lafto	158,126	177,614	335,740	68.3	4,915.70
10	Yeka	171,676	196,742	368,418	85.46	4,285
	Total	**1,389,821**	**1,527,474**	**2,917,268**	**526.47**	**129,004.00**

(Source: Addis Ababa city mayor office website, 2020)

3.2 Zoning System

Zoning means dividing the study area after defining the boundary into smaller land use areas called traffic analysis zones (TAZ). The zonal structure has been formed in order that areas sharing homogeneous characteristics are represented in terms of their population, land use, income, employment, accessibility. To simplifying the data collection procedure the zoning system requires to divide the study area into smaller units (Kadiyali, 2009). Therefore, to forecasting travel demand, kolfe keranio sub city is divided into 15 zones (TAZ) which is based on woredas boundaries (administrative classification). But this TAZ need only for data collection because the study analyses the sample in household level rather than in zonal level. The zone numbers and locations are presented in figure.

Figure 3.3: 15 Districts (Woreda) based zoning classification of KKSC

3.3 Sample Size Determination

Sample size determination is the important step in data collection process. Because, making a survey of all the values in the population is difficult especially when the population size is large. Simply, sample is any subset of sampling units from a population. The data's are analysed from the sample then can make interpretations to the population. The sample size should represent the population effectively, it depends upon the total population of the study area; also properly estimate the required level of statistical accuracy and acceptable number of standard error in the survey (Koppleman & Chandra, 2006).

There is no direct and one objective answer to the question of the calculation of sample size .in determining the sample size balancing is a main problem. Because, a very large sample is expensive to given the study objective and its requirement degree of accuracy and a very small sample is result an unacceptably high degree of variability by reducing the whole value (Ortuzar and Willumsen, 2011).

There are various common miss understanding about the required size of a sample. One is that the sample should be a regular proportion and the other is that any increase in the sample size will increase the precision of the sample results.

The development of a sampling design mostly depends on the manpower, the budget and the duration of the survey. The cost and time of the survey also increases with sample size .therefore it is necessary to restrict the sample size to ensure that the cost and time of the survey remains within predicted budget and time constraints (Koppleman & Chandra, 2006). There is no difficulty in determining the desired sample size by using standard formulas, if cost, time and other practical constraint do not enter into the decision.

There are two methods to determine sample size for variables.one method is use a sample size based on proportion. The second method is use the formula for the sample size for the mean. This formula applies when the sample size is greater than or equal to 30 and used to determine the minimum sample size to provide the desired level of precision when the population size is very large (Glenn, 1992).

Formula for sample size for the mean

For finite population size, $n = \{Z^2 \times \sigma^2 [N / (N - 1)]\} / \{e^2 + [Z^2 \times \sigma^2 / (N - 1)]\}$ (3.1)

For infinite population size, $n = (Z^2 \times \sigma^2) / e^2$ (3.2)

Formula for sample size for proportion

For finite population size, $n = [(Z^2 \times p \times q) + e^2] / [e^2 + Z^2 \times p \times q / N]$ (3.3)

For infinite population size, $n = [(Z^2 \times p \times q) + e^2] / (e^2)$ (3.4)

Where:

n: is the sample size.

Z: is the critical standard score.

N: Total size of the population.

e: level of precision(sampling error)

p: the population proportion.

q: (q = 1 – p)

σ^2: is the variance of an attribute in the population.

In this case use the formula for sample size for proportion with finite population size.

$$n = [(Z^2 \times \text{ p} \times \text{q}) + \text{e}^2]/[\text{e}^2 + Z^2 \times \text{ p} \times \text{q}/\text{N}]$$

This research is done in household level, so need to divide the total population size to average household size in the study area to get the target group. From the Addis Ababa city government website data in 2017 the study area population size is finite (456,219 persons) and the average house hold size is 5.2 persons per households in the city.

Determine population size (N)

$$N = \frac{\text{total population}}{\text{average household size}} = \frac{456{,}219 \text{ persons}}{5.2 \text{ persons/households}} = 87{,}734 \text{ households}$$

Now, we have the population size of 87,734 HHs.

Determine the critical standard score (Z)

To find this need some assumptions of the value with normal distribution

e = ± 5%

Confidence interval=95 %

p = 0.5, q=1-p = 1- 0.5 = 0.5

α = 1 - 0.95 = 0.05

μ =0

σ = 1

df= 1 - α/2 = 1 - 0.05/2 = 0.975

Using Z score tables Z = 1.96.

Where:

α: Significance Level

μ: Mean

σ: Standard deviation

df: degree of freedom

Determine the minimum sample size (n)

$$n = [(Z^2 \times p \times q) + e^2]/[e^2 + Z^2 \times p \times q/N]$$

$$n = [(1.96^2 \times 0.5 \times 0.5) + e^2]/[0.05^2 + 1.96^2 \times 0.5 \times 0.5/87{,}734]$$

$$n = 383.76 \approx 384 \text{ samples}$$

(Yamane, 1967) provide a simplified formula to calculate sample sizes.

$$n = N/[1 + N(e^2)] \tag{3.5}$$

Where:

n: is the sample size.

N: is the population size.

e: level of precision

The result of sample size by this formula also the same to the previous one

$$n = 87{,}734/[1 + 87{,}734(0.05^2)] = 398.48 \text{ samples}$$

Therefore, from both formulas calculation the minimum amounts of samples required are 400 samples. In this study, this number is extended to 421 samples for the estimation process to get a better data.

3.4 Sampling Method

After the sample size is determine the next step is the selection of surveyed household from each 15 TAZ proportionally by their percentage of population size. The choice of the method used for data collection depends upon the subject of the study, the characteristics of the population of respondents, the scale of the survey and the time and cost available for its completion. The stratified random sampling process has been adopting for this direct field survey data collection process and used representative simple random sampling process from each of the 15 TAZ's .The household selected for interview arbitrarily in their positions of settlement. The sample size of each TAZ is shown in table 3.3.

Table 3.2: Number of the household per traffic analysis zone for the study area and sample size requirement

TAZ Number (Woredas)	Population of TAZ	Number of Households	Number of Housing units*	Percent of Housing Units	Sample Size including Calibration
1	25,359	6,027	5,862	3.55	22
2	17,651	4,059	3,809	7.1	30
3	15,215	3,947	3,790	7.1	30
4	55,374	12,314	11,898	3.79	23
5	50,717	12,053	11,724	10.65	43
6	41,751	10,002	9,581	3.79	24
7	35,621	8,565	8,099	6.65	25
8	20,404	4,491	4,275	6.5	27
9	20,310	4,515	4,274	6.5	30
10	17,225	3,818	3,600	8.37	33
11	34,273	7,637	7,200	6.13	26
12	13,034	2,658	2,558	7.5	31
13	19,031	3,916	3,723	5.22	24
14	18,931	3,891	3,873	5.22	25
15	43,999	10,199	9,919	11.94	28
Total	**428,895**	**98,092**	**94,135**	**100**	**421**
*Number of housing units was found by dividing the population by the average household size (5.2 person/household)					

(Source: Population and housing census of Ethiopia (CSA), 2007)

3.5 Questionnaire Design

The questionnaire was developed based on the characteristics of trip, mode and trip maker. Pilot survey was done and some contents of the questionnaire were revised before collecting the whole data. To collect relevant data the questionnaires or interview should contain the following objectives: (Moussa, 2013)

- Acquire all of the required information as accurately and efficiently.
- All of the questions to be answered must be stated on a questionnaire.
- Irrelevant and badly worded questions must be avoided.
- The questions should be simple and direct.
- The interview should take minimum time.
- The interview should cause minimum burden to the respondent.
- The number of open questions should be minimized.

The questionnaire was divided into three major sections as detailed below. (Ortuzar and Willumsen, 2011).

Part 1 (Household characteristics): In this part of questionnaire design the household socio economic information are gathered which include, address of the household, family size, types of the house, ownership of the house, type of occupation, household monthly income, education level, age and gender of the members in the house, number of employed people, number of unemployed people, number of student, vehicle ownership, type of vehicles, and service year of the vehicles etc.

Part 2 (Personal characteristics): In this part of questionnaire design the Information required from each member of the household of six years of age or more are categorise according to the following aspects, relation to the head of the household (e.g. wife, son), sex, age, possession of a driving license, educational level, and occupation type.

Part 3 (Trip data): In this part of questionnaire design all the trip made by each member of the household of six years of age or more are detect and characterize. A trip is defined as any movement greater than 300 meters from an origin to a destination with a given purpose. The required information's are: origin and destination place, trip purpose, time of the day, trip start and ending times (trip duration), arrival frequency, trip distance, trip cost, mode of travel.

3.6 Method of Survey

After the questionnaire is prepared the actual survey is conduct. There are several methods of survey with their advantage and disadvantage. Before selecting the appropriate methods, there is need to know the sample size, the budget, the response rate, the size of study area and characteristics of surveyed people. In this research the Household Interview Survey (HIS) method will be used to collect data from the households because it is much effective and valuable over the other methods, as it is considered as the best method to provide suitable and detailed data about travel activity and behaviour of individual in each household. Interview was conducted for 421 households daily on Friday, Saturday and Sunday afternoon from 2:00 P.M to 6:00 P.M. During these hours most of the household heads and other family members were available for interview, because each member of the household should answer about their own travel details except for children below 15 years. Trip details of children below 6 years are normally ignored.

3.7 Model Estimation

The trip production aim is to estimate the total number of trips produced in each zone and relate it with the characteristics of the individuals and zones. In this research the trip production model will be estimated. Estimation is the process of developing trip models. After providing observed values, the trip production model estimate model coefficients by solving multiple regressions and multiple cross classification method equation using both the dependent and the explanatory variables. From the actual trip patterns the observed values of variables are found. The estimation process is a trial and error, which means that look for the parameter values which have the greatest chance of being accurate within acceptable error.

In this research the trip production models are divided into two major categories. Which is home based trip production model using multiple regression method and homebased trip production model using multiple cross classification method.

3.7.1 Trip Production Modelling and Statistical Test by Multiple Regression

Trip production modelling by multiple linear regression technique (MLR) is used to estimate trip rates.

To confirm the multiple linear regression model significant and validity some check and tests must be conducted.

Correlation analysis was performed to determine the strength of association between the dependent and independent variables. Goodness of fit is accounting for a large proportion of the total variance in the dependent variable. Also, the linearity between the dependent and the independent variables was checked using scatter plot.

The multicollinearity is the inter correlation of independent variables uses when two or more independent variables involved in the model. Its check independent variables are linearly correlated for each other. To assess multicollinearity uses tolerance or variance inflation factor (VIF), this is construct in the regressing of each independent variable on all the others. Tolerance is 1 - R^2 for the regression. The higher the inter correlation of the independents, the more the tolerance will approach zero. VIF is the reciprocal of tolerance, the larger value of VIF indicate the greater the degree of multicollinearity between each independent variables.

Then, the normality, non-auto regression and non-stochastic are checked that the residual is normally distributed, random and not correlated prediction respectively using a histogram and scatter plot of the residuals.

3.7.2 Trip Production Modelling and Statistical Test by Multiple Classification Analysis

Trip production modelling by multiple classification analysis (MCA) is used to estimate trip rates due to its ability to overcome the problems of regression as an extension of analysis of variance (ANOVA).

The grand mean is calculating to construct multiple cross classification matrix which can be estimated for the dependent variable. Also, group means can be estimated for each row and column of the cross-classification matrix. Use a weighted mean for each of the group means of one independent variable over the groupings of the other independent variables rather than a simple mean when relations are present to decrease the sizes of the adjustments to the grand mean.

To determine the strongest associations to trip making and the best grouping through ANOVA there is some statistical test to allow the estimation true.

F statistic used to test the whole significant of the model. A high significant F shows that the variable is strongly associated with the trip rate. F-test is used to test whether the coefficients for the dependent variables are equal to zero or at least one of the coefficient is not equal to zero.

The t-test is used to test the significance of individual coefficients by comparing alternative independent variables.

The R^2 (coefficient of determination) measures the goodness of fit of the model. It indicates the size of deviations from dependent variable that can be explained by the independent variables included in the model. The value of R is in the range of 0 - 1.A value nearer to 0 indicates that the model has poor fit.

4. RESULTS AND DISCUSSION

This section discuss briefly the home based trip production modelling by using both multiple linear regression (MLR) and multiple classification analysis (MCA) in household level and compare the results to select the best model for the study area, Also compare each of independent variables to select the significant one. This modelling was done by software programme SPSS by categorizing the similar character variable in one to make it suitable to the modelling. Table 4.1 shows the dependent and independent variables used in SPSS software with their syntax and description for both grouped and non-grouped variables.

Table 4.1: Independent variable with grouping

Independent Variables	Description	Ranges	Label	Categories
HHsize (ungrouped)	Number of household member	1-12		One(1),Two(2), Three(3), Four(4), Five(5), Six(6), Seven(7), Eight(8), Nine(9),Ten(10), Eleven(11) and Twelve(12) persons in HH
HHsize1 (grouped)	Number of household member 1	1-3	1	One, Two and Three persons in HH
			2	Four, Five and Six persons in HH
			3	Seven and more persons in HH
Htype	Housing type	1-4	1	Single floor House
			2	Condominium
			3	Apartment
			4	Multi-storey Building
Hown	Housing ownership	1-3	1	Own
			2	Rent
			3	Other
Age	Household head age	1-5	1	Age 29 and less
			2	Age between 30 to 39
			3	Age between 40 to 49
			4	Age between 50 to 59
			5	Age 60 and more
Gender	Household head gender	1-2	1	Male
			2	Female
Otype	Occupation type of household head	1-6	1	Government employee
			2	Private company
			3	NGO
			4	Employer
			5	Self employed
			6	Other
HHincome	Household Income	1-3	1	Low income

(grouped)	Level		2	Middle income
			3	High income
HHincome1 (ungrouped)	Household Income Level 1	1-6	1	Less than 2,000 birr
			2	Between 2,001 to 5,000 birr
			3	Between 5,001 to 10,000 birr
			4	Between 10,001 to 20,000 birr
			5	Between 20,001 to 30,000 birr
			6	More than 30,001 birr
EDU	Education Level of household head	1-6	1	Primary school and below
			2	High school and Preparatory
			3	Certificate and Diploma
			4	Degree
			5	Master's degree
			6	Doctoral degree
Nvehicle	Number of vehicles owned in household	0-3	0	No vehicles
			1	One vehicles
			2	Two vehicles
			3	Three and more vehicles
Dlicence	Driving licence	1-2	1	Yes
			2	No
Nemp	Number of employed person in the household	0-5		Zero(0),One(1),Two(2), Three(3), Four(4) and Five(5) person in HH
Nmale	Number of male in the household	0-6		Zero(0),One(1),Two(2),Three(3), Four(4), Five(5) and Six(6) persons in HH
Nfemale	Number of female in the household	0-7		Zero(0)One(1),Two(2), Three(3), Four(4), Five(5) ,Six(6) and Seven(7) persons in HH
Nlicence	Number of licenced driver in the household	0-5		Zero(0)One(1),Two(2), Three(3), Four(4) and Five(5) person in HH

4.1 Descriptive Data Analysis

In this part, the descriptive analysis shows by relating socioeconomic characteristic of households with the number of daily trips which are the most frequent with each of the independent variables by using tables and figure. The variables used for the descriptive data analysis are classified by three main groups (household characteristic, personal characteristic and trip characteristics) according to questionnaire design in appendix A include: household income, household size , housing type, the number of vehicles and the number of total trips, trip distances and duration, trip purposes etc.

1. Household Characteristics

Table 4.2: Descriptive statistics for household characteristics

Descriptive Statistics (Household Characteristics)							
No.	**Independent Variables**	**Number**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
1	Household Districts	421	14	1	15	7.97	4.239
2	Household Size	421	11	1	12	4.36	2.046
3	Housing type	421	3	1	4	1.53	1.047
4	House Ownership	421	2	1	3	1.6	0.549
5	Household head age	421	61	19	80	44.69	11.655
6	Household head gender	421	1	1	2	1.15	0.355
7	Occupation type	421	5	1	6	4.02	1.699
8	Household Monthly Income	421	2	1	3	1.47	0.645
9	Education Level	421	5	1	6	2.03	1.043
10	Vehicle Ownership	421	3	0	3	0.19	0.555
11	Driving Licence	421	1	1	2	1.6	0.491

Household Districts

The number of the sample from each districts are different because the data collected based on population number rather than area of square kilometre or other characteristics, for example district 4 has the same percentage 6% comparing to other but it has the higher area with low population number. Unlikely, district 12 take a percentage of 7% with lower area.

Household Size

The average household size of Addis Ababa is 5.2 persons per household from (Addis Ababa City Office, 2017).but now; in this research data the average household size found to be 4.3 persons per household (1835 person divided by 421 household) form the selected sample.it shows a slight difference.

Housing Type

The percentage of housing type for living distributed 76 % in houses with single floor building, 7.4 % in condominium, 3.8 % in an apartment and 12.8 % in multi-storey building.

House Ownership

In the house ownership rate the rent house is take the highest percentage.

Age

The household head age were divided into five group's .Results show that the household head age between 40 to 49 obtain the highest percentage and age less than or equal to 29 were take the lowest value.

Gender

The results show that gender of household head separated 85.3 % to male and 14.7 % to female.

Occupation Type

In this the higher value is taken by self-employed which is 50 % and the lower values goes to NGO jobs which have 4 %.the ‘other’ part contain un employed, retired and all other out of this five specified jobs.

Household Monthly Income

The household monthly income level groups in to three. The Low income level takes the highest percentage 61 % which is counted money less than 5,000 birr. The middle income level (5,001-20,000 birr) take 30.6 % and higher income level (more than 20,001 birr) take the less which is 8.3 %.

Education Level

The results shows that more than two third of the sample have education level under 8 grade and high school with 37 % and 35 % respectively. It indicates that the population is less educated.

Vehicle Ownership

Most of the household do not have vehicle (86.7 %). The household with vehicle take small percentage (13.3 %).

Driving Licence

The majority of household member doesn’t have driving licensed (60 %) and (40 %) have it.

2. Personal Characteristics

Table 4.3: Descriptive statistics for personal characteristics

Descriptive Statistics (Personal Characteristics)							
No.	**Independent Variables**	**Number**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
1	Number of Employed	421	5	0	5	1.98	0.994
2	Number of Unemployed	421	4	0	4	0.88	0.975
3	Number of Student	421	5	0	5	1.39	1.205
4	Number of Males	421	6	0	6	2.05	1.132
5	Number of Females	421	7	0	7	2.26	1.284
6	Age of HH Members (< 18 yrs.)	285	5	0	5	1.98	0.998
7	Age of HH Members (18-29 yrs.)	264	4	0	4	1.84	0.888
8	Age of HH Members (30-50 yrs.)	337	5	1	6	1.72	0.614
9	Age of HH Members (51-65 yrs.)	112	2	0	2	1.26	0.498
10	Age of HH Members (> 65 yrs.	48	2	0	2	1.1	0.425
11	Number of Licenced Driver	421	5	0	5	0.69	0.833

Age of HH Members

The household member's age less than 18 and age 30 to 50 take the higher and competitive percentage. It indicates the study area population is more in the range of working and studying age group.

Gender

Female member of the household take a slight more percentage over male member. It's satisfied the data from stated in statistical agency of Ethiopia.

Employment

From the total of 1,832 people in data about 369 people which is 20 % of the population is Unemployed. 'Other' indicates the children age below 15 who has not educated either not working.

Number of Licenced Driver

The result shows that 39.19 % of household at least one person have driving licence with or without vehicle ownership in the household.

3. Trip Characteristics

Table 4.4: Descriptive statistics for trip characteristics

Descriptive Statistics (Trip Characteristics)							
No.	**Independent Variables**	**Number**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
1	Total Trips (TT)	421	18	1	19	5.33	3.243
2	Work trips (HBW)	411	7	1	8	2.18	1.146
3	School trips (HBSCH)	292	7	1	8	2.26	1.154
4	Shopping trips (HBS)	242	5	0	5	1.24	0.744
5	Other trips (HBO)	218	7	0	7	1.78	1.177
6	Trip Duration (min)	103,761	1105	5	1110	246.46	194.518
7	Trip Distance (km)	8,705	289	1	290	20.6767	21.75143
8	Trip Costs (birr)	14,308	156	0	156	33.99	27.512
9	Trips by Private Car	50	7	1	8	3.16	2.004
10	Trips by Taxi	369	11	1	12	2.74	1.807
11	Trips by Bus	239	7	1	8	1.85	1.115
12	Trips by Motor Cycle	35	2	1	3	1.37	0.598
13	Trips by Bajaj	76	2	1	3	1.17	0.473
14	Trips by Walk	234	7	1	8	2.09	1.317

Trip Purpose

In this research 2243 trip produce from 421 sample household with the trip rate of 1.22 trips/ person. Among this homebased work trip take 39.95% and homebased school take 29.38 % of all trip produced from the household.

Trip Duration, Distance and Cost

The total number of household 421 makes 2243 trips with trip duration of 103,761 min, distance 8,705 km and trip cost 14,308 from 1835 member of the household.

Transportation Mode

From the trip made by household members taxi users take the highest percentage (45.07%) of all trip, followed by waking trip which is 21.84 % for most of nearest trip.

4.2 Trip Production Modelling by Multiple Linear Regression (MLR)

4.2.1 Selection of Significant Variables for MLR

Trip production analysis using multiple regressions is starting by defining the dependent and independent variables. The selection of variables is based on previous studies or testing of significance of variables. The number of homebased trip produced from the household which is called dependent variables grouped in five such as:

Table 4.5: Dependent variables (trip purpose) selected to MLR modelling

No.	Dependent Variables	Syntax Name	Range	Mean	Std. Deviation
1.	Total Trip	TT	18	5.33	3.243
2.	Homebased Work Trip	HBW	7	2.18	1.146
3.	Homebased School Trip	HBSCH	7	2.26	1.154
4.	Homebased Shopping Trip	HBS	5	1.24	0.744
5.	Homebased Other Trip	HBO	9	1.78	1.177

For multiple regressions modelling independent variables which is the socio-economic characteristics of the sample household selected are presented below in table.

Table 4.6: Independent variables selected to MLR modelling

No.	Independent Variables	Syntax Name	Range	Mean	Std. Deviation
1	Household Size	HHsize	11	4.36	2.046
2	Household Head Gender	Gender	1	1.15	0.355
3	Education Level	EDU	5	2.03	1.043
4	Number of Vehicle owned	Nvehicle	3	0.19	0.555
5	Number of Employed	Nemp	5	1.98	0.994
6	Number of Unemployed	Nunemp	4	0.88	0.975
7	Number of Student	Nstu	5	1.39	1.205
8	Number of Male	Nmale	6	2.05	1.132
9	Number of Female	Nfemale	7	2.26	1.284
10	Household Head Age1	Age01	4	3.00	1.175
11	Household Income 1	HHincome1	5	2.52	1.139

The above selected variables first correlated with dependent variables or each other to analysis in SPSS. Correlation test is performed to determine the strength of association between the two variables. From table 1 in appendix B the total household trip best express by household size and education level has weak correlation. And homebased work trip has strong correlation (0.84) with number of employment and also, negative and weak correlation with household head gender. Homebased School trips correlate strongly and weakly with number of student and number of employed respectively. Simply homebased shopping and homebased other trips fairly correlated with number of vehicle. Household size strongly correlated with other independent variables, number of student, number of male and number of female.

The other thing is the normality test by calculating skewness and kurtosis values for the distribution of the dependent variables. If 95% of points lies in the range (-2, 2) then the errors are normally distributed. Table 2 and table 3 in appendix B show the normality and linearity of the model. The distribution of error must be normal. This assumption can be tested by normal probability plot. Figure below shows line plot of errors for data of the study area.

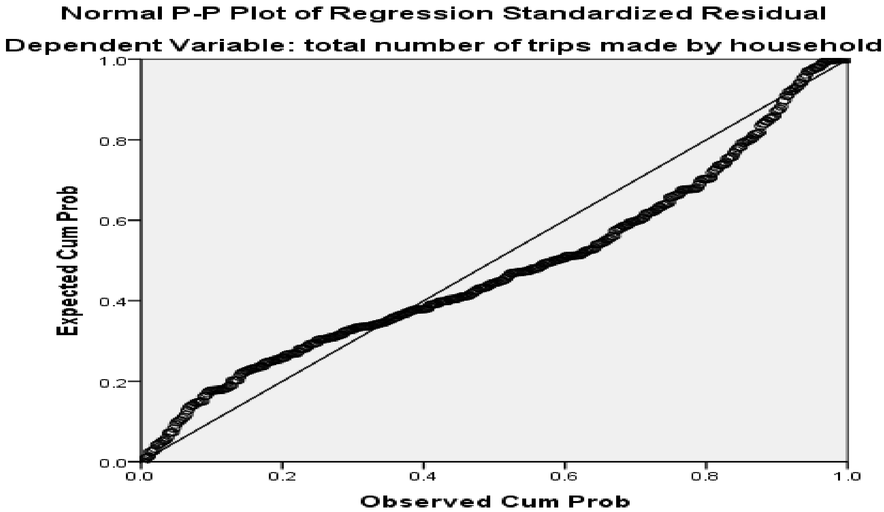

Figure 4.1: Normal p-p plot of regression standardized residual

4.2.2 Trip Production by MLR Model Estimation

Stepwise regression method was used for MLR modelling. The independent variable that has the largest F-statistic is chosen as the first entering variables. And statistic tests were conducted. The variables to determine should suite the selected F-statistic to enter criteria (Al-Zaidy, 2005). This technique needs F value Probability of entering equal to 0.05 and removal equal to 0.1.

The next step is ANOVA test for all models at 5% significance level to determine if the model is useful for predicting the response. The table 4 in appendix B shows the ANOVA tests for all five models. For all five trips purpose the results from ANOVA tests the significance level is less than 0.05 and all the null hypothesis are rejected.

The next important test is T-tests used to test the significance of individual b coefficients. Also to multicollinearity tests for each independent variable tolerance or VIF assessed. If independent variables inter correlate highly the tolerance will be zero, the (Variance-inflation factor) VIF also high and b & beta coefficients become unstable. The value for all models presented from table 5 to table 9 in appendix B. The results show for all trip purpose no indication of multicollinearity problem, because both tolerance and VIF values are greater than 0.2 and less than 10 respectively. And also the collinearity diagnostics table used to check multicollinearity (table 10 appendix B). The last thing is outlier check it shows in table 11 appendix B. Lastly trip production model presented for all trip purpose.

4.2.2.1 Total Trip (TT) by MLR

The total number of trip is highly affected by the variable household size with R^2 value of 0.603 from the total of eight variables in the modelling. The R^2 results of 0.524 in the TT model represent that 52.4% of trips influenced by the variation in the variables included in the model. The results in table below used to form MLR equation.

Table 4.7: Results of total trip production model for MLR

Variables	Coefficients	t	Sig.
(Constant)	0.746	1.801	0.072
HHsize	-0.851	-2.325	0.021
Nvehicle	1.265	5.505	0.000
Nfemale	1.963	5.224	0.000
Nmale	1.508	3.848	0.000
Nunemp	-0.507	-3.373	0.001
EDU	-0.535	-4.473	0.000
HHincome1	0.494	3.811	0.000
Age01	0.269	2.384	0.018
R square value for **TT** is, **R^2= 0.524 ,** Std. Error of the Estimate = **2.259**			

$$TT = 0.746 - 0.851HHsize + 1.265Nvehicle + 1.963Nfemale + 1.508Nmale - 0.507Nunemp - 0.535EDU + 0.494HHincome1 + 0.269Age01$$

4.2.2.2 Homebased Work Trip (HBW) by MLR

The HBW trips as expected highly affected by the number of employed person in the household with R^2 value of 0.841. This model represent by five variables as shown in table below. Also the variables in this model influence the trip strongly (73.5%).

Table 4.8: Results of HBW trip production model for MLR

Variables	Coefficients	t	Sig.
(Constant)	0.240	2.175	0.030
Nemp	0.878	25.827	0.000
Nvehicle	0.230	3.738	0.000
Age01	0.047	1.727	0.085
EDU	-0.097	-3.079	0.002
HHincome1	0.086	2.525	0.012
R square value for **HBW** is, **R^2= 0.735,** Std. Error of the Estimate = **0.594**			

$$HBW = 0.24 + 0.878Nemp + 0.23Nvehicle + 0.047Age01 - 0.097EDU + 0.086HHincome1$$

4.2.2.3 Homebased School Trip (HBSCH) by MLR

Like HBW trips the HBSCH expectedly influenced highly by number of student in the household with R^2 value of 0.832, Also this model is signified by six independent variables, which are listed below in the table. 77.2% of the HBSCH trips influenced by those six independent variables. This R^2 value for HBSCH trip is the highest from other models of homebased trips.

Table 4.9: Results of HBSCH trip production model for MLR

Variables	Coefficients	t	Sig.
(Constant)	1.270	8.106	0.000
Nstu	1.344	17.981	0.000
HHsize	-0.470	-6.864	0.000
Nemp	0.441	5.968	0.000
Nunemp	0.296	3.845	0.000
Gender	0.242	2.583	0.010
Age01	-0.081	-2.431	0.016
R square value for **HBSCH** is, **R^2= 0.772,** Std. Error of the Estimate =**0.556**			

$$HHSCH = 1.27 + 1.344Nstu - 0.47HHsize + 0.441Nemp + 0.296Nunemp + 0.242Gender - 0.081Age01$$

4.2.2.4 Homebased Shopping Trip (HBS) by MLR

The HBS trip is expected by number of vehicle owned by household and household monthly income with the value of R^2 0.534 and 0.43 respectively. The R^2 value of the final model was 0.447 which shows that the variables in the model are able to describe 44.7% of the total variation in the model.

Table 4.10: Results of HBS trip production model for MLR

Variables	Coefficients	t	Sig.
(Constant)	0.941	7.753	0.000
Nvehicle	0.515	6.799	0.000
Nemp	0.175	4.030	0.000
EDU	-0.226	-5.856	0.000
HHincome1	0.231	5.464	0.000
HHsize	-0.063	-3.046	0.003
R square value for **HBS** is, **R^2= 0.447,** Std. Error of the Estimate = **0.560**			

$$HBS = 0.941 + 0.515Nvehicle + 0.175Nemp - 0.226EDU + 0.231HHincome1 - 0.063HHsize$$

4.2.2.5 Homebased Other Trip (HBO) by MLR

The HBO trips weakly correlate with the most of variables in this model and also the R^2 value is weak to influence the model with those variables which is 0.271. The model is represented only by four variables. From these variables the number of vehicle ownership influences fairly this model with R^2 value of 0.367 than other three variables.

Table 4.11: Results of HBO trip production model for MLR

Variables	Coefficients	t	Sig.
(Constant)	1.359	6.327	0.000
Nvehicle	0.599	4.230	0.000
Nfemale	0.145	2.559	0.011
EDU	-0.343	-4.632	0.000
HHincome1	0.270	3.449	0.001
R square value for **HBO** is, **R^2= 0.271,** Std. Error of the Estimate = **1.015**			

$$HBO = 1.359 + 0.599Nvehicle + 0.145Nfemale - 0.343EDU + 0.27HHincome1$$

4.3 Trip Production Modelling by Multiple Classification Analysis (MCA)

4.3.1 Selection of Significant Variable for MCA

Before starting model estimation the variables which have appropriate significance in the model should be selected from collected data. The variable selection needed statistical tests to know the variables significance in the development of the model. So each variable in this study should pass through correlation and one way ANOVA test.

1. Pearson Correlation Test

It determines the strength of correlation between dependent and independent variables by calculating Pearson correlations test. The higher values of correlation test indicate that the variables can explain each other significantly in the model.

Therefore, as the results of the test presented in table 1 (appendix C) the best independent variables are household size for ungrouped variable (HHsize) and household size for grouped variables (HHsize1) for all dependent variables (trip purpose).

The household income level for ungrouped variables (HHincome1) and the household income level for grouped variables (HHincome), number of males in the household (Nmale) are also the next best results for all trip purpose.

The number of employed person in the household (Nemp) and number of students in the household (Nstu) are shows the highest correlation values, 0.841 for home based work trips (HBW) and 0.834 for home based school trips (HBSCH) respectively.

The number of employed person in the household (Nemp), numbers of vehicles owned in household (Nvehicles) and number of licenced drivers in the household (Nlicence) are significant for all trip purpose except home based school trips (HBSCH).Similarly, number of females in the household (Nfemale) and household head age (HHage) are also significant except in home based shopping trips (HBS).therefore, this five variables should wait the results of one way ANOVA test to include in the model.

Lastly, The other variables such as housing type (Htype),house ownership (Hown),household head gender (Gender), occupation type (Otype), education level (EDU),driving licence(Dlicence) and others omitted or excluded in the modelling of trip production. The final results of Pearson correlation test are summarized in table 4.12 below.

Table 4.12: Variable selection summaries in Pearson correlation test

Pearson correlation test results and variables selected to the model					
No.	Independent Variables	Result *	No.	Independent Variables	Result *
1	HHsize1	Included	9	Nfemale	Waiting
2	Hhsize	Included	10	Age	Waiting
3	HHincome	Included	11	Htype	Excluded
4	HHincome1	Included	12	Hown	Excluded
5	Nmale	Included	13	Gender	Excluded
6	Nvehicle	Waiting	14	Otype	Excluded
7	Nemp	Waiting	15	EDU	Excluded
8	Nlicence	Waiting	16	Dlicence	Excluded
Result *Included, Excluded or Waiting (one way ANOVA test)					

2. One Way ANOVA Test

The one way ANOVA test is essential to compare the alternative variables the high value of F test indicate that the independent variables are strongly associate to dependent variables.

The ANOVA test results presented in table 2 (appendix C).it results household size for grouped variables (HHsize1), number of employed person in the household (Nemp) and house hold income level for grouped variables (HHincome) are the significant variable in all trip purpose.

Number of employed person (Nemp) and number of student (Nstu) are show the highest variation for HBW trips F (4,406) = 246.87 and HBSCH trips F (5,286) = 145.15 respectively.

The house hold size for ungrouped variables (HHsize), number of males in the household (Nmale) and number of females in the household (Nfemale) are significant but shows insignificance for HBS(F(11,230) =1.55 ,F(5,236) =1.55 and F(7,234) =0.64 respectively) and HBO (F(11,206) =2.86 F(6,211) =3.54 and F(7,210) =2.70 respectively) trips.

Also, the number of licenced driver (Nlicence) and household income level for ungrouped variables (HHincome1) and number of owned vehicle in the household (Nvehicle) are shows insignificancy in HBSCH trips which is F(5,286) = 2.66 , F(5,286) = 2.38 and F(3,288) = 1.36 respectively. Except HBSCH trips all other trip purpose are significant.

The household head age (Age) is exclude in the modelling which is in waiting in correlation test also insignificant in F-test for all trip purposes.

The variable included in the modelling of trip production according to correlation and F test are HHsize,HHsize1,HHincome,HHincome1,Nemp,Nvehicle,Nmale,Nfemale and Nlicence.

The selected variables model by using two dimensional multiple cross classification matrix for each of five trip purposes.

4.3.2 Trip Production by MCA Model Estimation

For estimation purpose ANOVA test was done again to determine the best grouping of data to use. The results of the procedure presented in table 3 Appendix C by using Multivariate ANOVA test. Then the following five models in each trip purpose are the results of the test.

4.3.2.1 Total Trip (TT) by MCA

The total trip produced significant in the variables household size 1(HHsize1) which is grouped in three categories ((1, 2, 3 person), (4, 5, 6 person) and (7+ person)). Number of vehicle owned in the HH grouped in two which is Nvehicle with four categories (0 vehicle,1 vehicle, 2 vehicle and 3+ vehicle) and Nvehicle1 with two categories(0 vehicle and 1+ vehicle).also number of employed in the HH grouped in to two such as Nemp with six categories (0 person,1 person,2 person, 3 person, 4 person and 5 person) and Nemp with three categories ((≤1 person)(2-3 person) and(≥4 person)).

Table 4.13: TT significant cross classification matrixes

No.	Cross Classification Matrixes	R^2	RMSE
1	HHsize1 ((1,2 , 3),(4,5,6),(7+)) and Nvehicle(0,1,2,3+)	0.485	2.481
2	Nveh1(0,1+) and Nemp(0,1,2,3,4,5)	0.448	2.848
3	Nveh1(0,1+) and Nemp1(≤1 ,2-3,≥4)	0.389	2.88

From the result in table 4.13, HHsize1 and Nvehicle have the higher R^2 value of 0.485 and the lower RMSE 2.481 selected to cross classification modelling. But all the value of R^2 for those three possible matrixes is moderate.

From table 4.14 the highest value in vehicle ownership zero for all household size categories. The all empty cell observed on vehicle ownership more than three with household size less than three people, this cell is less than suggested minimum observation of 25 due to small sample size.

Table 4.14: Number of household by household size1 and vehicle number (TT)

Household Size 1	Vehicle Ownership				Total
	0	1	2	3+	
(1,2,3)	143 (33.97%)	8 (1.90%)	1 (0.24%)	0 (0.0%)	152
(4,5,6)	181 (42.99%)	22 (5.22%)	4 (0.95%)	3 (0.71%)	210
7+	41 (9.74%)	8 (1.90%)	6 (1.42%)	4 (0.95%)	59
Total	365	38	11	7	421

The table 4.15 below shows the number of total trip produced in the household for each cell of combination.

Table 4.15: Number of total trips (TT) by household size 1 and vehicle number

Household Size 1	Vehicle Ownership				Total
	0	1	2	3+	
(1,2,3)	429	25	11	0	465
(4,5,6)	1012	169	48	27	1256
7+	350	54	54	55	513
Total	1791	248	113	82	2234

The table below calculate the total trip rates by dividing HH total trip by number of household.

Table 4.16: Conventional trip rates of total trip (TT)

Household Size 1	Vehicle Ownership				Total
	0	1	2	3+	
(1,2,3)	3	3.12	11	0	17.12
(4,5,6)	5.59	7.68	12	9	34.27
7+	8.54	6.75	9	13.75	38.04
Total	17.13	17.55	32	22.75	89.43

The table 4.17 shows that the values of grand mean 7.45 by calculating the mean of mean. Each of the average (mean) trip rates subtract from grand mean gives the deviations. The deviation results for column are -3.17,1.12 and 2.06 also for row -1.74,-1.60,3.22 and 0.13.Then, a cell value can be estimated by adding to the grand mean the row and column deviations corresponding to the cell.

Table 4.17: Multiple Cross Classification Matrix (TT)

Household Size 1	Vehicle Ownership				Average
	0	1	2	3+	
(1,2,3)	2.54	2.68	7.5	4.41	4.28
(4,5,6)	6.83	6.97	11.79	8.7	8.57
7+	7.77	7.91	12.73	9.64	9.51
Average	5.71	5.85	10.67	7.58	7.45

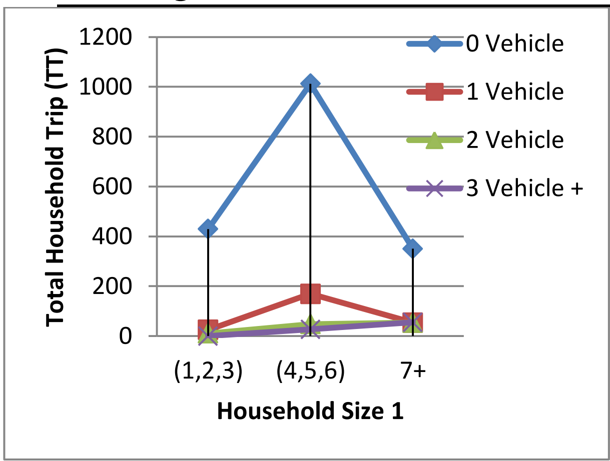

Figure 4.2: Number of TT by HHsize1 and number of vehicle

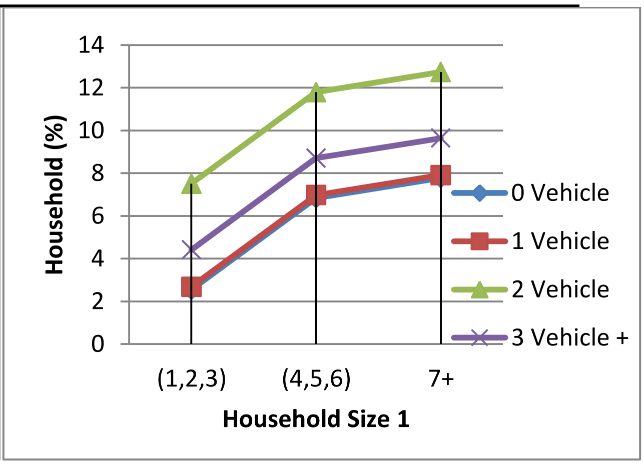

Figure 4.3: Trip Rates for MCA by HHsize1 and number of vehicle (TT)

4.3.2.2 Home Based Work Trip (HBW) by MCA

The HBW trip significant in the variables: Nvehicle1 (0 vehicle and 1+ vehicle), Nemp (0, 1, 2, 3, 4, 5) and Nlicence (0, 1, 2, 3, 4, 5).

Table 4.18: HBW significant cross classification matrixes

No.	Cross Classification Matrixes	R^2	RMSE
1	Nvehicle1(0,1+) and Nemp(0,1,2,3,4,5)	0.708	0.609
2	Nemp(0,1,2,3,4,5) and Nlicence(0,1,2,3,4,5)	0.716	0.612

From the result in table 4.18, Nemp and Nvehicle1 have the lower RMSE value 0.609 and equal R^2 value of 0.708 selected to cross classification modelling.

From table 4.19 employed numbers two with vehicle ownership zero high value and there are two cells empty.

Table 4.19: Number of household by employed number and vehicle number 1 (HBW)

Employed Number	Vehicle Number 1		Total
	0	1+	
0	0 (0%)	0 (0.0%)	0
1	130 (31.7%)	10 (2.4%)	140
2	149 (36.3%)	19 (4.6%)	168
3	54 (13.2%)	11 (2.7%)	65
4	19 (4.6%)	11 (2.7%)	30
5	2 (0.5%)	5 (1.2%)	7
Total	354	56	410

Table 4.20: Home based work trip (HBW) by employed number and vehicle number 1

Employed Number	Vehicle Number 1		Total
	0	1+	
0	0	0	0
1	146	16	162
2	318	49	367
3	170	35	205
4	77	46	123
5	9	26	35
Total	720	172	892

The values of cell in table 4.21 below is calculating by dividing HBW trips by number of HH

Table 4.21: Conventional trip rates of total trip (HBW)

Employed Number	Vehicle Number 1		Total
	0	1+	
0	0	0	0
1	1.12	1.6	2.72
2	2.14	2.58	4.72
3	3.15	3.18	6.33
4	4.05	4.18	8.23
5	4.5	5.2	9.7
Total	14.96	16.74	31.7

The table 4.22 shows that the values of grand mean 2.64 by calculating the mean of mean. Each of the average (mean) trip rates subtract from grand mean gives the deviations. The deviation results for column are -2.64,-1.28,-0.28,0.52,1.47 and 2.21 also for row -0.15 and

0.15.Then, a cell value can be estimated by adding to the grand mean the row and column deviations corresponding to the cell.

Table 4.22: Multiple Cross Classification Matrix (HBW)

Employed Number	Vehicle Number 1		Average
	0	1+	
0	-0.15	0.15	0
1	1.21	1.51	1.36
2	2.21	2.51	2.36
3	3.01	3.31	3.16
4	3.96	4.26	4.11
5	4.70	5.00	4.85
Average	2.49	2.79	2.64

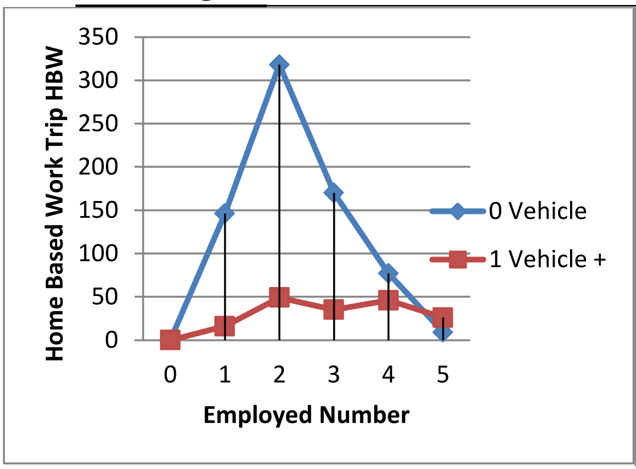

Figure 4.4: HBW trip by employed number and vehicle number 1

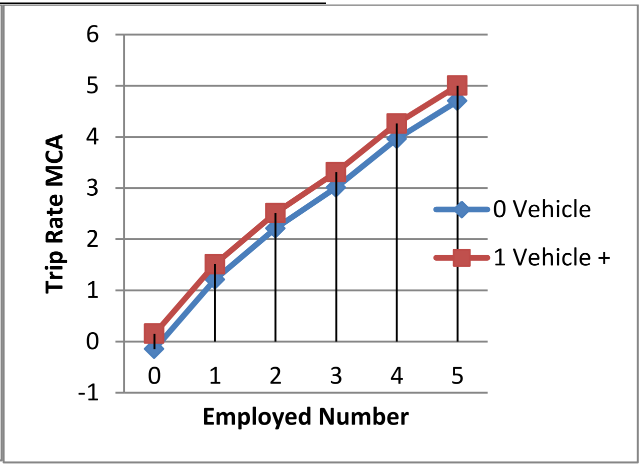

Figure 4.5: Trip Rates for MCA by Nemp and Nveh1 (HBW)

4.3.2.3 Home Based School Trip (HBSCH) by MCA

The HBSCH trip produced significant in the variables HHincome1 (6 group) ,Nmale1((≤1 person ,2-3 person, ≥4 person) , Nfemale (0,1,2,3,4,5,6,7) and HHsize1 ((1,2 , 3),(4,5,6),(7+)).

Table 4.23: HBSCH significant cross classification matrixes

No.	Cross Classification Matrixes	R^2	RMSE
1	Nstu1(≤1 ,2-3,≥4) and HHincome1(6 group)	0.735	0.683
2	Nstu1(≤1 ,2-3,≥4) and Nmale1 (≤1 ,2-3,≥4)	0.639	0.776
3	Nstu1(≤1 ,2-3,≥4) and HHsize1 ((1,2 , 3),(4,5,6),(7+))	0.652	0.762
4	Nstu1(≤1 ,2-3,≥4) and Nfemale1 (≤1 ,2-3,≥4)	0.645	0.769

From the result in table 4.23, Nstu1 and HHincome1 have the higher R^2 value of 0.735 and the lower RMSE 0.683 selected to cross classification modelling.

Table 4.24: Number of household by household income 1 and student number 1(HBSCH)

Household Income1	Student Number 1			Total
	≤ 1	2 - 3	≥ 4	
≤ 2000 br.	16	12	1	29
2,001-5,000 br.	47	74	7	128
5,001-10,000 br.	18	50	7	75
10,001-20,000 br.	11	13	6	30
20,001-30,000 br.	8	13	3	24
≥ 30,001 br.	1	4	1	6
Total	101	166	25	292

Table 4.25: Home based school trip (HBSCH) by household income 1 and student number 1

Household Income1	Student Number 1			Total
	≤ 1	2 - 3	≥ 4	
≤ 2000 br.	19	29	4	52
2,001-5,000 br.	58	186	28	272
5,001-10,000 br.	22	127	36	185
10,001-20,000 br.	12	41	23	76
20,001-30,000 br.	11	34	15	60
≥ 30,001 br.	1	9	4	14
Total	123	426	110	659

The trip rate is found by dividing HBSCH trips by HH number for each cell.

Table 4.26: Conventional trip rates of home based school trip (HBSCH)

Household Income1	Student Number 1			Total
	≤ 1	2 - 3	≥ 4	
≤ 2000 br.	1.19	2.42	4	7.61
2,001-5,000 br.	1.23	2.51	4	7.74
5,001-10,000 br.	1.22	2.54	5.14	8.9
10,001-20,000 br.	1.09	3.15	3.83	8.07
20,001-30,000 br.	1.37	2.61	5	8.98
≥ 30,001 br.	1	2.25	4	7.25
Total	7.1	15.48	25.97	48.55

The table 4.27 shows that the values of grand mean 2.69 by calculating the mean of mean. Each of the average (mean) trip rates subtract from grand mean gives the deviations. The deviation results for column are -0.15,-0.11,0.28,0,0.3 and -0.27 also for row -1.51,-0.11 and 1.64 .Then, a cell value can be estimated by adding to the grand mean the row and column deviations corresponding to the cell.

Table 4.27: Multiple Cross Classification Matrix (HBSCH)

Household Income1	Student Number 1			Average
	≤ 1	2 - 3	≥ 4	
≤ 2000 br.	1.03	2.43	4.18	2.54
2,001-5,000 br.	1.07	2.47	4.22	2.58
5,001-10,000 br.	1.46	2.86	4.64	2.97
10,001-20,000 br.	1.18	2.58	4.33	2.69
20,001-30,000 br.	1.48	2.88	4.63	2.99
≥ 30,001 br.	0.91	2.31	4.06	2.42
Average	1.18	2.58	4.33	2.69

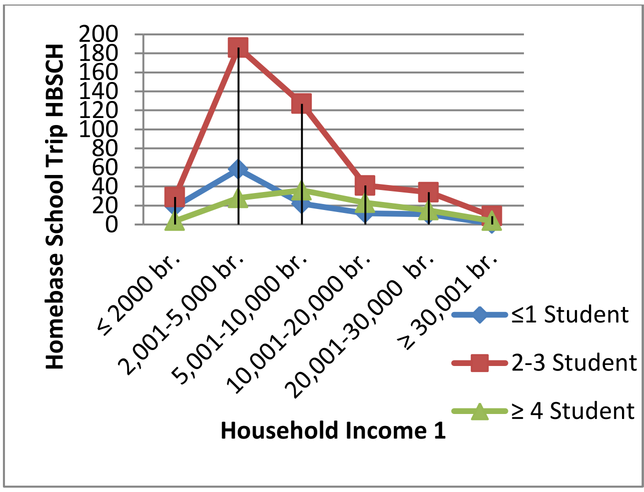

Figure 4.6: HBSCH by household income 1 and student number 1

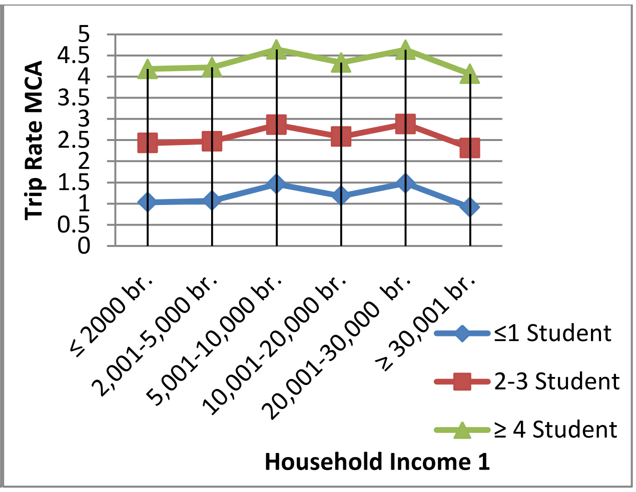

Figure 4.7: Trip Rates for MCA by HHincome1and Nstu1 (HBSCH)

4.3.2.4 Home Based Shopping Trip (HBS) by MCA

The HBS trip produced significant in the variables household size grouped in to two which are HHsize with 12 group and HHsize1 grouped in three ((1,2 , 3),(4,5,6),(7+)) and HHincome (low, middle, high). Number of vehicle grouped in to two which are Nvehicle (0,1,2,3+) and Nvehicle1(0,1+)and also number of employed grouped in to two which are Nemp(0,1,2,3,4,5) and Nemp1(1(≤1 ,2-3,≥4).

Table 4.28: HBS significant cross classification matrixes

No.	Cross Classification Matrixes	R^2	RMSE
1	HHsize1 ((1,2 , 3),(4,5,6),(7+)) and Nvehicle(0,1,2,3+)	0.412	0.628
2	HHsize(12group) and HHincome (low, middle, high)	0.490	0.649
3	Nvehicle1(0,1+) and Nemp(0,1,2,3,4,5)	0.401	0.637
4	Nveh1(0,1+) and Nemp1(≤1 ,2-3,≥4)	0.331	0.643
5	Nveh1(0,1+) and Nlicence(0,1,2,3,4,5)	0.359	0.623

From the result in table 4.28, HHsize and HHincome selected to cross classification modelling with R^2 value of 0.490 and the RMSE 0.649.the other correlations ignore because of low R^2 values.

From table 4.29 household size 5 with low household income take the highest number and there are eight empty cells.

Table 4.29: Number of household by household size and household income (HBS)

Household Size	Household Income			Total
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	6	1	0	13
2	23	4	0	27
3	21	12	1	34
4	26	15	3	44
5	28	27	3	58
6	18	13	2	33
7	9	8	4	21
8	3	3	3	9
9	0	3	0	3
10	0	1	0	1
11	0	1	0	1
12	0	0	1	1
Total	134	94	17	245

Table 4.30: Home based shopping trips (HBS) by household size and household income

Household Size	Household Income			Total
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	6	1	0	7
2	25	4	0	29
3	21	15	1	37
4	26	26	7	59
5	28	36	9	73
6	18	16	4	38
7	11	11	17	39
8	4	3	6	13
9	0	3	0	3
10	0	2	0	2
11	0	1	0	1
12	0	0	2	2
Total	139	118	46	303

Table 4.31: Conventional trip rates of home based shopping trip (HBS)

Household Size	Household Income			Total
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	1.00	1.00	0.00	2.00
2	1.09	1.00	0.00	2.09
3	1.00	1.25	1.00	3.25
4	1.00	1.73	2.33	5.06
5	1.00	1.33	3.00	5.33
6	1.00	1.23	2.00	4.23
7	1.22	1.37	4.25	6.84
8	1.33	1.00	2.00	4.33
9	0.00	1.00	0.00	1.00
10	0.00	2.00	0.00	2.00
11	0.00	1.00	0.00	1.00
12	0.00	0.00	2.00	2.00
Total	8.64	13.91	16.58	39.13

The table 4.32 shows that the values of grand mean 1.09 by calculating the mean of mean. Each of the average (mean) trip rates subtract from grand mean gives the deviations. The deviation results for column are -0.42,-0.39,-0.01,0.6,0.69,0.32,1.19,0.35,-0.76,-0.42 and -0.76 also for row -0.37,0.07 and 0.29 .Then, a cell value can be estimated by adding to the grand mean the row and column deviations corresponding to the cell.

Table 4.32: Multiple Cross Classification Matrix (HBS)

Household Size	Household Income			Average
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	0.3	0.74	0.96	0.67
2	0.33	0.77	0.99	0.7
3	0.71	1.15	1.37	1.08
4	1.32	1.76	1.98	1.69
5	1.41	1.85	2.07	1.78
6	1.04	1.48	1.7	1.41
7	1.91	2.35	2.57	2.28
8	1.07	1.51	1.73	1.44
9	-0.04	0.4	0.62	0.33
10	0.3	0.74	0.96	0.67
11	-0.04	0.4	0.62	0.33
12	0.3	0.74	0.96	0.67
Average	0.72	1.16	1.38	1.09

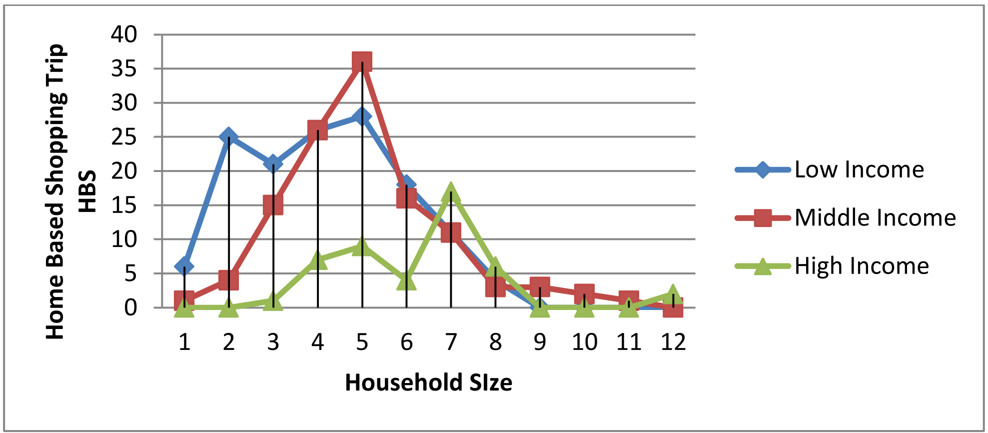

Figure 4.8: Number of home based shopping trip by household size and household income

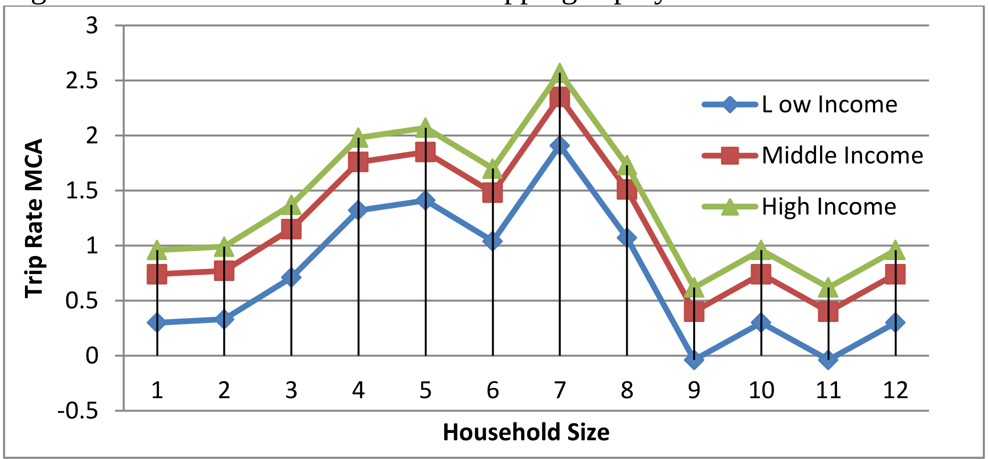

Figure 4.9: Trip Rates for MCA by HHsize and HHincome (HBS)

4.3.2.5 Home Based Other Trip (HBO) by MCA

The HBO trip produced significant in the variables household size grouped in to two which are HHsize with 12 group and HHsize1 grouped in three ((1,2 , 3),(4,5,6),(7+)).Also household income grouped in to two which is HHincome (low, middle, high) and HHincome1 with 6 group. The other variables are Nmale1 (≤1 person, 2-3 person, ≥4 person), Nemp(0,1,2,3,4,5) and Nlicence(0,1,2,3,4,5).

Table 4.33: HBO significant cross classification matrixes

No.	Cross Classification Matrixes	R^2	RMSE
1	HHsize(12group) and HHincome(low,middle,high)	0.429	1.081
2	HHsize(12group) and HHincome1(6 group)	0.501	1.088
3	HHincome1(6 group) and Nmale1 (≤1 ,2-3,≥4)	0.322	1.089
4	Nemp(0,1,2,3,4,5) and Nlicence(0,1,2,3,4,5)	0.35	1.091

From the result in table 4.33, HHsize and HHincome have the lowest RMSE value of 1.081 and the second high R^2 value of 0.429 selected to cross classification modelling, because the first model is too broad for cross classification matrix.

From table 4.34 the household size with low income has high value. This cross classification matrix is containing the ten cells with empty value.

Table 4.34: Number of household by household size and household income (HBO)

Household Size	Household Income			Total
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	9	3	0	12
2	19	3	0	22
3	14	7	1	22
4	19	11	5	35
5	28	25	4	57
6	18	14	1	33
7	8	8	3	19
8	4	3	3	10
9	0	3	0	3
10	0	1	0	1
11	0	1	0	1
12	0	0	1	1
Total	119	79	18	216

Table 4.35: Number of home based other trip (HBO) by household size and household income

Household Size	Household Income			Total
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	10	3	0	13
2	30	4	0	34
3	16	13	1	30
4	27	28	10	65
5	40	44	13	97
6	28	27	4	59
7	14	21	16	51
8	14	4	5	23
9	0	7	0	7
10	0	3	0	3
11	0	4	0	4
12	0	0	3	3
Total	179	158	52	389

The HBO trip rates for each cells is found to be with the ratio of HBO trip and HH number.

Table 4.36: Conventional trip rates of home based other trip (HBO)

Household Size	Household Income			Total
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	1.11	1.00	0.00	2.11
2	1.58	1.33	0.00	2.91
3	1.14	1.86	1.00	4.00
4	1.42	2.54	2.00	5.96
5	1.43	1.76	3.25	6.44
6	1.55	1.93	4.00	7.48
7	1.75	2.62	5.33	9.70
8	3.5	1.33	1.67	6.50
9	0.00	2.33	0.00	2.33
10	0.00	3.00	0.00	3.00
11	0.00	4.00	0.00	4.00
12	0.00	0.00	3.00	3.00
Total	13.48	23.7	20.25	57.43

The table 4.37 shows that the values of grand mean 1.59 by calculating the mean of mean. Each of the average (mean) trip rates subtract from grand mean gives the deviations. The deviation results for column are -0.89,-0.62,-0.26,0.4,0.56,0.9,1.64,0.57,-0.81,-0.59,-0.26 and -0.59 also for row -0.47,0.38 and 0.1 .Then, a cell value can be estimated by adding to the grand mean the row and column deviations corresponding to the cell.

Table 4.37: Multiple Cross Classification Matrix (HBO)

Household Size	Household Income			Average
	Low (< 5,000 br.)	Middle (5,001-20,000 br.)	High (>20,001 br.)	
1	0.23	1.08	0.8	0.7
2	0.5	1.35	1.07	0.97
3	0.86	1.71	1.43	1.33
4	1.52	2.37	2.09	1.99
5	1.68	2.53	2.25	2.15
6	2.02	2.87	2.59	2.49
7	2.76	3.61	3.33	3.23
8	1.69	2.54	2.26	2.16
9	0.31	1.16	0.88	0.78
10	0.53	1.38	1.1	1
11	0.86	1.71	1.43	1.33
12	0.53	1.38	1.1	1
Average	1.12	1.97	1.69	1.59

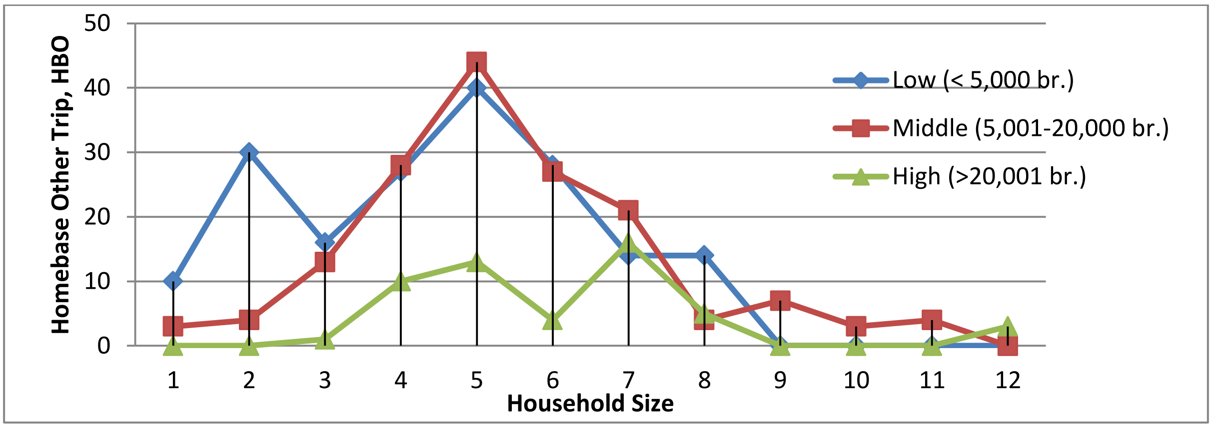

Figure 4.10: Number of home based other trip (HBO) by household size and household income

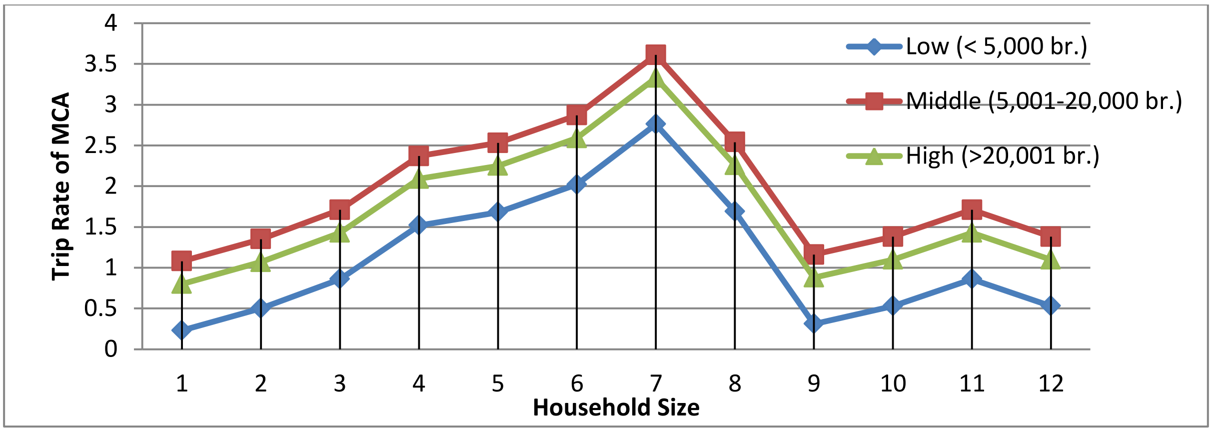

Figure 4.11: Trip Rates for MCA by household size and household income (HBO)

4.4 Comparison of MLR and MCA Trip Production Model

The difference between MLR and MCA models for five trip purpose developed in this section. The coefficient of determination (R^2) value of a model is considered as the measure of model accuracy. The table below shows the comparative analysis between modes.

Table 4.38: Comparison between MLR and MCA methods

Modelling Methods		Trip Purpose				
		TT	HBW	HBSCH	HBS	HBO
R^2	Multiple Classification Analysis (MCA)	0.485	0.708	0.735	0.49	0.429
	Multiple Linear Regression (MLR)	0.524	0.735	0.772	0.447	0.271
Difference (%)		7.44	3.67	4.79	8.77	36.83
Better Method		MLR	MLR	MLR	MCA	MCA

From the results of the above tables the multiple regression methods shows higher R^2 value for three models such as, TT, HBW and HBSCH trips. Also the multiple classification analysis takes the higher value of R^2 for HBS and HBO trips. To conclude this multiple regressions is the best methods for modelling homebased trip production in kolfe keranio sub city.

Also as mention before in selection of significant variables portion, the most significant variables for all five trip purpose are show in correlation table .Therefore, for total trip purpose the household size is the most significant variable among other with correlation value of 0.603.And, the other significant variable is number of employed person with correlation value of 0.841 for home based trip. The student number is also the highest significant variable for home based school trip with 0.832 values of correlation. For both homebased shopping and other trip the number of vehicles is the most significant one with 0.534 and 0.367 R value respectively. Lastly by comparing all the results the most significant variables to trip production in the study area is number of employed person in the household followed by number of student in the household and household size.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The main objective of this thesis is to develop a home based trip generation model for Kolfe Keranio sub city using a simple and suitable technique for suburb area.

The first objective of the analysis is to Identify appropriate alternative techniques of home based trip generation models, such as category analysis, multiple classification analysis multiple linear regressions ,growth factor method, tobit model, poisson model, ordered logit model, fuzzy optimization method, bayesian inference, and artificial neural networks .From those alternative method multiple linear regression and multiple classification analysis are select for model development of trip production.

The next objective of the thesis is developing a homebased trip production model by multiple linear regressions (MLR) and multiple classification analysis (MCA) method.

For trip production modelling by multiple linear regression method used eleven independent variables .this variables selected by correlated with dependent variables or each other by analysing in SPSS software. And the other tests are the normality and linearity check of dependent variables, also ANOVA test, T-tests and multicollinearity test were check for all eleven independent variables.

Then the model estimated using stepwise regression method in SPSS for all trip purposes resulted with high coefficient of determination (R^2) value 0.772 of home based school trip (HBSCH), which means that the six independent variables included in the model explain 77.2% of the HBSCH trip. From the six independent variables number of student (Nstu) is the most effective with coefficient of correlation value (R) 0.832.

Next to HBSCH trip the home based work trip (HBW) take the second rank in the value of R^2, which is 0.735.from five independent variables used for modelling HBW trip number of employed (Nemp) is the most effective with R value of 0.841.

The third model with R^2 value 0.524 is total trip (TT), from eight independent variables using for modelling TT is household size (HHsize) the most effective one (R=0.603). Then followed by homebased shopping trips (HBS) with R^2 value of 0.447, from five independent variables using for modelling HBS trip is number of vehicle owned (Nvehicle) the most effective one (R=0.534). Then homebased other trips (HBO) take the last value of R^2 (0.271), which is less than 0.3 and not significant for transportation planning in the study area, And from four independent variables using for modelling HBO trip is number of vehicle owned (Nvehicle) the most effective with R value of 0.534.

Then after model development the trip production modelling by MLR is calibrated by calculating root mean square error (RMSE) between observed and predicted travel demand for each of five trip purposes. And validate by using split validation method with 50:50 split ratio.

And the second method of trip production modelling is multiple classification analysis (MCA) which is the extension of category analysis modelled by using selected nine independent variables from sixteen independent variables tested by Pearson correlation and one way ANOVA test.

The trip production by MCA method estimated for five trip purposes with different independent variables combination using two dimensional multiple classification analysis matrix. The combination selected for modelling is tested by there value of coefficients of determination (R^2).

So, for the total trip (TT) purpose modelling the household size 1 (HHsize1) versus number of vehicle (Nvehicle) selected with high value of R^2 = 0.485 and lower value of RMSE=2.481 among other significant combination. Similarly, for homebased work trip (HBW) modelling the combination of number of employed (Nemp) versus number of vehicle 1(Nvehicle1) with value of R^2 = 0.708 and RMSE=0.609.And, for home based school trip (HBSCH) modelling select the combination of number of student1 (Nstu1) versus household income 1 (HHincome1) with R^2 = 0.735 and RMSE=0.683 values. Lastly, for the homebased shopping (HBS) and homebased other (HBO) trip modelling use HHsize versus HHincome with R^2 value of 0.490 & 0.429 and RMSE value of 0.649 & 1.081 respectively. However, the others variables and there combination are omitted from modelling.

After model estimation for trip production using MCA model calibrate for matching predicted travel with observed travel demand by using Goodness of fit measurement (F-test), R^2 and RMSE for all five of trip purposes. Then model validation

The third objective of this thesis is comparing the performance of multiple linear regression and multiple classification analysis methods for all trip purposes using coefficient of determination (R^2).Therefore, from the result MLR method is the best method for modelling TT, HBW and HBSCH trip and MCA is best for modelling of HBS and HBO trips in the kolfe keranio sub city.

The last objective for the thesis work is determine the household travel characteristic based on socio economic, individual and trip data collected in the study area. From the result the average household size of study area is 4.3 peoples per household. And, household size, household income, number of employed and student are the most significant variables.

5.2 Recommendations

There are some recommendations for further study:

- The future research can focus on trip attraction model by including non-home based trips with different independent variables and methods of modelling for KKSC.
- The researchers are encouraged to complete the rest of four steps of urban transport planning process: trip distribution, model choice and trip assignment modelling in KKSC.
- The researchers can validate the model by collecting new data with similar study for comparison.
- The future research can study the same trip production model in other sub city of the Addis Ababa city with different variables and trip purpose.
- Policy maker can use this research work as an initial model for further development of transport planning.

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Appendix A: Questionnaire Form

Trip Production Questionnaire (English Form)

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Questionnaire for a research about:

Developing Trip Generation Model for Suburb Area of a City: Case of Kolfe Keranio Sub City, Addis Ababa

This questionnaire was prepared for the partial fulfilment of the Master of Science in Road and Transport Engineering. It aims to study daily trips characteristics made by household and the pattern of these trips by developing a mathematical Trip production model for homebased trips in Kolfe Keranio Sub City, Addis Ababa for the purpose of predicting the future of transportation in a sub city.

The respondent chosen to fill this questionnaire should satisfy the following criteria.

1. The person should leave in kolfe keranio sub city

2. The person should mostly make homebased trip between 6:00 AM to12:00 PM

3. The person age should equal or older than 6 year

Please cooperate by filling the following questionnaire with facts. We insure you that every data and information in this questionnaire will be classified as restricted confidentially item and it will be preserved and used for the purpose of scientific research only.

"Thanks for your participation"

Prepared by: Hana Nega

Supervised by: Dr. Bikila Teklu

Part 1: Household Characteristics (Filled by the head of the household)

1. How many people live in your household including you? ………..………

2. Housing type

☐ Single floor House ☐ Condominium ☐ Apartment ☐ Multi-storey Building

3. Housing ownership

☐ Own ☐ Rent ☐ Other (Specify) …………..……

4. Occupation type

☐ Government employee ☐ private company ☐ NGO

☐ Employer ☐ Self-Employed ☐ Other (Specify) ………

5. Total household income level

☐ Less than 2,000 birr ☐ 10,001 - 20,000 birr

☐ 2,000 - 5,000 birr ☐ 20,001 - 30,000 birr

☐ 5,001 - 10,000 birr ☐ More than 30,000 birr

6. Education level

☐ Primary school and below ☐ Degree

☐ High school and preparatory ☐ Master Degree

☐ Certificate and Diploma ☐ Doctoral Degree

7. How many numbers of employed people in your household? …………..………

8. How many numbers of unemployed people in your household? …………..……

9. How many numbers of students in your household? …………..……

10. Did your family own a vehicle? (Motorcycle, Bajaj, car, taxi, pickup, mini bus, bus, truck)

☐ Yes ☐ No

11. If your answer is '**Yes**', fill the box below.

No.	Vehicle Model	Service Year
1		
2		

Part 2: Personal Characteristics (Filled by household member's age 6 and older including you)

Person No.	Age	Gender		Education Level*	Occupation Type**	Driving Licence		Work or Education Place
		Male	Female			Yes	No	
1								
2								
3								
4								
5								
6								
Education level *:- Primary school and below (**A**)፣ High school and preparatory (**B**)፣ Certificate and Diploma (**C**)፣ Degree(**D**)፣ Masters(**E**)፣Doctoral degree(**F**)								
Occupation type**:- Government employee (**A**)፣ private company (**B**)፣ NGO(**C**)፣ Employer (**D**)፣ Self-Employed (**E**)								

Part 3: trip characteristics (Filled by one regular working day trip number by household member's age 6 and older including you)

1. Origin and destination must be at trip maker **home.**

2. One trip is **300 meter** and above.

No.	Trip Purpose																			
	Homebased work					**Homebased School**					**Homebased Shoping**					**Homebased Other**				
	No. of Trip	Trip Duration (Min)	Trip Distance (KM)	Trip cost (Birr)	Transportation Method	No. of Trip	Trip Duration (Min)	Trip Distance (KM)	Trip cost (Birr)	Transportation Method	No. of Trip	Trip Duration (Min)	Trip Distance (KM)	Trip cost (Birr)	Transportation Method	No. of Trip	Trip Duration (Min)	Trip Distance (KM)	Trip cost (Birr)	Transportation Method
1																				
2																				
3																				
4																				
5																				
6																				
Transportation Method:-Private Car **(A)**፣ Taxi **(B)**፣ Bus **(C)**፣ Motor Cycle **(D)**፣Bajaj (E) ፣Waking **(F)**																				

Trip Production Questionnaire (Amharic Form)

አዲስ አበባ ዩኒቨርሲቲ
አዲስ አበባ የቴክኖሎጂ ተቋም
የሲቪል እና የኢንቫይሮመንታል ምህንድስና ትምህርት ቤት

የጥናታዊ ፅሁፍ መጠይቅ ስለ ፡
ጉዞዎች መነሻ ሞዴል ዝግጅት ከከተማ ወጣ ባለ ስፍራ ፤ በኮልፌ ቀራኒዮ ክፍለ ከተማ/ አዲስ አበባ

ይህ መጠይቅ የተዘጋጀው በ መንገድ እና ትራንስፖርት ምህንድስና ትምህርት ክፍል ለማስተርስ ዲግሪ መመረቂያ ፅሁፍ ጥናት ዝግጅት ነው።አላማው በኮልፌ ቀራኒዮ ክፍለ ከተማ ከቤት ለሚነሱ ጉዞዎች የጉዞዎች መነሻ ሞዴል ሂሳባዊ ቀመር በማዘጋጀት በየቀኑ የሚደረጉ ጉዞዎችን ባህሪ በማጥናት የወደፊቱን የትራንስፖርት ሁኔታ መገመት ነው።

ይህን መጠይቅ ለመሙላት የተመረጡ ምላሽ ሰጪዎች የሚከተሉትን መስፈርቶች ሊያሟሉ ይገባል።

1. ግለሰቡ በኮልፌ ቀራኒዮ ክፍለ ከተማ ነዋሪ መሆን አለበት።
2. ግለሰቡ በብዛት ከቤት የሚነሳ ጉዞ ከ ጠዋቱ 12:00 እስከ ምሽቱ 12:00 የሚያደርግ መሆን አለበት።
3. የግለሰቡ ዕድሜ 6 እና ከዚያ በላይ መሆን አለበት።

እባክዎ የሚከተለውን መጠይቅ በእውነታዎች በመሙላት ይተባበሩን::በዚህ መጠይቅ ውስጥ የሚገኝ ማንኛውም መረጃ ሚስጥራዊነቱ የተጠበቀ እና ለሳይንሳዊ ጥናት ብቻ የሚያገለግል መሆኑን እናረጋግጥሎታለን።

"ስለ ትብብሮ እናመሰግናለን"

አዘጋጅ፡ ሀና ነጋ

ሱፐርቫይዘር፡ ዶ/ር ቢቂላ ተክሉ

ክፍል 1.የቤተሰብ ባህሪያት (በቤተሰቡ አስተዳዳሪ የሚሞላ)

1. በቤተሰብዎ ውስጥ እርሶን ጨምሮ ስንት ሰዎች ይኖራሉ? ………..………

2. የቤትዎ አይነት

☐ ባለ 1 ጣሪያ ☐ ኮንዶሚኒየም ☐ አፓርታማ ☐ ባለ ፎቅ

3. የቤትዎ ባለቤትነት

☐ የራስዎ ☐ የኪራይ ☐ ሌላ ………..………

4.የስራ አይነት

☐ የመንግስት ሰራተኛ ☐ የግል ድርጅት ሰራተኛ ☐NGO

☐ ቀጣሪ ☐ የግል ስራ ሌላ ስራ………..………

5.ጠቅላላ የቤተሰብዎ ወርሃዊ ገቢ

☐ ከ 2,000 ብር በታች ☐ ከ 10,001 እስከ 20,000 ብር

☐ ከ 2,000 እስከ 5,000 ብር ☐ ከ 20,001 እስከ 30,000 ብር

☐ ከ 5,001 እስከ 10,000 ብር ☐ ከ 30,000 ብር በላይ

6.የትምህርት ደረጃ

☐ 8ኛ ክፍል እና ከዚያ በታች ☐ ዲግሪ

☐ ከሁለተኛ ደረጃ እስከ መሰናዶ ☐ ማስተርስ

☐ ሰርተፊኬት እና ዲፕሎማ ☐ ዶክትሬት ዲግሪ

7.በቤተሰብዎ ውስጥ ስንት ስራ ያለው ሰው አለ? ………….………

8.በቤተሰብዎ ውስጥ ስንት ሰራ -አጥ አለ? ………….………

9.በቤተሰብዎ ውስጥ ስንት ተማሪ አለ? ………….………

10.በቤትዎ ውስጥ መኪናዎች አሉ? (ሞተር ሳይክል ፣ ባጃጅ፣የቤት መኪና፣ ታክሲ፣ ፒክ አፕ፣ባስ....)

☐ አዎ ☐ አይ

11.መልሰ ‘’አዎ’’ ከሆነ ከታች ያለውን ሳጥን ይሙሉ

ተ.ቁ	የመኪናዎ ሞዴል	ያገለገለበት አመት
1		
2		

ክፍል 2.የግል ባህሪያት (እርሶን ጨምሮ ዕድሜያቸው 6 እና ከዛ በላይ በሆኑ የቤተሰብ አባላት ብቻ የሚሞላ)

የቤተሰብ ተ.ቁ	ዕድሜ	ጾታ		የትምህርት ደረጃ*	ስራ**	የመንጃ ፈቃድ		የስራ ወይም የትምህርት ቦታ
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የትምህርት ደረጃ *:- 8 ኛ ክፍል(**ሀ**)፣ ሁለተኛ ደረጃ(**ለ**)፣ ሰርቲፊኬት እና ዲፕሎማ(**ሐ**)፣ ዲግሪ(**መ**)፣ ማስተርስ(**ሰ**)፣ዶክትርት ዲግሪ(**ረ**)								
ስራ**:-የመንግስት ሰራተኛ (**ሀ**)፣የግል ድርጅት ሰራተኛ(**ለ**)፣ NGO(**ሐ**)፣ቀጣሪ(**መ**)፣ የግል ስራ(**ሰ**)								

ክፍል 3.የጉዞ ባህሪያት (እርሶን ጨምሮ ዕድሜያቸው 6 እና ከዛ በላይ በሆኑ የቤተሰብ አባላት በመደበኛ የስራ ቀናት በሚደረግ **የአንድ ቀን** የጉዞ ብዛት የሚሞላ)

1. መነሻ ወይም መድረሻ ቦታ **ቤት** መሆን አለበት
2. አንድ ጉዞ **300 ሜትር** እና ከዛ በላይ ነው

ተ.ቁ.	የጉዞ ምክኒያት																			
	ወደ ስራ					**ወደ ትምህርት**					**ወደ ገበያ**					**ወደ ሌላ**				
	የጉዞ ብዛት	የጉዞ ሰዓት (በደቂቃ)	የጉዞ ርቀት (ኪ.ሜ)	የጉዞ ዋጋ (ብር)	የሚጠቀሙት የትራንስፖርት አይነት	የጉዞ ብዛት	የጉዞ ሰዓት (በደቂቃ)	የጉዞ ርቀት (ኪ.ሜ)	የጉዞ ዋጋ (ብር)	የሚጠቀሙት የትራንስፖርት አይነት	የጉዞ ብዛት	የጉዞ ሰዓት (በደቂቃ)	የጉዞ ርቀት (ኪ.ሜ)	የጉዞ ዋጋ (ብር)	የሚጠቀሙት የትራንስፖርት አይነት	የጉዞ ብዛት	የጉዞ ሰዓት (በደቂቃ)	የጉዞ ርቀት (ኪ.ሜ)	የጉዞ ዋጋ (ብር)	የሚጠቀሙት የትራንስፖርት አይነት
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የሚጠቀሙት የትራንስፖርት አይነት:-የግል መኪና (**ሀ**)፣ ታክሲ (**ለ**)፣ ባስ (**ሐ**)፣ ሞተር ሳይክል (**መ**)፣ ባጃጅ (**ሰ**) ፣በእግር(**ረ**)																				

Appendix B: Statistical Analysis of Trip Production by MLR in SPSS

Table 1: correlation between dependent and independent variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	**TT**	1															
2	**HBW**	0.636**	1														
3	**HBSCH**	0.504**	0.096	1													
4	**HBS**	0.732**	0.590**	0.149*	1												
5	**HBO**	0.762**	0.426**	0.204**	0.675**	1											
6	**HHsize**	0.603**	0.399**	0.470**	0.150*	0.298**	1										
7	**Gender**	-0.137**	-0.072	-0.040	-0.006	-0.093	-0.188**	1									
8	**EDU**	-0.051	0.054	-0.029	-0.070	-0.141*	0.043	-0.109*	1								
9	**Nvehicle**	0.391**	0.419**	0.079	0.534**	0.367**	0.237**	-0.120*	0.200**	1							
10	**Nemp**	0.437**	0.841**	-0.018	0.399**	0.276**	0.467**	-0.059	0.113*	0.361**	1						
11	**Nunemp**	0.256**	0.001	0.061	-0.080	0.210**	0.625**	-0.119*	-0.001	0.031	-0.015	1					
12	**Nstu**	0.502**	0.045	0.832**	-0.007	0.160*	0.731**	-0.162**	0.006	0.108*	0.019	0.270**	1				
13	**Nmale**	0.448**	0.359**	0.300**	0.173**	0.268**	0.802**	-0.285**	0.098*	0.265**	0.405**	0.538**	0.537**	1			
14	**Nfemale**	0.573**	0.310**	0.441**	0.099	0.275**	0.837**	-0.036	-0.027	0.128**	0.363**	0.506**	0.666**	0.375**	1		
15	**Age01**	0.421**	0.344**	0.125*	0.148*	0.209**	0.526**	-0.110*	-0.035	0.188**	0.326**	0.399**	0.306**	0.419**	0.454**	1	
16	**HHincome1**	0.408**	0.421**	0.166**	0.430**	0.310**	0.387**	-0.174**	0.427**	0.480**	0.403**	0.121*	0.244**	0.358**	0.277**	0.272**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2: measure of normality for all trip purpose

Descriptive Statistics						
Model		**TT**	**HBW**	**HBSCH**	**HBS**	**HBO**
N		421	411	292	242	218
Range		18	7	7	5	7
Mean		5.33	2.18	2.26	1.24	1.78
Std. Deviation		3.243	1.146	1.154	.744	1.177
Skewness	**Statistic**	1.553	1.137	1.267	2.874	1.606
	Std. Error of Skewness	0.119	0.120	0.143	0.156	0.165
Kurtosis	**Statistic**	2.953	1.629	2.915	7.968	2.471
	Std. Error of Kurtosis	0.237	0.240	0.284	0.312	0.328

Table 3: model summary for all trip purpose

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
TT	0.724[a]	0.524	0.515	2.259	0.007	5.686	1	412	0.018
HBW	0.857[b]	0.735	0.731	0.594	0.004	6.373	1	405	0.012
HBSCH	0.879[c]	0.772	0.768	0.556	0.005	5.911	1	285	0.016
HBS	0.668[d]	0.447	0.435	0.560	0.022	9.277	1	236	0.003
HBO	0.520[e]	0.271	0.257	1.015	0.041	11.897	1	213	0.001

a. Predictors: (Constant), HHsize, Nvehicles , Nfemale, Nmale , Nunemp, EDU, HHincome1,Age01
b. Predictors: (Constant), Nemp, Nvehicle, Age01, EDU, HHincome1
c. Predictors: (Constant), Nstu, HHsize, Nemp, Nunemp, Gender, Age01
d. Predictors: (Constant), Nvehicle, Nemp, EDU, HHincome1, HHsize
e. Predictors: (Constant), Nvehicle, Nfemale, EDU, HHincome1

Table 4: ANOVA tests for all trip purpose

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
TT	Regression	2313.464	8	289.183	56.646	0.000[a]
	Residual	2103.301	412	5.105		
	Total	4416.765	420			
HBW	Regression	395.658	5	79.132	224.085	0.000[b]
	Residual	143.018	405	0.353		
	Total	538.676	410			
HBSCH	Regression	299.523	6	49.921	161.284	0.000[c]
	Residual	88.213	285	0.310		
	Total	387.736	291			
HBS	Regression	59.641	5	11.928	38.076	0.000[d]

	Residual	73.933	236	0.313		
	Total	133.574	241			
HBO	Regression	81.419	4	20.355	19.757	0.000[e]
	Residual	219.448	213	1.030		
	Total	300.867	217			

a. Predictors: (Constant), HHsize, Nvehicle, Nfemale, Nmale, Nunemp, EDU, HHincome1, Age01
b. Predictors: (Constant), Nemp, Nvehicle, Age01, EDU, HHincome1
c. Predictors: (Constant), Nstu, HHsize, Nemp, Nunemp, Gender, Age01
d. Predictors: (Constant), Nvehicle, Nemp, EDU, HHincome1, HHsize
e. Predictors: (Constant) Nvehicle, Nfemale, EDU, HHincome1

Table 5: stepwise regression model for total trips

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	**Std. Error**	**Beta**	**t**	**Sig.**	**Zero-order**	**Partial**	**Part**	**Tolerance**	**VIF**
TT	(Constant)	0.746	0.414		1.801	0.072					
	HHsize	-0.851	0.366	-0.537	-2.325	0.021	.603	-0.114	-0.079	0.022	46.087
	Nvehicle	1.265	0.230	0.216	5.505	0.000	.391	0.262	0.187	0.748	1.338
	Nfemale	1.963	0.376	0.777	5.224	0.000	.573	0.249	0.178	0.052	19.153
	Nmale	1.508	0.392	0.526	3.848	0.000	.448	0.186	0.131	0.062	16.186
	Nunemp	-0.507	0.150	-0.152	-3.373	.001	0.256	-0.164	-0.115	0.567	1.765
	EDU	-0.535	0.120	-0.172	-4.473	.000	-0.051	-0.215	-0.152	0.781	1.281
	HHincome1	0.494	0.130	0.173	3.811	.000	0.408	0.185	0.130	0.558	1.792
	Age01	0.269	0.113	0.097	2.384	.018	0.421	0.117	0.081	0.691	1.446

Table 6: stepwise regression model for home based work trips

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	**Std. Error**	**Beta**	**t**	**Sig.**	**Zero-order**	**Partial**	**Part**	**Tolerance**	**VIF**
HBW	(Constant)	0.240	0.110		2.175	0.030					
	Nemp	0.878	0.034	0.761	25.827	0.000	0.841	0.789	0.661	0.755	1.325
	Nvehicle	0.230	0.062	0.112	3.738	0.000	0.419	0.183	0.096	0.736	1.359
	Age01	0.047	0.027	0.048	1.727	0.085	0.344	0.086	0.044	0.847	1.181
	EDU	-0.097	0.032	-0.089	-3.079	0.002	0.054	-0.151	-0.079	0.792	1.263
	HHincome1	0.086	0.034	0.085	2.525	0.012	0.421	0.124	0.065	0.579	1.728

Table 7: stepwise regression model for home based school trips

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
HBSCH	(Constant)	1.270	0.157		8.106	0.000					
	Nstu	1.344	0.075	1.404	17.981	0.000	0.832	0.729	0.508	0.131	7.634
	HHsize	-0.470	0.068	-0.833	-6.864	0.000	0.470	-0.377	-0.194	0.054	18.434
	Nemp	0.441	0.074	0.380	5.968	0.000	-0.018	0.333	0.169	0.197	5.071
	Nunemp	0.296	0.077	0.250	3.845	0.000	0.061	0.222	0.109	0.189	5.300
	Gender	0.242	0.094	0.074	2.583	0.010	-0.040	0.151	0.073	0.963	1.039
	Age01	-0.081	0.033	-0.083	-2.431	0.016	0.125	-0.143	-0.069	0.690	1.449

Table 8: stepwise regression model for home based shopping trips

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
HBS	(Constant)	0.941	0.121		7.753	0.000					
	Nvehicle	0.515	0.076	0.384	6.799	0.000	0.534	0.405	0.329	0.736	1.359
	Nemp	0.175	0.044	0.234	4.030	0.000	0.399	0.254	0.195	0.694	1.441
	EDU	-0.226	0.039	-0.317	-5.856	0.000	-0.070	-0.356	-0.284	0.799	1.251
	HHincome1	0.231	0.042	0.354	5.464	0.000	0.430	0.335	0.265	0.560	1.786
	HHsize	-0.063	0.021	-0.174	-3.046	0.003	0.150	-0.194	-0.148	0.722	1.385

Table 9: stepwise regression model for home based other trips

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
HBO	(Constant)	1.359	0.215		6.327	0.000					
	Nvehicle	0.599	0.142	0.282	4.230	0.000	0.367	0.278	0.248	0.770	1.300
	Nfemale	0.145	0.057	0.158	2.559	0.011	0.275	0.173	0.150	0.897	1.115
	EDU	-0.343	0.074	-0.304	-4.632	0.000	-0.141	-0.303	-0.271	0.794	1.259
	HHincome1	0.270	0.078	0.261	3.449	0.001	0.310	0.230	0.202	0.599	1.669

Table 10: Collinearity Diagnostics

Model	Dimension	1	2	3	4	5	6	7	8	9
TT	**Eigenvalue**	7.064	0.862	0.492	.0206	0.138	0.110	0.075	0.050	0.003
	Condition Index	1.000	2.862	3.788	5.859	7.154	8.015	9.678	11.914	52.635
HBW	**Eigenvalue**	4.746	0.807	0.203	0.114	0.078	0.051			
	Condition Index	1.000	2.424	4.830	6.450	7.825	9.611			

HBSCH	**Eigenvalue**	5.829	0.525	0.346	0.180	0.082	0.031	0.007		
	Condition Index	1.000	3.333	4.104	5.692	8.411	13.799	29.147		
HBS	**Eigenvalue**	4.744	0.800	0.213	0.101	0.074	0.067			
	Condition Index	1.000	2.435	4.716	6.837	8.003	8.403			
HBO	**Eigenvalue**	3.803	0.807	0.235	0.084	0.071				
	Condition Index	1.000	2.170	4.025	6.724	7.325				

Table 11: Residual Statistics for all models

	Residuals Statistics					
MODEL		**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**N**
TT	**Predicted Value**	-0.20	13.42	5.33	2.347	421
	Std. Predicted Value	-2.357	3.450	0.000	1.000	421
	Residual	-7.922	10.254	0.000	2.238	421
	Std. Residual	-3.506	4.538	0.000	0.990	421
HBW	**Predicted Value**	-0.02	5.69	2.18	0.982	421
	Std. Predicted Value	-2.237	3.573	0.000	1.000	421
	Residual	-2.206	2.706	-0.031	0.593	411
	Std. Residual	-3.712	4.554	-0.051	0.998	411
HBSCH	**Predicted Value**	0.43	5.09	2.26	1.015	421
	Std. Predicted Value	-1.797	2.790	0.000	1.000	421
	Residual	-1.718	3.204	-0.449	0.747	292
	Std. Residual	-3.088	5.759	-0.807	1.342	292
HBS	**Predicted Value**	0.01	3.68	1.24	0.497	421
	Std. Predicted Value	-2.457	4.912	0.000	1.000	421
	Residual	-1.771	2.771	-0.021	0.574	242
	Std. Residual	-3.165	4.951	-0.037	1.026	242
HBO	**Predicted Value**	0.25	4.67	1.78	0.613	421
	Std. Predicted Value	-2.497	4.703	0.000	1.000	421
	Residual	-2.110	5.209	-0.108	1.027	218
	Std. Residual	-2.079	5.132	-0.106	1.011	218

Appendix C: Statistical Analysis of Trip Production by MCA in SPSS

Table 1: Pearson Correlation Tests

Pearson Correlation Test						
1. Ungrouped Variables						
		Dependent Variables (Trip purpose)				
Independent Variables	**Test**	**TT**	**HBW**	**HBSCH**	**HBS**	**HBO**
Household Size (HHsize)	Pearson Correlation	0.603**	0.399**	0.470**	0.150*	0.298**
	Sig. (2-tailed)	0.000	0.000	0.000	0.020	0.000
	N	421	411	292	242	218
Housing type (Htype)	Pearson Correlation	0.156**	0.120*	0.064	0.049	0.070
	Sig. (2-tailed)	0.001	0.015	0.275	0.449	0.301
	N	421	411	292	242	218
House Ownership (Hown)	Pearson Correlation	-0.241**	-0.133**	-0.154**	-0.109	-0.180**
	Sig. (2-tailed)	0.000	0.007	0.008	0.092	0.008
	N	421	411	292	242	218
Household head age (Age)	Pearson Correlation	0.428**	0.353**	0.164**	0.125	0.207**
	Sig. (2-tailed)	0.000	0.000	0.005	0.051	0.002
	N	421	411	292	242	218
Household head gender (Gender)	Pearson Correlation	-0.137**	-0.072	-0.040	-0.006	-0.093
	Sig. (2-tailed)	0.005	0.147	0.494	0.922	0.172
	N	421	411	292	242	218
Occupation type (Otype)	Pearson Correlation	-0.116*	-0.097*	0.000	-0.041	0.003
	Sig. (2-tailed)	0.017	0.048	0.998	0.525	0.963
	N	421	411	292	242	218
Education Level (EDU)	Pearson Correlation	-0.051	0.054	-0.029	-0.070	-0.141*
	Sig. (2-tailed)	0.298	0.271	0.620	0.275	0.038
	N	421	411	292	242	218
Number of vehicles (Nvehicle)	Pearson Correlation	0.391**	0.419**	0.079	0.534**	0.367**
	Sig. (2-tailed)	0.000	0.000	0.180	0.000	0.000
	N	421	411	292	242	218
Driving licence (Dlicence)	Pearson Correlation	-0.174**	-0.168**	-0.044	-0.251**	-0.137*

	Sig. (2-tailed)	0.000	0.001	0.451	0.000	0.044
	N	421	411	292	242	218
Number of employed person (Nemp)	Pearson Correlation	0.437**	0.841**	-0.018	0.399**	0.276**
	Sig. (2-tailed)	0.000	0.000	0.759	0.000	0.000
	N	421	411	292	242	218
Number of unemployed person (Nunemp)	Pearson Correlation	0.256**	0.001	0.061	-0.080	0.210**
	Sig. (2-tailed)	0.000	0.991	0.297	0.212	0.002
	N	421	411	292	242	218
Number of student (Nstu)	Pearson Correlation	0.502**	0.045	0.832**	-0.007	0.160*
	Sig. (2-tailed)	0.000	0.365	0.000	0.915	0.018
	N	421	411	292	242	218
Number of males (Nmale)	Pearson Correlation	0.448**	0.359**	0.300**	0.173**	0.268**
	Sig. (2-tailed)	0.000	0.000	0.000	0.007	0.000
	N	421	411	292	242	218
Number of females (Nfemale)	Pearson Correlation	0.573**	0.310**	0.441**	0.099	0.275**
	Sig. (2-tailed)	0.000	0.000	0.000	0.125	0.000
	N	421	411	292	242	218
Number of persons under 18 years(Age1)	Pearson Correlation	0.057	-0.093	0.497**	-0.133	-0.075
	Sig. (2-tailed)	0.338	0.120	0.000	0.075	0.349
	N	285	282	273	181	158
Number of persons between 18 and 29 years (Age2)	Pearson Correlation	0.234**	0.351**	0.117	-0.009	0.126
	Sig. (2-tailed)	0.000	0.000	0.115	0.908	0.120
	N	264	261	183	162	154
Number of persons between 30 and 50 years (Age3)	Pearson Correlation	0.148**	0.129*	0.153*	-0.034	-0.046
	Sig. (2-tailed)	0.007	0.018	0.015	0.644	0.550
	N	337	332	250	191	172
Number of persons between 51 and 65 years(Age4)	Pearson Correlation	0.172	0.120	0.046	0.170	0.078
	Sig. (2-tailed)	0.070	0.212	0.660	0.127	0.487
	N	112	110	93	82	81
Number of persons more than 65years (Age5)	Pearson Correlation	0.311*	0.053	0.426**	0.123	0.374*
	Sig. (2-tailed)	0.031	0.731	0.009	0.461	0.013
	N	48	45	37	38	43

Number of licenced driver (Nlicence)	Pearson Correlation	0.369**	0.470**	0.071	0.369**	0.266**
	Sig. (2-tailed)	0.000	0.000	0.229	0.000	0.000
	N	421	411	292	242	218
Household Income Level 1 (HHincome1)	Pearson Correlation	0.408**	0.421**	0.166**	0.430**	0.310**
	Sig. (2-tailed)	0.000	0.000	0.004	0.000	0.000
	N	421	411	292	242	218
2. Grouped Variables						
Household Income Level (HHincome)	Pearson Correlation	0.412**	0.406**	0.152**	0.445**	0.344**
	Sig. (2-tailed)	0.000	0.000	0.009	0.000	0.000
	N	421	411	292	242	218
Household Size 1 (HHsize1)	Pearson Correlation	0.598**	0.377**	0.411**	0.233**	0.346**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
	N	421	411	292	242	218
Household head age 01 (Age01)	Pearson Correlation	0.421**	0.344**	0.125*	0.148*	0.209**
	Sig. (2-tailed)	0.000	0.000	0.033	0.021	0.002
	N	421	411	292	242	218
Number of employed person 1 (Nemp1)	Pearson Correlation	0.389**	0.773**	-0.053	.328**	0.213**
	Sig. (2-tailed)	0.000	0.000	0.368	0.000	0.002
	N	421	411	292	242	218
Number of unemployed person 1 (Nunemp1)	Pearson Correlation	0.200**	0.052	0.037	-0.055	0.180**
	Sig. (2-tailed)	0.000	0.293	0.526	0.394	0.008
	N	421	411	292	242	218
Number of student 1 (Nstu1)	Pearson Correlation	0.464**	0.072	0.781**	0.034	0.173*
	Sig. (2-tailed)	0.000	0.142	0.000	0.604	0.010
	N	421	411	292	242	218
Number of males 1 (Nmale1)	Pearson Correlation	0.458**	0.338**	0.268**	0.181**	0.280**
	Sig. (2-tailed)	0.000	0.000	0.000	0.005	0.000
	N	421	411	292	242	218
Number of females 1 (Nfemale1)	Pearson Correlation	0.516**	0.281**	0.309**	0.077	0.240**
	Sig. (2-tailed)	0.000	0.000	0.000	0.236	0.000
	N	421	411	292	242	218
Number of licenced driver	Pearson Correlation	0.284**	0.290**	0.008	0.234**	0.219**

1 (Nlicence1)	Sig. (2-tailed)	0.000	0.000	0.889	0.000	0.001
	N	421	411	292	242	218
Number of vehicles (Nvehicle1)	Pearson Correlation	0.327**	0.328**	0.105	0.453**	0.294**
	Sig. (2-tailed)	0.000	0.000	0.072	0.000	0.000
	N	421	411	292	242	218
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

Table 2: ANOVA Test results for variables

ANOVA Test							
1. Grouped Variables							
			Dependent Variables				
Independent variables	**Test**		**TT**	**HBW**	**HBSCH**	**HBS**	**HBO**
HHsize	**df**	**Between**	11	11	10	11	11
		Within	388	378	262	209	185
		Total	399	389	272	220	196
	F		51.525	9.464	15.952	4.401	3.228
	Sig.		0.000	0.000	0.000	0.000	0.000
Htype	**df**	**Between**	3	3	3	3	3
		Within	396	386	269	217	193
		Total	399	389	272	220	196
	F		6.907	3.527	.607	.316	.858
	Sig.		0.000	0.015	0.611	0.814	0.464
Hown	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		19.603	3.926	4.693	2.848	3.628
	Sig.		0.000	0.021	0.010	0.060	0.028
Age	**df**	**Between**	52	50	45	50	48
		Within	347	339	227	170	148
		Total	399	389	272	220	196
	F		4.083	2.352	2.118	1.166	1.073
	Sig.		0.000	0.021	0.010	0.060	0.028
Gender	**df**	**Between**	52	50	45	50	48
		Within	347	339	227	170	148
		Total	399	389	272	220	196
	F		4.083	2.352	2.118	1.166	1.073
	Sig.		0.000	0.000	0.000	0.234	0.366
Otype	**df**	**Between**	5	5	5	5	5

		Within	394	384	267	215	191
		Total	399	389	272	220	196
	F		2.215	0.638	1.426	.530	.635
	Sig.		0.052	0.671	0.215	0.754	0.673
HHincome	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		15.627	18.678	2.865	.773	1.440
	Sig.		0.000	0.000	0.059	0.463	0.239
EDU	**df**	**Between**	5	5	5	5	5
		Within	394	384	267	215	191
		Total	399	389	272	220	196
	F		0.194	0.919	0.407	0.177	0.877
	Sig.		0.965	0.469	0.844	0.971	0.497
Nvehicle	**df**	**Between**	3	3	3	3	3
		Within	396	386	269	217	193
		Total	399	389	272	220	196
	F		2.971	11.350	1.789	0.096	0.633
	Sig.		0.032	0.000	0.150	0.962	0.594
Dlicence	**df**	**Between**	1	1	1	1	1
		Within	398	388	271	219	195
		Total	399	389	272	220	196
	F		1.059	2.107	0.239	0.007	1.377
	Sig.		0.304	0.147	0.625	0.936	0.242
Nemp	**df**	**Between**	5	4	5	5	5
		Within	394	385	267	215	191
		Total	399	389	272	220	196
	F		13.699	310.493	.639	4.324	2.542
	Sig.		0.000	0.000	0.670	0.001	0.030
Nunemp	**df**	**Between**	5	4	5	4	4
		Within	393	384	267	216	192
		Total	398	388	272	220	196
	F		17.550	3.704	2.286	4.902	13.324
	Sig.		0.000	0.006	0.047	0.001	0.000
Nstu	**df**	**Between**	5	5	5	5	5
		Within	392	382	267	214	190
		Total	397	387	272	219	195
	F		63.661	1.905	173.530	0.416	2.751
	Sig.		0.000	0.093	0.000	0.837	0.020
Nmale	**df**	**Between**	6	6	6	5	6
		Within	393	383	266	215	190
		Total	399	389	272	220	196

	F		28.848	10.158	6.852	3.966	3.348
	Sig.		0.000	0.000	0.000	0.002	0.004
Nfemale	**df**	**Between**	7	7	7	7	7
		Within	391	381	265	213	189
		Total	398	388	272	220	196
	F		67.358	6.750	21.480	6.893	4.917
	Sig.		0.000	0.000	0.000	0.000	0.000
Nlicence	**df**	**Between**	5	5	5	5	5
		Within	322	315	221	183	164
		Total	327	320	226	188	169
	F		5.048	18.071	3.168	.628	.346
	Sig.		0.000	0.000	0.009	0.679	0.884
2. Ungrouped Variables							
HHsize1	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		164.204	31.117	34.715	5.446	12.295
	Sig.		0.000	0.000	0.000	0.005	0.000
Age01	**df**	**Between**	4	4	4	4	4
		Within	395	385	268	216	192
		Total	399	389	272	220	196
	F		23.814	10.788	1.149	0.663	1.666
	Sig.		0.000	0.000	0.334	0.618	0.160
HHincome1	**df**	**Between**	5	5	5	5	5
		Within	394	384	267	215	191
		Total	399	389	272	220	196
	F		9.293	9.993	1.823	.601	.987
	Sig.		0.000	0.000	0.109	0.700	0.427
Nemp1	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		30.475	381.041	1.041	8.038	4.832
	Sig.		0.000	0.000	0.355	0.000	0.009
Nunemp1	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		22.894	4.548	2.447	8.421	14.460
	Sig.		0.000	0.011	0.088	0.000	0.000
Nstu1	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		104.732	1.498	243.282	.418	4.012

	Sig.		0.000	0.225	0.000	0.659	0.020
Nmale1	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		66.226	23.120	13.030	2.082	8.452
	Sig.		0.000	0.000	0.000	0.127	0.000
Nfemale1	**df**	**Between**	2	2	2	2	2
		Within	397	387	270	218	194
		Total	399	389	272	220	196
	F		139.956	18.732	19.938	3.467	12.136
	Sig.		0.000	0.000	0.000	0.033	0.000
Nlicence1	**df**	**Between**	1	1	1	1	1
		Within	398	388	271	219	195
		Total	399	389	272	220	196
	F		21.540	22.051	.001	1.075	2.172
	Sig.		0.000	0.000	0.979	0.301	0.142
Nvehicle1	**df**	**Between**	1	1	1	1	1
		Within	398	388	271	219	195
		Total	399	389	272	220	196
	F		5.456	12.814	2.835	0.130	0.727
	Sig.		0.020	0.000	0.093	0.719	0.395

Table 3: Multivariate ANOVA tests for model TT (HHsize1, Nvehicle).

Statistics		**Trip Purpose**				
		TT	**HBW**	**HBSCH**	**HBS**	**HBO**
F		60.57	29.45	12.61	20.37	12.69
Df	**Between**	5	5	5	5	5
	Within	415	405	286	236	212
	Total	420	410	291	241	217
Sig.		0.000	0.000	0.000	0.000	0.000
R^2		0.485	0.38	0.192	0.412	0.285
Eta-square	**HHsize1**	0.598	0.391	0.415	0.248	0.368
	Nvehicle	0.395	0.429	0.118	0.536	0.384
Significant Interaction		Yes	No	No	Yes	No

Table 4: Multivariate ANOVA tests for model HBW (Nemp, Nvehicle1).

Statistics		**Trip Purpose**				
		TT	**HBW**	**HBSCH**	**HBS**	**HBO**
F		21.76	208.7	1.02	15.6	6.29
Df	**Between**	6	5	6	6	6
	Within	414	405	285	235	211
	Total	420	410	291	241	217
Sig.		0.000	0.000	0.420	0.000	0.000
R^2		0.448	0.708	0.06	0.401	0.262
Eta-square	**Nemp**	0.443	0.842	0.101	0.438	0.341
	Nvehicle1	0.327	0.328	0.118	0.453	0.294
Significant Interaction		Yes	Yes	No	Yes	Yes

Table 5: Multivariate ANOVA tests for model HBSCH (HHincome1, Nmale1).

Statistics		**Trip Purpose**				
		TT	**HBW**	**HBSCH**	**HBS**	**HBO**
F		29.834	15.559	67.33	11.777	4.94
Df	**Between**	7	7	7	7	7
	Within	413	403	284	234	210
	Total	420	410	291	241	217
Sig.		0.000	0.000	0.000	0.000	0.000
R^2		0.507	0.377	0.735	0.418	0.243
Eta-square	**Nstu1**	0.472	0.110	0.786	0.105	0.181
	HHincome1	0.438	0.440	0.200	0.489	0.357
Significant Interaction		No	No	Yes	No	No

Table 6: Multivariate ANOVA tests for model HBS and HBO (HHsize,HHincome).

Statistics		**Trip Purpose**				
		TT	**HBW**	**HBSCH**	**HBS**	**HBO**
F		26.32	11.86	12.09	6.79	4.1
Df	**Between**	13	13	12	13	13
	Within	407	397	279	228	204
	Total	420	410	291	241	217
Sig.		0.000	0.000	0.000	0.000	0.000
R^2		0.608	0.471	0.527	0.490	0.501
Eta-square	**HHsize**	0.644	0.435	0.579	0.262	0.364
	HHincome	0.412	0.428	0.167	0.496	0.35
Significant Interaction		No	No	No	Yes	Yes