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Travel demand modeling for developing countries

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Travel Demand Modeling For Developing Countries

by

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ABSTRACT

The transportation planning process or travel demand forecasting process which is most commonly used at present, called the Urban Transportation Planning Process (UTPP), has its origins in studies performed about three decades ago in urban areas in the United States. This conventional planning process was designed primarily for the western/developed world where affordability and accessibility to a personal automobile is a common feature.

The UTPP based models used in forecasting future travel demand rely heavily on socio-economic variables that are associated with an individual's propensity to travel. The socio-economic environments in the developing and the under-developed world are different from that prevailing in the developed world. Many urban areas in the third-world contain a mix of ethnic groups or households with structural differences in income and social characteristics. Thus, a direct application of the methodology of the UTPP may not be relevant to developing countries in third-world settings.

The main objectives of this research are to study the travel characteristics and sensitivity of key factors affecting travel demand of the people in the third world and to develop a framework that allows for the treatment of different groups based on one or more socio-economic features, such as income, household size etc.

Trip generation models are developed to study the travel behavior in a third world city, Dar-es-Salaam, capital of Tanzania, located in Africa. The study area is divided into 33 traffic analysis zones, and data for 22 zones of the 33 were available for this study. Typical Downtown, Residential, and Industrial areas are chosen for study. The influence of key trip generation socio-economic variables such as income, household size, age etc.,

are evaluated, and models developed for different groups under consideration. A marked variation is observed in the behavior of people depending upon where they reside. A single model for the entire study area proved to be unsatisfactory, thus highlighting some of the short-comings of the conventional process. Therefore, several models were calibrated. The travel behavior of individuals in the medium income group is less predictable. High income groups show a definite behavior. Also, recommendations are made to develop strategies to improve data collection procedures, in order to obtain accurate household information. Walk is a major mode of transport and thus, requires serious consideration in terms of mode choice calibration. Improvements in the operations of transit facilities and services, frequency, travel fare are likely to affect the travel behavior of the poor to a large extent. Other important variables not included in the study, such as distance to the downtown area, labor force in the household, ethnic origin etc., may prove to be significant in better explaining and forecasting travel demand. The terms "third-world" and "developing countries" are used interchangeably throughout the work.

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CHAPTER 1

INTRODUCTION

WHY TRANSPORTATION PLANNING?

An urban transportation system is a basic component of an urban areas's social, economic, and physical structure. Not only does transportation system provide opportunities for mobility, but over the long term, it influences patterns of growth and the level of economic activity through the accessibility it provides to land. Urban transportation issues are concerned primarily with the movement of people and goods between origins and destinations within an urban area. This movement can be carried out through a variety of modes, use different energy sources, and serve different needs. At the level of the individual traveler, urban transportation is a trip from an origin to a destination to accomplish some activity at the destination. At the level of a metropolitan region, transportation demand is the aggregate of thousands, or, in some cases, millions of individual trip-making decisions. These decisions result in passenger trips, using various modes, over the transportation facilities provided in an urban area during specific time periods (travel flows). A transportation system, thus consists of the facilities and services that allow these travel flows throughout an urban area. The characteristics of urban travel flows and the facilities that permit such travel are basic to understanding current and future transportation needs. Planning for the development or maintenance of the urban transportation system is an important activity, both for promoting the efficient movement of people and goods in an urban area and for maintaining the strong supportive role that transportation can play in attaining other community objectives.

A rational approach could be used for the process of planning transportation systems or an approach that seeks to furnish unbiased information about the effects that a proposed transportation project will have on the community and its expected users. Transportation planning processes in urban areas are defined at different levels of complexity and purpose. While transit planners examine alternative service configurations, traffic engineers might identify problems with traffic flows on the highway network, regional planners might study urban development patterns and the provision of public services, individual employers might be considering alternative employee transportation programs, and social service agencies might be examining transportation options to improve delivery of their services to the general public. With different groups and organizations concurrently conducting transportation planning activities in an urban area, the requirements of these planning efforts will vary from one group to the next.

The models used in forecasting future travel demand rely heavily on socio-economic variables that are associated with individual's propensity to travel. Among such variables are income, family size, gender and age of the trip maker, type of employment, and vehicle ownership etc. Also, spatial and network characteristics, such as distance to the Central Business District, accessibility to the downtown area, link speeds and capacity influence the trip makers' choice of transportation mode. These factors influence the travel pattern of an area and affect the number of trips generated in an area. A detailed study of the land-use developments and socio-economic characteristics of an area is needed in order to develop a safe and efficient transportation system.

THE TRANSPORTATION PLANNING PROCESS

Transport planning studies have been conducted in a large number of urban areas throughout the world during the past few decades (see Chapter 2: Literature review). A process for conducting these studies has developed, and is still evolving, while attempts are being made to provide a systematic method for travel demand forecasting to help solve

urban transport problems. The planning process that is most commonly used at present, called the Urban Transportation Planning Process (UTPP), has its origins in studies performed in several cities in the United States during the 1950-1960 period, particularly in Detroit and Chicago [Hutchinson, 1974]. Figure 1 shows the principal elements of the process developed for the Chicago Area Transportation Study [Hutchinson, 1974]. While more recent transport studies have made significant contributions to the development of land-use prediction models, travel-demand forecasting methods, and evaluation procedures, most of these studies have been organized within the same framework developed for the Chicago study.

The UTPP is a formalized planning methodology designed to provide guidelines and priorities for future transportation investment, and construction of urban transport infrastructure and facilities. An integral part of the UTPP is travel demand forecasting, which consists of four distinct steps: Trip Generation, Trip Distribution, Mode Split, and Traffic Assignment. The UTPP is discussed briefly next.

In the traditional UTPP, an urban area is divided into spatial analysis units, called traffic analysis zones (TAZs) which form the basis for analysis of travel movements within, into, and out of the urban area. This division is based on several criteria including homogeneity of socio-economic characteristics of each zone's population, homogeneity of land-use characteristics of the zones, reduction in the number of intrazonal trips, and zonal boundaries based on census units such as blocks and tracts.

Trip Generation is the process of determining the number of trips that will begin or end in each TAZ within the study area. Each trip has two ends: production end and attractions end. For trips that have an end at home, the home end of the trip is considered, by destination, to be the production end and the other end the attraction. These trips are known as home-based trips. Trips are further described in terms of trip purposes (Home

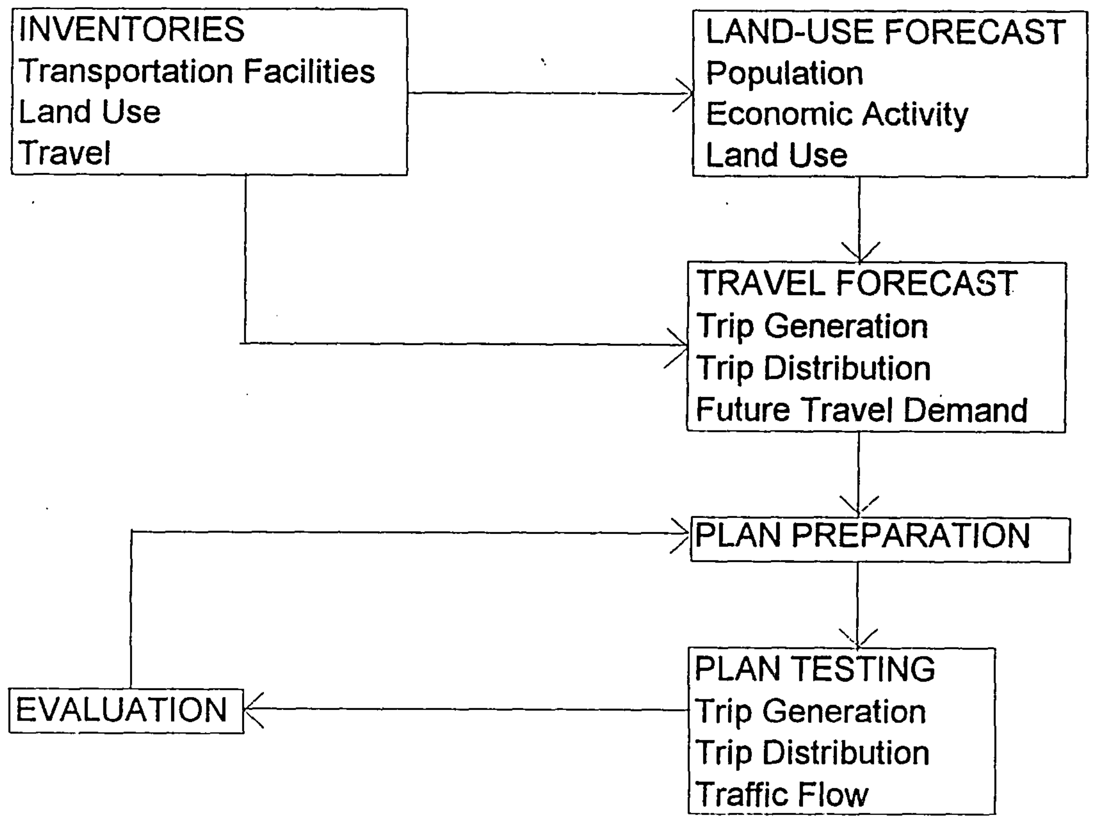

Figure 1: The planning process used in the Chicago Area Transportation Study
(Source: Hutchinson, 1974, Chapter 1)

Based Work, Non-Home Based, Home Based Other). For example, a Home Based Work trip would be considered to have a trip end produced in the home zone and attracted to the work zone.

Trip generation analysis has two primary functions: (1) to develop a relationship between trip productions or attractions and land use and socio-economic characteristics of trip makers, and (2) to use the relationship developed to estimate the number of trips that will be generated at some future target year under a new set of predicted land-use conditions and socio-economic characteristics. Some of the most commonly used methods for trip generation analysis are cross-classification method, and regression analysis. Cross-classification analysis is a technique for estimating trip-production rates of households which have been classified into a number of separate categories according to a set of socio-economic parameters that characterize the household. Regression analysis involves calibration of regression equations relating the number of trips generated to the socio-economic characteristics. The most appropriate prediction equations may then be selected based on certain statistical criteria.

Trip distribution analysis is a process by which the trips generated in and attracted to a zone are used to predict the distribution of trips between pairs of origins and destinations. The most widely used trip distribution model is the gravity model, which states that the number of trips Tij from zone i to zone j is directly proportional to the number of trips generated in zone i, number of trips attracted by zone j and inversely proportional to a function of travel impedance between the two zones.

Mathematically, the gravity model is expressed as follows.

$$T_{ij} = P_i \frac{A_j F_{ij} K_{ij}}{\sum_k A_j F_{ik} K_{ik}} \qquad (1)$$

where

T_{ij} = number of trips that are produced in zone i and attracted to zone j;

P_i = total number of trips produced in zone i, obtained from trip generation step;

A_j = number of trips attracted to zone j, obtained from trips generation step;

F_{ik} = a value which is an inverse function of the travel impedance; and

K_{ik}= socio-economic adjustment factor for interchange ik.

A trip interchange matrix is obtained summarizing the number of trips produced from each zone and attracted to each other zone in the study area. The distribution of the total trip productions depends on measures of relative attractiveness of the destination zone, such as travel impedance between the origin-destination pair as compared to travel impedances of all possible destinations.

Mode Split is the step in the UTP process that determines the number (or percentage) of trips between zones that are made by different modes of transport. The selection of the mode of travel depends on factors such as traveler's income, the availability of transit service, auto ownership, and the relative advantages or utilities of each mode in terms of travel time, cost, comfort, convenience, and safety.

Traffic Assignment is the final step in the travel demand forecasting process. This is used to determine the actual street and highway routes that will be used and hence, an estimate of the volume of traffic that can be expected on each highway segment. The procedure used to determine the expected traffic volumes is known as traffic assignment. Examples of algorithms used for this purpose include all-or-nothing, incremental or equilibrium assignment techniques.

IMPLEMENTATION OF THE UTP PROCESS

Transport planning recommendations derived from the UTPP are arrived at through the simulation of land use and transport relationships based on an area-wide study, employing data from household and roadside surveys, as well as planning studies. The basic stages of the process include:

1. preparation of land use, transport and travel inventories of the study area;

2. analysis of present land use and travel characteristics;
3. forecast of land use and travel characteristics;
4. setting of planning goals and the formulation of transport alternatives designed to accommodate the projected travel demands and land use changes;
5. testing and evaluation of alternative transport plans; and
6. selection of plan for implementation.

The above stages have remained the major corner-stones of conventional urban transport planning process since the inception of the process in the USA during the 1950s.

A CRITIQUE OF THE PROCESS

The conventional planning process described above is intended primarily for the western/developed world. The socio-economic environment in the third-world countries is different from that prevailing in the western world. In the developing countries, there is a prevalence of a large mix of ethnic groups or households with structural differences in income and social characteristics, availability of a variety of modes of transportation including walk, and large variations in the economical status of "haves" and "have-nots". This is markedly different from settings in the western world. Thus, a direct application of the methodology of the UTPP may not be relevant to the third-world. A "developmental approach" [Dimitriou, 1992], rather than the conventional approach may be more suitable for application to the third world.

The 'developmental approach' to urban transport planning is different from the conventional approach in that it relies more on developments in the field of planning for transport, while the conventional approach relies on planning transport needs for urban development. The implementation of this approach requires the adoption of measures aimed at improving the productive potentials of cities, the distribution of urban opportunities, and the improvement of social life and the physical environment.

RESEARCH OBJECTIVE

The main objective of this research is to study the trip making characteristics and travel sensitivity of the people in a third-world city. A framework is developed to model groups of people based on one or more key factors influencing travel demand such as income, household size, accessibility to private automobile, etc. Dar-es-Salaam, a third-world city located in Africa and the capital of Tanzania, is used as a case study to illustrate the application of the framework developed.

Trip generation models are developed for different socio-economic groups in the study area, and travel making characteristics within and across groups are presented, analyzed and compared. Deficiencies in the application of the conventional UTPP are highlighted, and implications of the findings to the overall transportation planning process in the country are discussed.

OUTLINE OF THESIS

Discussions on the application of the UTP process in third-world countries with details on the third-world characteristics, principles and assumptions of the UTP process are presented in Chapter 2.

The methodology used for the study and the procedure followed are discussed in Chapter 3. Details of the study area under consideration and analysis of the study area data are described in Chapter 4. Chapter 5 provides the analysis of the results obtained for different groups, and Chapter 6 includes the conclusions and recommendations. The terms "third-world" and "developing countries" are used interchangeably throughout the work.

CHAPTER 2

APPLICATION OF THE UTP PROCESS TO THIRD-WORLD COUNTRIES

THIRD-WORLD CHARACTERISTICS

The 'Third World' countries share several common socio-economic characteristics, which can briefly be summarized as follows [Dimitriou, 1992]:

1. dependence on the industrialized world for trade, investment, monetary arrangements, university education, research and development activities etc.;
2. rapid growth phenomena in major socio-economic trends affecting development;
3. a dual economy with widespread inequalities; and
4. a dominant role played by the public sector in national development.

A dual economy manifests itself in the co-existence of modern and traditional methods of production; 'formal' (registered and taxable) and 'informal' (unregistered and often illegal) economic activities; as well as extreme poverty and affluence.

PRINCIPLES AND ASSUMPTIONS

A primary assumption of the UTP process, irrespective of context, is that there is a land-use system with an employment base from which trips are generated, and that this relationship (between land-use and travel) is stable over time. While cultural differences need to be taken into account if motorized private vehicles alone are considered, the overall transport picture of Third World cities will be incomplete since other significant modes of travel such as walk and bicycle are ignored.

Another key assumption warranting further attention is the aggregation assumption i.e., the assumption that a group of people can be treated in the same way if reference is made to their average characteristics. In view of the greater diversity of income and ethnic composition of the inhabitants of many Third World cities, people within a traffic analysis zone need not necessarily behave in the same way. Thus, such situations need to be dealt with separately.

The conventional approach of the UTP process assumes that the people behaving in a certain manner previously, will continue to respond according to same criteria, in the same way, in a new set of circumstances and over time. This is a major problem since Third World nations are growing at a fast pace with overall economic development and urbanization. Thus, travel behavior of the people changes constantly while adapting to the improving/improved overall developments in the society. Thus, taking the above observations into consideration, the development of a single model for entire study area may not be appropriate.

LITERATURE REVIEW

Said, Young, and Ibrahim [1991] discuss the travel behavior of people living in Kuwait city. The urban areas in Kuwait contain a mix of ethnic groups or households with structural differences in income and social status (Kuwaitis, Arabs, and Asians). Current trip generation techniques, according to the authors, do not explicitly allow for the treatment of these different groups. The recommended stratification developed separate models for trips per household, for different ethnic groups, revealing certain interesting facts such as, the type of house owned by the residents was found to be a significant factor affecting trip generation in the Arab community. Also, the number of adults, number of children, and the income of the household were observed to be significant for all groups. It can be noted here, that the aggregate trip generation model across population groups

may not always be a better approach in developing a model for a third world city.

Abdelgader [1981] proposes a need-based approach to the transportation problems in the third world countries, since the poor form the major portion of the total population. Also, problems such as high rate of migration into urban areas by the rural poor, and increased rate of population growth with very little development in transportation systems supply, according to the author, lead to a pressing need for a need-based approach, as opposed to the demand-oriented approach, that is, planning transport for urban development based on the needs of the poorer community which forms a major proportion of the transit users. He also highlighted some of the deficiencies in conventional travel demand forecasting. The problem with demand models used in the Amman study was that they estimated the travel demand by the poor as those observed at the time of the study, and did not inquire about any other additional trips the poor needed to make. According to Abdelgader, many areas where the poor reside lack adequate public transit systems and that the poor are spending a high percentage of their income on travel; thus leading to lower trip demand by the poor. It is therefore, important to estimate trips made by the poor based on their assessed need.

Swait and Ben-Akiva [1986] addressed the appropriateness of choice theory for modeling travel demand. In a highly constrained environment, such as can be found in low-income areas, observed choice may well be the result of the elimination of alternatives through active constraints, as opposed to the exercise of a choice prerogative by the decision maker. According to the authors the effect of constraints on travel behavior is particularly important for analyses in developing nations. Issues dealt highlight fundamental differences between developed and developing countries in terms of travel demand.

Dimitriou [1992] discusses the conventional planning process and the technology transfer of the same and its derivatives to Third World countries, and the subsequent formulation of the theoretical basis for a 'developmental approach' to urban transport

planning. In view of the greater diversity of income and ethnic composition of the inhabitants of many Third World cities, according to the author, people within a traffic analysis zone need not necessarily behave in the same way.

Early transportation planning studies for Dar-es-Salaam, done by Wilbur Smith Associates [1991] for the government of The United Republic of Tanzania, included addressing major problems such as meeting the growing demand for public transport services in a cost effective manner. They also addressed the need for a strengthened institutional framework for urban transport, and realized that a fragmented, project oriented solution will not be sufficient. Public transport services in Dar-es-Salaam do not operate in isolation. The physical state of the roads, the existence of effective traffic management systems, and the integration of public transport operations and planning with all other aspects of urban transport planning is essential for an effective transportation system.

The conclusions based on previous studies about the local bus company Shirika la Usafiri Dar-es-Salaam Ltd. (UDA) revealed that while the average travel time for a UDA passenger was approximately 60 minutes, only 24 minutes was in-vehicle travel time and 28 minutes was waiting time at bus stop, and 8 minute walking time. The present supply of public transport in Dar-es-Salaam does not meet the total transport demand by any measure. There is a large suppressed transport demand. Household survey and traffic surveys were done and a bus trip generation model was developed. The bus trip generation model related the number of trips generated per 100 inhabitants to the service level, and to the respective location of areas with respect to the city center. The model has been used to estimate the total public transport demand. At the time of traffic surveys, UDA did transport 375,000 passengers in a day, whereas the total demand was estimated at 560,000 passengers in May 1982, provided that no overloading takes place and that waiting time will be reduced.

Other major problems included traffic congestion in and around the city center causing problems for the efficient operation of the bus system. Traffic congestion is primarily due to insufficient road network and the poor state of roads.

CHAPTER 3

METHODOLOGY

TRAVEL-DEMAND FORECASTING PROCESS

Urban travel demand forecasts, first developed in the 1950s, required that extensive databases be prepared using home interview and roadside interview surveys. The information gathered provided useful insights concerning the characteristics of the trip maker, the land use at each end of the trip, and the mode of travel. Travel data could then be aggregated by zone and/or be used at a more disaggregate level - i.e., household or individual, to formulate relationships between variables and to calibrate travel demand models. These data collection and calibration efforts involved a significant investment in money and personnel resources. Subsequent studies for the same study area were based on updating the existing database and the use of models that had been developed previously.

STRUCTURE OF THIRD-WORLD ENVIRONMENT

An understanding of the environment, travel demand, needs, land-use characteristics, and cultural differences prevailing in third-world countries is imperative in order to develop a suitable approach for estimating travel demand generation in third world countries.

Travel Demand

One of the major parameters that influence urban travel and efforts at meeting travel demand in Third-World cities is the out-of-pocket cost of travel, with some

consideration of time costs. Some of the aspects that could be highlighted are the trip home for lunch and subsequent return to work, which has a marked impact on traffic movement patterns throughout the day. Also, widespread ownership of refrigerators is a common feature in the industrialized countries, while its absence in most Third World households has an obvious impact on urban trip-making. The situation has a consequent impact on the location of stores and on the working capital of business. Trip rates in Third World cities, in general, are found to be much lower than those of the industrialized nations. These differences are for the most part explainable in terms of incomes, family sizes, motorization rates, etc. The transport mode mix and emphasis also differs, with a much heavier use of public transport in Third World cities.

Travel Needs

There is a difference between 'travel needs' and 'travel desires' in a Third World context. There are people who cannot afford public transport to get to work but who clearly 'need' to be mobile. Situations in Third World countries demand supply of 'minimum standards' regardless of costs. This is the minimum amount of services that people have an inherent right to for survival, such as housing/shelter, clothing, food, etc.- which is not the meaning of the term as it is used in the UTPP. Urban transport needs are obvious measures of opportunities for better living standards, jobs, health care and education for which employment is the requisite.

Land-Use Control and Development

Designing and building a transport system that is robust enough to work under different urban land-use options is a very critical issue, since planning studies normally take a long time to complete, with very little time left for testing all the alternatives. Thus, a great deal of effort goes into building the UTP model and relatively little into testing the alternatives generated.

Cross-cultural Differences

A clear understanding of the background and values of the culture in which a transport planner is working is a key factor in better addressing the needs of the community. One of the issues of concern is the problem of how to support public transport, given that the proportion of automobile owners in Third World cities is very low. In many cities there is a considerable proportion of the population which cannot even afford public transport and are walking perhaps ten kilometers each way to work and back. In these conditions, issues of fare structures, choice of mode, etc., need to be put into a totally different perspective than that usually associated with industrialized countries. Common features prevailing in Third-World countries include very large household sizes with less household incomes, lack of homogeneity in the distribution of different classes of community and classification of area into zones based on land-use developments, and the use of a variety of modes for transportation. Gender of the trip-maker is also an important factor in determining the trip-making pattern in some of the communities. It has not been taken into account in the changing relationship between household structure and size in many Third World cities experiencing rapid urbanization. Yet, projecting changes in household size and composition is critical in travel behavior forecasts.

Automobile Dependency

While automobile ownership is a key factor in the planning process in the developed world, it is an unaffordable commodity for the low and middle income groups who constitute a large proportion of Third-World communities. However, these cities have an inherent advantage with freedom to choose among options to tackle their travel problems. The provision of adequate mobility and not over-designing the roads is critical. Alternative measures are available with respect to traffic restraint, traffic management, the introduction of extensive bus priority schemes, bicycle paths and/or walking facilities. But the advantage exists only if the plans for change are related intelligently to the plans for

transport needed.

Trip Chaining

It is a common occurrence in third-world countries to link trips to visit more than one destination after leaving the origin (usually home). The spatial distribution of trip ends and trip timing, as well as the total number of trips, vary substantially depending on the way trips are linked to each other. Consolidating these trips can prove effective in terms of travel time and cost. Thus, it is likely that urban residents' trip chaining behavior will change over time as travel cost, congestion, land-use patterns, and other contributing factors change.

APPROACH

Considering the above mentioned differences in the socio-economic characteristics of third-world countries, this research involves study of trip making characteristics and travel sensitivity of the people in third-world countries. A framework is developed to model groups of people based on one or more key factors influencing travel demand such as income, household size, accessibility to private automobile, etc. Trip generation models are developed for different socio-economic groups in the study area using regression analysis.

The most commonly used technique for the development of the prediction equations, the Classical Multiple Linear Regression (CMLR) Analysis is employed in the study. This involves the study of one variable as a function of various other explanatory variables, which are likely to affect the dependent variable.[Hutchinson, 1974]

The general form of the CMLR model is:

$$y_i = b_0 + b_1 x_{i1} + b_2 x_{i2} + \ldots + b_k x_{ik} + u_i = b_j X_i + u_i \qquad (2)$$

where

y_i is the number of trips reported by household i;

b's are the coefficients, $b_j = (b_0, b_1, \ldots, b_k)$;

X's are explanatory variables, such as household size, household income etc.;

$X_i = (1, x_{i1}, x_{i2}, \ldots, x_{ik})$;

u_i is a random error term.

CALIBRATION PROCESS

The trip generation models are developed using a standard regression analysis package/program (MS Excel 3.0). All models are estimated using the ordinary least squares regression technique. The principal assumptions of regression analysis are:

1. The variance of the dependent variable about the regression line must be the same for all magnitudes of the independent variables.
2. The deviations of the dependent variable about the regression line must be independent of each other and normally distributed.
3. The independent variables are measured without error and are independent of each other.
4. The regression of the dependent variable on the independent variable is linear.

Thus, the dependent variable is regressed over a number of independent variables, and a relationship is developed. The coefficients of the independent variables explain the variation in the dependent variable for a unit change in the independent variables, taken one at a time. The multiple coefficient of determination, R^2, gives the proportion or percentage of the total variation in the dependent variable explained by the set of explanatory variables. The R^2 value of a model gives the goodness of fit of the model, and the F value indicates the overall performance of model. The difference in the size of data (N) and the number of variables (k) gives the degrees of freedom available. The ratio of R^2/k to $(1-R^2)/(N-k-1)$ gives the value of F. The higher the F value, the better is the

overall model. A correlation matrix is developed to detect the independent variables which have a statistical association with the dependent variable, and also to detect any potential sources of collinearity between pairs of the independent variables. High correlation between a dependent and an independent variable indicates the degree of association of the explanatory variable with the dependent variable, while a high correlation value between two independent variables indicates that either one of the two variables may be used in the model, instead of both.

Further, the coefficients of a developed model are tested for statistical significance. A one-tail t-test is used to test whether or not a particular independent variable is statistically significant in explaining the behavior or variation in the dependent variable. This test may be done for a desired level of confidence. For the purpose of this study, a t-statistic lying between -1.00 and +1.00 is chosen, which is within a range of a 70 percent confidence level. Also, an F-statistic of 3.00 is a chosen minimum for explaining the overall performance of the developed models. However, each model is tested for the level of confidence (C.L.) based on the F-statistic for degrees of freedom in the numerator and denominator.

Full models including all the variables are calibrated and then variables with coefficients that are not statistically significant are systematically dropped from the models, resulting in "final" models. Statistical significance is measured using the t-statistics.

The variables that are likely to affect trip generation include household size, household income, gender and age of the individual, employment type and occupation of the individual, automobile and bicycle ownership, labor force in a household. These variables can be used in the study. The effect of these trip factors in explaining trip generation and travel pattern will be studied using a case-study. A typical trip generation regression model would be of the following form:

Total trips/HH = f(Income, Family Size, Age of the head, Gender of the head, Industry, Automobile ownership, ...) (3)

Signs a priori

An increase in size of a family is expected to increase the number of trips generated by a household. Thus, the coefficient for the household size variable is expected to be positive. Also, higher income households are expected to make more recreational and non-work trips, and thus the coefficient for this variable is expected to be positive. Similarly, accessibility to any kind of private vehicle, motorized or non-motorized, is expected to increase the total number of trips generated by a household. Thus, these coefficients are expected to take positive signs. The affects of age and gender of household head variables, and the type of industry in which the household head is employed are not explicit, and thus need to be studied.

CHAPTER 4

STUDY AREA AND DATA SET

STUDY AREA

Dar-es-Salaam is the largest city in Tanzania, located in Africa, with a population of approximately one million inhabitants as of January 1982 [National Transport Corporation, 1985]. It is the principal center of commerce and industry. The city is located on the Tanzanian coastal plain with the Indian Ocean on the eastern side. Other geographical features that have influenced the pattern of urban development in Dar-es-Salaam are the location of the harbor. The port of Dar-es-Salaam is one of the busiest East African ports. The total size of the city is 1393 square kilometers.

Commercial activities at the Dar-es-Salaam port and the geographical characteristics of the urban area have resulted in a radial road network. There are four major roads emanating from the city center:

a. Pugu road

b. Morogoro road

c. Bagamoyo road

d. Kilwa road

Figure 2 shows the study area map. Administratively, the study area is divided into three districts, Kinondoni, Ilala, and Temeke, under the administration of the Dar-es-Salaam City Council (DSMCC). The city has experienced a population growth rate of 4.9

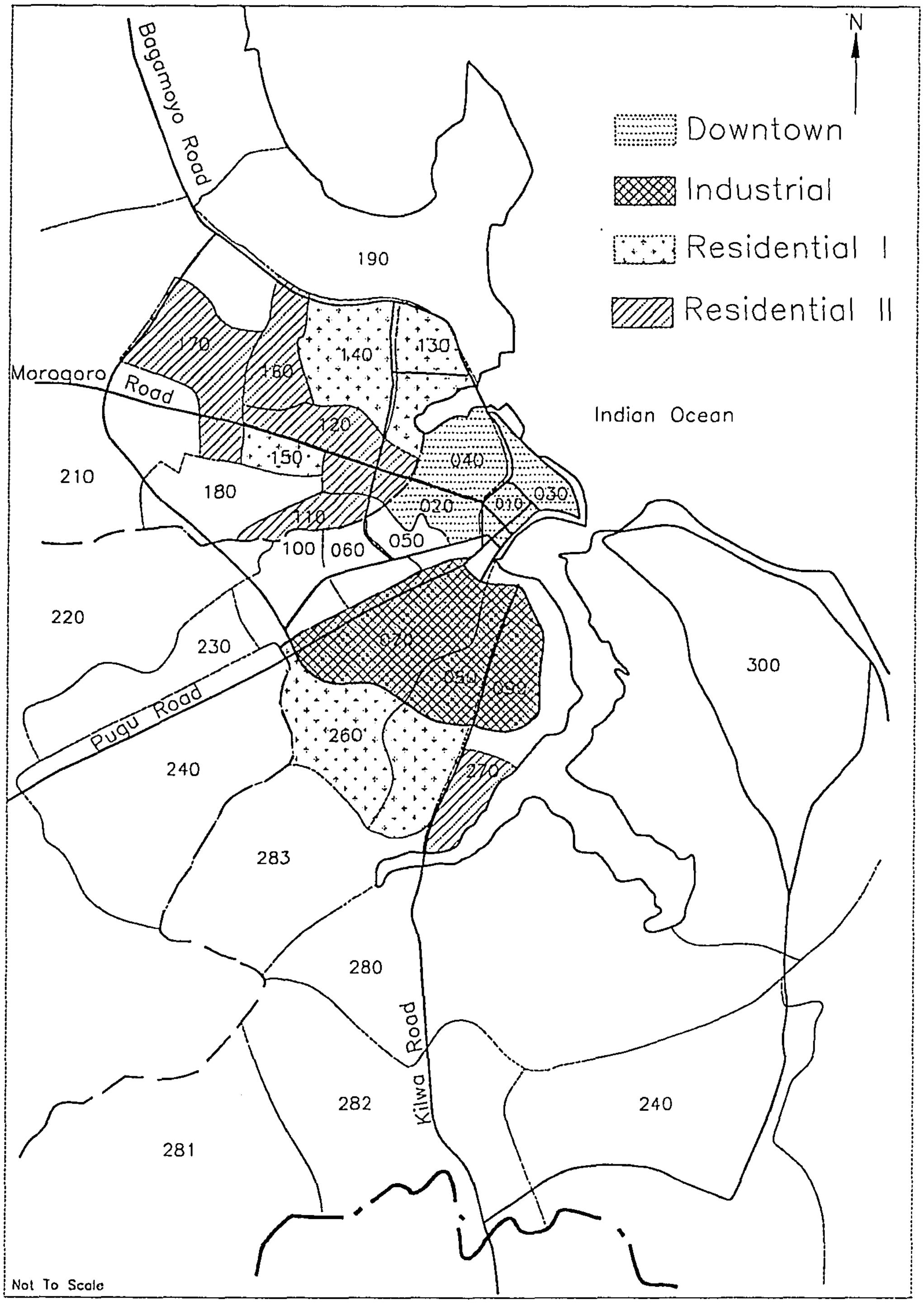

Figure 2. Dar–es–Salaam Study Area Traffic Analysis Zone System

percent per annum in 1991, which is much higher than the national average of 2.8 percent per annum [Wilbur Smith Associates, 1991]. The accelerated urban growth rate has placed extreme pressure on the city authorities that have responsibility for the provision of urban services. Public transport services, in particular, are inadequate for the city's needs.

DATA FOR THE STUDY

The city of Dar-es-Salaam is divided into 33 traffic analysis zones (TAZ's) (Figure 2). However, data was collected for only 22 TAZ's (Source: University of Dar-es-Salaam, Dar-es-Salaam, Tanzania). A home interview survey of 3583 households done late 1993 for the area (Dr. Rwebangira, University of Dar-es-Salaam) provides three levels of information: household information, personal information, and trip information. This information is based on individuals over 16 years of age who were interviewed. Each trip made by a household member has information on where the trip originated, along with the purpose of trip made and mode used to make the trip. From this information, the destination zone is deduced as the origin zone of the subsequent trip. Households providing only partial information have been dropped from study data set.

Household information includes zone number to which the household belongs, sequence of the household in the zone, and size of the household. Each household in a zone which is interviewed, is given a number in order to keep an account of the total number of households interviewed. Similarly, each person who is interviewed from a particular household is given a serial number for record purposes. This system is referred to as sequence. Personal information includes, sequence of the number of the person in the household, total income per month in Tanzanian Shillings earned by the person, zone number where individual resides, zone number of individual's work place, gender and age of the person interviewed, occupation and type of industry in which the individual is employed, whether or not the individual has an access to a private vehicle. The third level of information provided, i.e.,, trip information includes, number of the trip made, zone of

departure, time of departure, travel time in minutes from origin to destination, purpose of trip made, and the mode chosen to make the trip.

The collected data elements are itemized in Table 1: the sequence of the household in the zone, the sequence of the number of person in a family, household size, total income per month in Tanzanian Shillings earned by the person, the zone where the individual resides, zone the individual works, gender and age in years, of the person interviewed, occupation (employer, employee, student, house-keeper, unemployed, self employed), type of industry in which the individual works (agriculture, forestry, fishery, mining, construction, manufacturing, commerce, finance, transportation service, public service etc.), whether or not the individual has access to a private vehicle, motor cycle, and bicycle for use at any time, the number of the trip made, origin TAZ[a], time of departure, travel time in minutes, the purpose of the trip (work, school, business, shopping, and others), the various modes used to make trips (walk, bicycle, motor cycle, taxis, minibus, bus on a regular route, passenger car, light goods truck, medium goods truck, heavy goods truck, and others). Gender, accessibility to private motorized and non-motorized vehicles, and type of industry in which an individual is employed take dummy values 1 or 0. Gender takes a value 1 for a male, and 0 for a female. Likewise, accessibility measure for private vehicle, motor cycle, and a bicycle are indicated by 1 for each of the motorized or non-motorized vehicle. Around 80 percent of the households are employed in commerce, finance, transportation service, public service etc., belonging to industry type 3. Thus, this type is coded 1 while the other types is coded 0. Each individual trip made by a person is divided into a number of segments. For each leg of a trip, a separate mode could be chosen. For example, a trip made to work place, though essentially is one trip, may have many segments, such as walk to a bus stop, a transit trip, a walk trip from the bus stop to the work place, etc. Thus, each leg of one complete trip has a separate chosen mode by an individual, which is coded as first mode, second mode, third mode, etc. A

[a]. The destination zone is deduced from the origin zone of the subsequent trip.

maximum of five modes have been observed to be chosen for any single trip based on purpose.

Household data are used for trip generation analysis. A FORTRAN program [Appendix I] was written to aggregate the personal trip data into household trip data, including the total household income, size, total number of household trips, total number of household trips by purpose, by mode, average travel time per household. Table 2 itemizes the data generated after processing the initial data with the FORTRAN program. Figure 3 shows the steps involved in processing the data using the program.

The processed data-set is used to develop trip generation models for total trips, work trips, non-work trips, and walk trips per household as a function of a set of socio-economic and land-use variables.

PROCEDURE

Study Area Model (Total Trips/Household)

The calibration process explained in the previous section is used to develop a model for the complete study area. A single model for all the 22 zones under consideration gives a very poor fit explaining only 13 percent of the variation in total household trips generated. Table 3 summarizes the coefficients and corresponding t-statistic of the study area model. It can be observed from the table that all the variables in the model except income are significant in explaining the variation in trip generation. However, the overall model is good with a high F-statistic of 27 significant at 99% confidence level (C.L.). Thus, there is a need to separate the zones into different groups based on the individual zonal characteristics.

Stratification of zones

People living in different areas of the city, belonging to different classes of income levels etc. are expected to show differences in travel behavior. Thus, stratification of the study area based on the land-use and household socio-economic characteristics is done.

TABLE 1: DATA ELEMENTS IN HOUSEHOLD SURVEY

1.	Zone number
2.	Sequence of household in the zone
3.	Sequence of the number of the person in a family
4.	Household size
5.	Total income per month in Tanzanian Shillings earned by the person
6.	Zone number where individual resides
7.	Zone number of individual's work place
8.	Gender of the person interviewed
9.	Age of the person interviewed in years
10.	Occupation (employer, employee, student, house-keeper, unemployed, self-employed etc.)
11.	Industry type (agriculture, forestry, fisheries, mining, construction, manufacturing, commerce, finance, transportation services, public services etc.)
12.	Accessibility measure to private vehicle, motor cycle, bicycle
13.	Number of the trip made
14.	Zone of departure
15.	Time of departure
16.	Travel time in minutes from Origin to Destination
17.	Purpose of the trip made (work, school, business, shopping, others)
18.	First mode, second mode, third mode, fourth mode and fifth mode chosen to make a trip (walk, bicycle, motor cycle, taxis, minibus, bus on a regular route, passenger car, light goods truck, medium goods truck, heavy goods truck, and others)

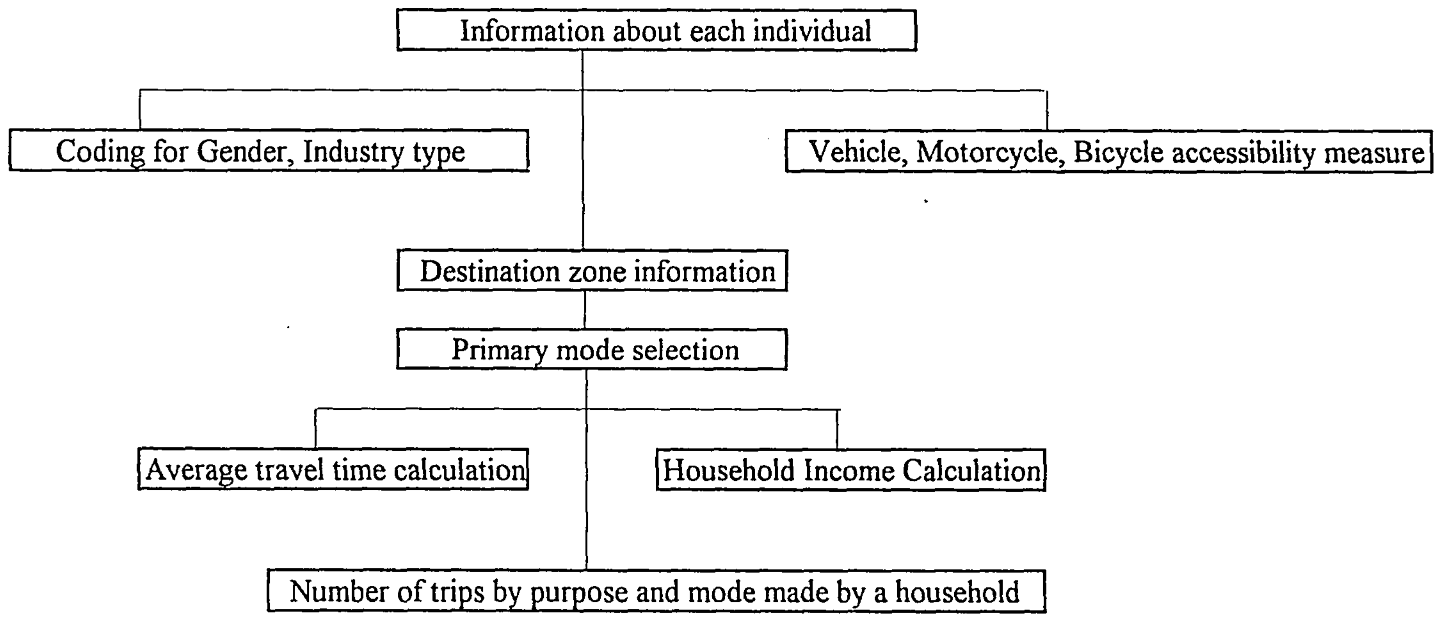

Figure 3: Steps involved in data processing

TABLE 2: ELEMENTS OF PROCESSED DATA

1.	Zone number
2.	Sequence of household in the zone
3.	Household size
4.	Total income per month in Tanzanian Shillings earned by the household
5.	Origin zone of trip
6.	Destination zone of trip
7.	Gender of the household head
8.	Age of the household head in years
9.	Occupation (employer, employee, student, house-keeper, unemployed, self-employed etc.)
10.	Industry type (agriculture, forestry, fisheries, mining, construction, manufacturing, commerce, finance, transportation services, public services etc.)
11.	Accessibility measure to private vehicle, motor cycle, bicycle
12.	Total number of trip made by the household
13.	Number of work trips made by the household
14.	Number of non-work trips made by the household
15.	Average travel time in minutes
16.	Primary mode of a trip
17.	Number of trips made by each mode (walk, bicycle, motor cycle, taxis, minibus, bus on a regular route, passenger car, light goods truck, medium goods truck, heavy goods truck, and others)

The study area is divided into different groups, based on the premise that there are underlying differences in the travel behavior of the people living in different parts of the city - downtown, residential and industrial. The residential area is further divided into

residential area I and residential area II based on average monthly income. Table 4 details the grouping of zones. Further, each category is divided into four groups based on income classifications, as low income group, medium income group, high income group, and very high income group. Figure 4 gives a schematic representation of the classification of study area into various groups. Of the areas available for study, Kisutu, Mchafukoge (Zone 10), Kariakoo, Jangwani (Zone 20), Kivukoni (Zone 30), Upanga East, and Upanga West (Zone 40) include land-uses for commercial, business, retail centers and government offices. Thus, these areas may be grouped as the Central Business District, Kigogo (Zone 110), Mzimuni, Ndugumbi, Magomeni (Zone 120), Kinondoni (Zone 130), Mwananyamala (Zone 140), Makurumla (Zone 150), Tandale (Zone 160), Manzese (Zone170), and Temeke (Zone 260), Mtoni (Zone 270) are predominantly residential areas. These areas may thus be grouped for study of the residential area models. The residential areas further divided into two groups, residential area I and II, based on their average monthly zonal incomes. Areas Kinondoni (Zone 130), Mwananyamala (Zone 140), Makurumla (Zone 150), and Mtoni (Zone 260) belong to the residential area I with an average zonal income of 35,000 shillings or more a month. The other zones comprise of the residential area II with an average zonal income less than 35,000 shillings a month. Areas Keko (Zone 70), Miburani (Zone 80), and Buguruni (Zone 90) have significant industrial land-uses, and thus are treated separately to develop a models for the industrial areas.

ANALYSIS OF ZONAL STRATIFICATION

A study of the available household data for the 22 zones reveals that around 15 percent of the households living in the residential and industrial regions have access to private vehicles, while around 47 percent of the households in the Downtown areas have access to private vehicles. Similarly, around 10 percent have access to motor cycles, while around 46 percent have access to private vehicles in the downtown areas. Access to

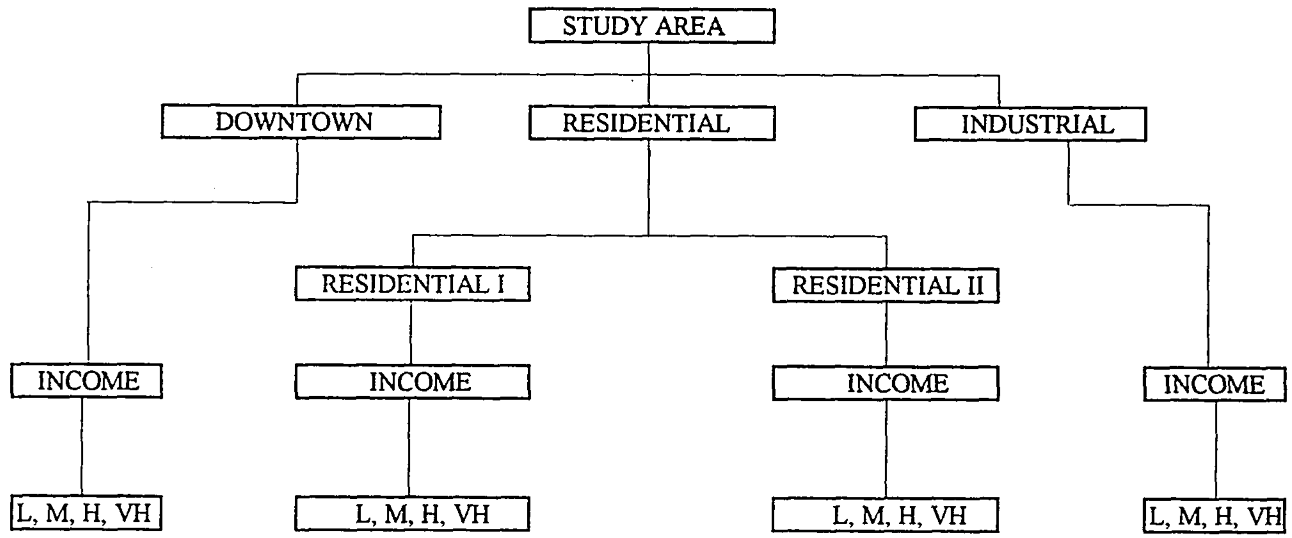

Figure 4. Sequence of steps involved in developing final models

L - Low
M - Medium
H - High
VH - Very High

TABLE 3: COMPLETE STUDY AREA MODEL

Variable	Coefficient (t-stat)
HH Size	0.267(10.430)
Income	-0.001(-0.455)
Gender	0.189(1.094)
Age	0.018(2.454)
Industry	-0.305(-1.719)
Vehicle	0.898(4.978)
Motor	1.158(3.973)
Bicycle	0.632(2.954)
R^2	0.137
F / C.L.	27.904 / 99%
df	1401
N	1410

TABLE 4: STRATIFICATION OF ZONES

Downtown Area	Kisutu, Mchafukoge, Kariakoo, Jangwani, Kivukoni, Upanga East, and Upanga West
Residential Area I	Kinondoni, Mwananyamala, Makurumla, Mtoni
Residential Area II	Kigogo, Mzimuni, Ndugumbi, Magomeni, Tandale, Manzese, Temeke
Industrial Area	Keko, Miburani, Buguruni

bicycles is only 15 percent. Around 85 percent of the household heads interviewed are employed in commerce, financial, transportation services, public services etc., while the other 15 percent is involved in agriculture, forestry, fisheries, construction, maintenance etc. Also, it was observed from the data that around 80 percent of the households have male household heads. Table 5 summarizes the statistics of the study area. Figure 5 shows the relative percentages of vehicle, motorcycle, and bicycle accessibility among households in the different areas. Figures 6 show the proportion of households employed in industry type I and II, and figure 7 shows the percentage of households with male and female heads in the study area.

TABLE 5: SUMMARY STATISTICS OF STUDY AREA VARIABLES

Area Type/Variable	Downtown Area	Residential Area	Industrial Area
Access to private vehicle	47%	15%	15%
Access to motorcycle	46%	10%	10%
Access to bicycle	15%	15%	15%
Employment Type I/II	85% / 15%	85% / 15%	85% / 15%
Head of HH Male/Female	80% / 20%	80% / 20%	80% / 20%

Table 6 summarizes the averages for household income and size for the different groups in the study area. It can be observed from the table that the downtown area has high income groups with large families. The average household income of households in residential area I is relatively high compared to that in residential area II, with smaller average household sizes in residential area I. These differences in the characteristics of groups is likely to affect the trip generation pattern of these groups. In general, the average income of households in the industrial area is much lower than those residing in other areas of the city.

TABLE 6: GROUP AVERAGES FOR HOUSEHOLD INCOME AND SIZE

Area Type	Average Household Income	Average Household Size
Downtown Area	62000 Shillings/month	5.8 persons
Residential Area I	39000 Shillings/month	5.1persons
Residential Area II	29000 Shillings/month	5.3 persons
Industrial Area	25000 Shillings/month	5.0 persons

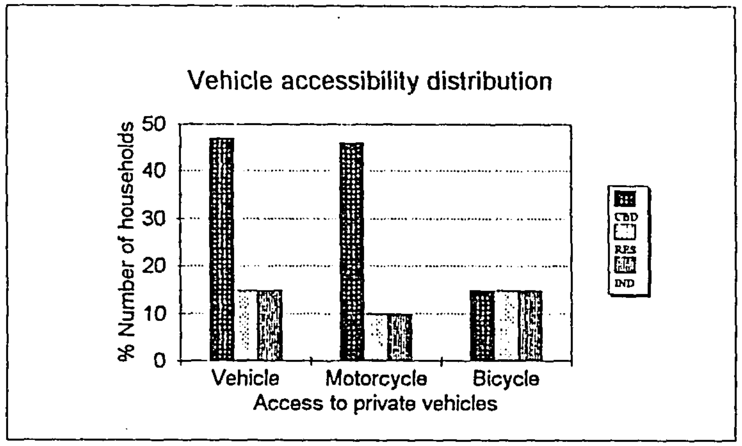

Figure 5: Vehicle accessibility distribution in the study area

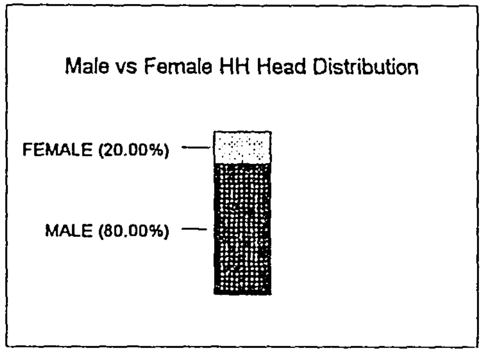

Figure 6: Household head distribution in the study area

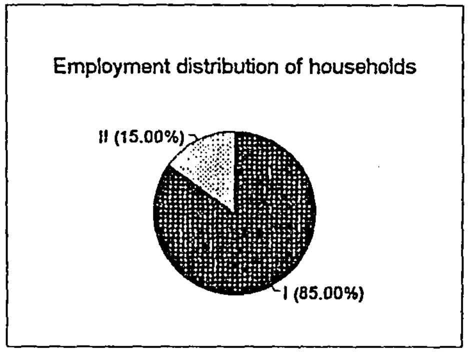

Figure 7: Employment type distribution in the study are

To check for correlation between the socio-economic variables, correlation matrices are developed for each group, as shown in tables 7, 8, 9 and 10. It can be observed from the tables that all the in the data may be used for developing the trip generation models, since the independent variables have very low correlations with other independent variable.

The calibration of models started by including all the variables in the models (i.e., "Full Models" (Appendix II) and then variables with coefficients that were not statistically significant were systematically dropped from the models, resulting in "final" models. Statistical significance is measured using the t-statistics.

Figures 8, 9, 10, and 11 show the income distributions of the households in the four areas based on land-use: Downtown, Residential I and II, and Industrial areas respectively. It can be observed from the figures that there is a large variation in the distribution of income groups among different areas. While the distribution is skewed towards low income for the residential and industrial areas, the distribution for downtown area does not follow any pattern. While there is a equal concentration of all the income groups in the downtown area, a large proportion of the people living in the residential and industrial areas belong to the medium income group, with a very small proportion belonging to the high and very high income groups. The downtown area comprises of around 35 percent of the very high income group households, while the other zones have only 14 percent of households in this group. A large proportion of the population in the residential areas belongs to the medium income groups. It is also observed that low income household also have large families. However, the residential area is divided into two separate groups depending on the average income of the zones. Based on income distributions, and the values obtained for each of the above variables from statistical calculations (Appendix III) i.e., mean +/- 1 standard deviation, reasonable cut-off values are achieved for developing different categories. All households with incomes less than or equal to 15,000 Tanzanian Shillings per month are classified as low income groups.

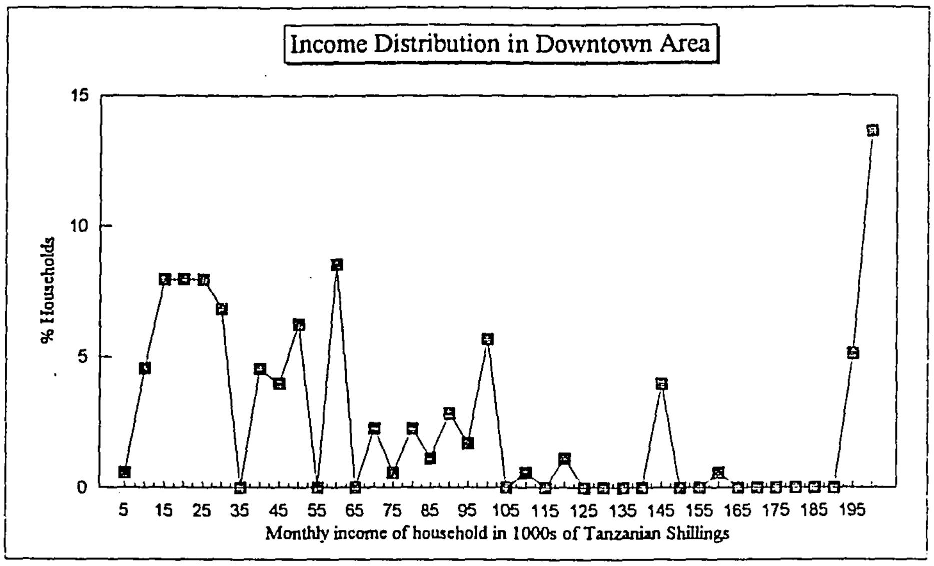

Figure 8: Income Distribution of Households in Downtown Area

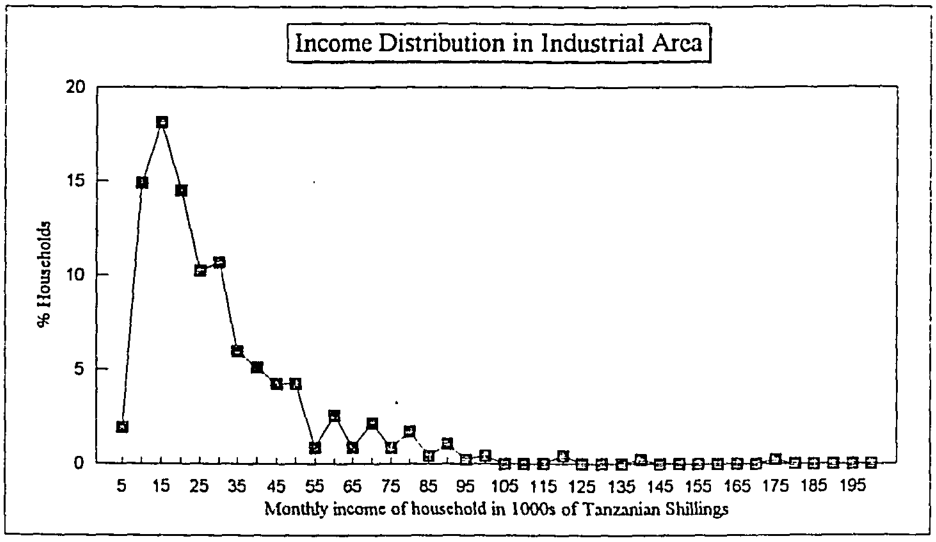

Figure 9: Income Distribution of Households in Industrial Area

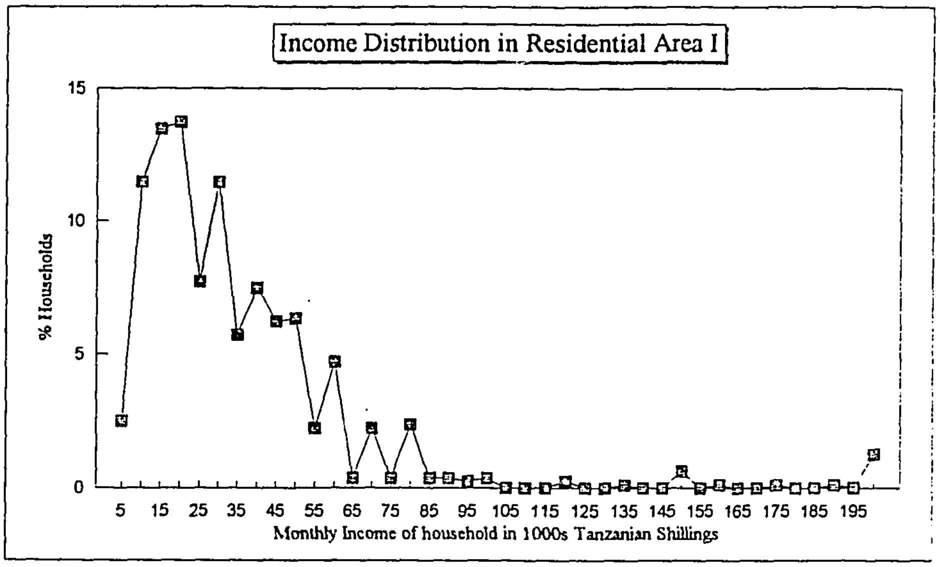

Figure 10: Income Distribution of Households in Residential Area I

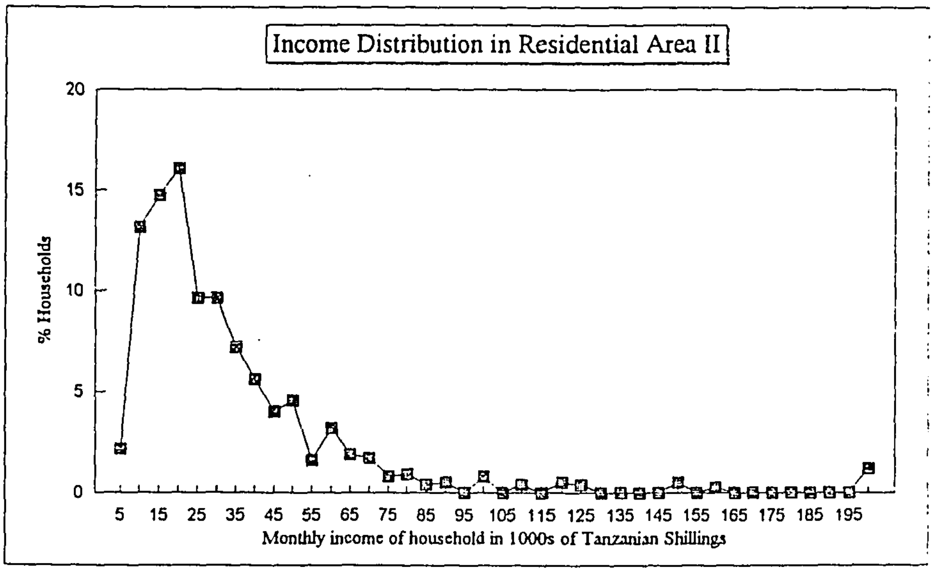

Figure 11: Income Distribution of Households in Residential Area II

Income ranges more than 15,000 shillings to 50,000 shillings are classified as medium income groups. Households with incomes greater than 50,000 shillings and less than 80,000 shillings are grouped as the high income groups. Very small proportion of the population (12 percent) belongs to income groups higher than those mentioned above. Thus, these income groups belong to the very high income groups.

CORRELATION COEFFICIENT MATRICES

TABLE 7: DOWNTOWN AREA

Variable	HH Size	Income	Gender	Age	Industry	Vehicle	Motor	Bicycle
HH Size	1	0.069	-0.059	0.091	-0.042	0.063	-0.091	0.063
Income	0.069	1	0.073	0.039	0.149	0.276	0.037	0.072
Gender	-0.059	0.073	1	0.211	-0.038	0.118	0.047	-0.099
Age	0.091	0.039	0.211	1	0.011	0.058	-0.015	-0.051
Industry	-0.042	0.149	-0.038	0.011	1	0.021	0.097	0.043
Vehicle	0.063	0.276	0.118	0.058	0.021	1	0.116	0.065
Motor	-0.091	0.037	0.479	-0.015	0.097	0.116	1	0.183
Bicycle	0.063	0.072	-0.099	-0.051	0.043	0.065	0.183	1

TABLE 8: RESIDENTIAL AREA I

Variable	HH Size	Income	Gender	Age	Industry	Vehicle	Motor	Bicycle
HH Size	1	0.008	0.006	0.281	0.004	0.104	0.073	0.086
Income	0.088	1	0.103	0.179	0.048	0.301	0.035	0.013
Gender	0.006	0.103	1	0.195	0.039	0.077	0.066	0.067
Age	0.281	0.179	0.195	1	-0.041	0.165	0.063	0.001
Industry	0.004	0.048	0.039	-0.041	1	0.032	0.018	0.024
Vehicle	0.104	0.301	0.077	0.165	0.032	1	-0.008	-0.019
Motor	0.073	0.035	0.066	0.063	0.018	-0.008	1	-0.018
Bicycle	0.086	0.013	0.067	0.001	0.024	-0.019	-0.018	1

TABLE 9: RESIDENTIAL AREA II

Variable	HH Size	Income	Gender	Age	Industry	Vehicle	Motor	Bicycle
HH Size	1	0.156	-0.126	0.351	-0.096	0.135	0.083	0.052
Income	0.156	1	0.039	0.152	-0.026	0.314	0.085	0.094
Gender	-0.126	0.039	1	0.085	0.034	0.022	0.094	0.084
Age	0.351	0.152	0.085	1	-0.083	0.134	0.064	0.075
Industry	-0.096	-0.026	0.034	-0.083	1	0.017	0.014	0.011
Vehicle	0.135	0.314	0.022	0.134	0.017	1	0.056	0.074
Motor	0.083	0.085	0.094	0.064	0.014	0.056	1	0.101
Bicycle	0.052	0.094	0.084	0.075	0.011	0.074	0.101	1

TABLE 10: INDUSTRIAL AREA

Variable	HH Size	Income	Gender	Age	Industry	Vehicle	Motor	Bicycle
HH Size	1	0.173	-0.001	0.256	-0.011	0.105	0.037	0.062
Income	0.173	1	0.101	0.139	-0.043	0.291	0.152	0.046
Gender	-0.001	0.101	1	0.142	0.001	0.067	0.118	0.092
Age	0.256	0.139	0.142	1	-0.057	0.116	0.044	0.006
Industry	-0.011	-0.043	0.001	-0.057	1	0.010	-0.002	0.057
Vehicle	0.105	0.291	0.067	0.116	0.010	1	0.123	0.139
Motor	0.037	0.152	0.119	0.044	-0.002	0.123	1	-0.037
Bicycle	0.062	0.046	0.092	0.006	0.057	0.139	-0.037	1

CHAPTER 5

ANALYSIS OF RESULTS

STATISTICAL MODELS AND DISCUSSION OF RESULTS

This chapter presents a discussion of the results of the study of the trip making behavior of the study area with respect to key variables influencing travel demand. Accessibility to private vehicle is also considered for study.

As discussed in chapter 4, multiple linear regression analysis technique is employed for the study. A relationship between the total trips made by a household as a function of household size, income of the household, gender and age of the head of the household, type of industry in which the head of the household is employed, and dummy variables representing accessibility to private automobile, motor cycle, and bicycle, is developed in this study. The number of trips per household is then given as:

$$\text{trips / HH} = b_0 + b_1\text{hhsize} + b_2\text{income} + b_3\text{gender} + b_4\text{age} + b_5\text{industry} + b_6\text{vehicle} + b_7\text{motor} + b_8\text{bicycle} \quad (4)$$

where trips/HH = the total number of daily trips made by the household;

hhsize = the size of the family;

income = the total monthly income of the household in Tanzanian Shillings;

gender = 1 if the household head is a male, 0 otherwise;

age = age of the household head in years;

industry = 1 if the head of the household is employed in commerce, finance, transportation

service, public service, and 0 if employed in agriculture, forestry, fisheries;

vehicle = 1 if household has an access to a private vehicle, else 0;

motor = 1 if household has an access to a motor cycle, else 0;

bicycle = 1 if household has an access to a bicycle, else 0.

Signs a priori

Ceterus paribus, a larger size of a family is expected to make more trips, thus the coefficient for the household size variable is expected to be positive. Also, higher income households are expected to make more recreational, non-work and other trips, and thus the coefficient for this variable is expected to be positive. Similarly, accessibility to any kind of private vehicle, motorized or non-motorized, is expected to increase the total number of trips generated by a household. Thus, these coefficients are expected to take positive signs. The affects of age and gender of household head variables, and the type of industry in which the household head is employed are not explicit, and thus need to be studied.

Empirical Analysis

As discussed in chapter 4, one model for the complete study area gives a poor fit (Table 3: complete study area model) explaining only 13 percent of the variation in total household trips generated. It can be observed from Table 3 that household size, gender and age of the head of the household, type of industry in which the head of the household is employed, and accessibility to any private motorized and non-motorized vehicles are all significant in explaining the overall model. However, household income, being a key element in the generation of trips, does not explain the variation in trip generation. Although the R^2 is low, the performance of overall model is good with a high F-statistic value of 27.90 significant at 99% confidence level. Thus, regression models are developed for each strata, and each group is further stratified based income, to study the travel behavior more closely.

As indicated in chapter 4, households in each group are divided into different income categories such as low, medium, high, and very high based on their average household income. Models developed for different income groups included all the variables that in the analysis. These models are referred to as "full models" (Appendix II). Further, all the variables with relatively insignificant coefficients (t-statistic < 1), are systematically dropped from the models to obtain the final models. These final models best explain the trip generation behavior for the respective groups.

MODELS BASED ON INCOME CLASSIFICATION

Downtown Area Models

Tables 11a, 11b, 12a, and 12b summarize the total, walk, work, and non-work trip generation models for all the income groups of the downtown area. The first column of each table indicates the variables used to develop the models. The entries in the other columns indicate the coefficient and t-statistic of the variables for all the income groups.

Low Income Model

The low income model shows a good fit, explaining 36 percent of the variation in total trips generated in the area. The most significant variable is the household income. The total trips generated is also influenced by the household size and type of industry in which the head of the household is employed.

The household size and income variables indicate, as expected, that households with larger families and higher incomes tend to make more trips. The industry type variable indicates that households with their heads employed in industry type 3 i.e., commerce, transportation services etc. are likely to generate fewer trips. From Table 11a, it can be observed that for every additional member in the household, an additional 0.53 trip is produced. Similarly, a 1000 Shillings increase in the total monthly income leads to an additional 0.483 trips by the households in the low income groups, while every

additional member of the household, employed in industry type 3 is likely to produce 2.5 fewer trips. This model development effort indicates that total trip generation among the low income groups is primarily determined by the size of the family, the total household income, and the industry type in which the head of the household is employed, and is not influenced by gender and age of the head of the family, or accessibility to any vehicle (motorized or non-motorized).

Walk is a very primary mode of transportation used in the Third World Countries, which should therefore be given due consideration. A detailed analysis of the walk trip models for various income groups is done for the area. Table 11b summarizes the walk trip generation models.

The walk trip generation model for this group shows a good fit, explaining about 47 percent of the variation in total walk trips generated from the area. The gender of the head of the family, accessibility to vehicle and motorcycle variables are the only significant explanatory variables, while the others are not found to be significant. Also, these significant variables have a negative impact on the trips generated. Thus, as was expected, access to vehicles and motorcycles among low income groups leads to decrease in walk as a primary mode.

A summary of the work and non-work trip generation models for all income groups for the downtown area are presented in tables 12a and 12b respectively. The most significant variable in the work trip generation model for the low income groups is the gender of the head of the family. The model gives a good fit, explaining about 40 percent of the variation in work trips generated by the household. Other variables significant in explaining the model are the household income, accessibility to vehicle and bicycle. Thus, all other variables held constant, an increase in the household income leads to generation of more work trips. Also, same is the case with vehicle and bicycle accessibility. It can be observed that a household with a female head is likely to generate 0.67 trips more than that with a male head.

All shopping, recreation, and other trips are grouped as non-work trips. Around 38 percent of the non-work trips generated by the low income groups are explained, with the household size, income variables being significant, with a positive impact on the number of trips generated, and type of industry with a negative impact. Other variables are observed to be not significant.

Medium Income Model

The model gives a poor fit, explaining only 12.3 percent of the variation in total trips generated by the medium income households. The number of trips generated by a household is determined primarily by the accessibility of the household to a vehicle or a bicycle, whose coefficients are found to be significant. As expected, access to vehicle and bicycle leads to 1.2 to 2.0 additional trips, respectively. The coefficients of other variables in the model are not found to be significant, and thus do not affect trip generation.

The walk trip generation pattern for this income group has a very low predictability. Only 6 percent of the variation in walk trips generated are explained by this model.

The work trip generation pattern of the medium income households is difficult to predict. This model, like the total trip generation model, has a very poor fit, explaining only 10.6 percent of the variation in work trips generated by the household. Household size and gender of the household head are the only significant variables.

This group is least predictable, with only 15 percent of the variation in non-work trips generated being explained. However, income, accessibility to vehicle and bicycle variables are significant.

High Income Model

The high income total trip generation model shows a good fit, explaining 62.4 percent of the trips generated in the area. The number of trips generated by the high

TABLE 11a. DOWNTOWN AREA TOTAL TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.530 (2.014)		-0.248 (-1.929)	0.165 (1.358)
Income	0.483 (2.392)		0.079 (1.092)	-0.003 (-2.354)
Gender				-2.347 (-2.207)
Age			0.054 (1.247)	0.066 (1.771)
Industry	-2.524 (-1.764)		-1.374 (-1.289)	-1.551 (-1.444)
Vehicle		1.193 (1.936)		2.956 (2.672)
Motorcycle			8.429 (4.449)	1.843 (1.694)
Bicycle		2.056 (2.069)		
R^2	0.356	0.123	0.624	0.309
F /C.L.	3.504 / 95.53%	4.699 / 98.38%	4.982 / 99%	3.335 / 99%
df	19	63	15	52
N	23	66	21	60

TABLE 11b. DOWNTOWN AREA WALK TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Low	Medium	High	Very High
HH Size			0.141 (2.681)	0.243 (2.937)
Income				-0.002 (1.937)
Gender	-1.902 (-2.982)			-1.744 (-2.435)
Age				0.046 (1.819)
Industry		0.514 (1.021)		-0.772 (-1.054)
Vehicle	-1.361 (-2.304)	-0.949 (-1.776)	-1.032 (-1.577)	-1.165 (-1.554)
Motorcycle	-2.426 (-1.627)			-0.841 (-1.064)
Bicycle			2.698 (2.589)	
R^2	0.468	0.058	0.506	0.358
F / C.L.	5.573 / 99%	2.052 / 77.64%	5.798 / 99%	4.139 / 99%
df	19	63	17	52
N	23	66	21	60

Coef - Coefficient
t-stat - t-statistic

TABLE 12a. DOWNTOWN AREA WORK TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Low	Medium	High	Very High
HH Size		0.078 (1.949)		0.145 (2.442)
Income	0.089 (1.681)			-0.001 (-1.121)
Gender	-0.672 (-2.179)	0.655 (2.301)		
Age				
Industry				-0.431 (-1.042)
Vehicle	0.4663 (1.663)			
Motorcycle			1.150 (1.021)	1.014 (2.475)
Bicycle	0.726 (1.452)			-0.538 (-1.220)
R^2	0.402	0.106	0.106	0.208
F / C.L.	3.022 / 95.22%	3.906 / 95.41%	2.507 / 75.61%	3.148 / 95.72%
df	18	63	19	54
N	23	66	21	60

TABLE 12b. DOWNTOWN AREA NON-WORK TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Lcw	Medium	High	Very High
HH Size	0.456 (2.067)		-0.126 (-1.082)	
Income	0.422 (2.495)	0.027 (1.025)	0.075 (1.025)	-0.002 (-2.010)
Gender				-2.170 (-2.193)
Age				0.051 (1.445)
Industry	-2.331 (-1.945)			-1.034 (-1.014)
Vehicle		0.961 (1.598)		2.622 (2.498)
Motorcycle			6.716 (3.496)	
Bicycle		2.045 (2.166)		
R^2	0.381	0.147	0.454	0.226
F / C.L.	3.894 / 95.41%	3.809 / 95.76%	4.718 / 95.76%	3.155 / 95.73%
df	19	62	17	54
N	23	66	21	60

Coef - Coefficient
t-stat - t-statistic

income groups is primarily determined by the household size, income, age of the head of the household, type of industry, and the accessibility to a motor cycle.

Unlike the low income group model, the household size variable has a negative coefficient indicating that as the size of the family increases, the number of trips generated decreases. Also, as the age of the household head increases, more number of trips are likely to be generated. Access to motorcycles leads to 4.45 additional trips per household. Other variables used in the model are not significant in explaining the trips generated.

Like the low income groups, around 51 percent of the variation in walk trips are explained by this model. Interesting observations are that as household size increases, high income groups are likely to generate more walk trips. Also, access to vehicle results in less walk trips, while access to bicycle results in more walk trips.

Like the medium income groups, the variation in work trip generation for the high income groups has a poor fit, with only 11 percent explainability. The only variable significant is the accessibility to motor cycle.

Around 45.3 percent of the variation in non-work trips generated are explained for the high income groups, with the household size, income, and accessibility to motorcycle variables being significant in explaining the model. Other variables remain not significant. The size of the household has a negative impact on the trips generated.

Very High Income Model

The total trip generation model for this group gives a reasonable fit, explaining 31 percent of the variation in trip generation pattern. The vehicle accessibility variable is highly significant. All the variables except accessibility to bicycle are significant in explaining the trips generated. While household size, age of the head of the family, accessibility to vehicle and motorcycle have a positive impact on the trips generated, the income, gender of the head of the household, industry type have a negative impact, with all variables being significant.

The trip generation model for the very high income groups explains around 36 percent of the variation in walk trips generated. All the variables except bicycle accessibility are significant for the group.

Only 21 percent of the variation in work trip generation pattern is being explained for this group. The household size, income, industry motorcycle and bicycle accessibility variables are significant, with a negative coefficient for the income variable. The other variables are found to be insignificant. Thus, an increase in the family size, accessibility to vehicle and bicycle result in more work trips per household. However, an increase in income indicates less number of trips generated from the area.

The model for the very high income groups explains around 23 percent of the variation in non-work trips generated. The household income, gender of the head, and industry type are found to have negative impact on the total nonwork trips generated. Age of the household head and vehicle accessibility variables have positive effect on the total nonwork trips generated by the household. Other variables are not found to be significant in explaining the model.

In general, the total trips per household model gives a good fit for the low and high income groups, while the model for the medium income groups gives a poor fit.

While industry type variable is found to have a negative effect on the total trips generated for all income groups, increase in household size is found to decrease total trips for the high income groups, increase in income decreases total trips for the very high income groups. Similar is the effect of gender of the household head on the very high income groups.

Household income is not found to be significant in explaining the walk trips generated by the high income groups, while it has a negative impact on the very high income groups. Income variable is less significant in explaining the variation in walk trip generation among low income groups in the Downtown area. Common observations are that access to vehicle and motor cycle is found to decrease walk trips among all the

income groups. Also, gender of household head is found to be significant among the low and very high income groups. Households with female heads are likely to produce more walk trips than those with male heads.

It can be observed that low income groups are more sensitive to income and bicycle accessibility than the very high income groups. The very high income groups are more sensitive to household size, vehicle and motor cycle accessibility.

It can also be observed that vehicle accessibility is significant among the low income groups for work trip generation with a positive affect. However, it is not significant in the explaining the variation in total trip generation. It can thus be noted that, access to vehicles among the low income groups is mostly used for making essential i.e., work trips. Households earning 200,000 Tanzanian Shillings per month and over are more sensitive to household size, income, gender, and vehicle accessibility for the total trips model. Motor cycle accessibility is significant and sensitive for generating work trips.

It can be observed that, increase in household size increases total nonwork trips in the low income categories, while it decreases the nonwork trips among the high income groups. Also, motor cycle accessibility is likely to have a great impact on increasing the number of nonwork trips among the high income groups.

Vehicle accessibility and household size are observed to have a positive effect on nonwork trips generated by the very high income groups. Household size, and gender of household head have a negative impact.

The various income groups behave similarly in terms of the total trips and nonwork trips. It can be observed that vehicle accessibility is significant among low income groups for work trips model, while in vehicle accessibility has no effect on these groups for nonwork trips. Gender of household head is found to have significant effect on generation of nonwork trips while it is insignificant in work trip generation for the income groups earning 200,000 Shillings a month and more.

It can be observed that vehicle and bicycle accessibility decreases walk trips among the very high income groups, while it increases the total trips, work trips, and nonwork trips generated. Increased motor cycle accessibility is observed to increase total, work, and nonwork trips generated by the high income groups, while it has no significant affect on walk trips. An increase in vehicle, motor cycle accessibility decreases walk trips and increases work trips among the low income groups.

One possible conclusion is that automobile accessibility leads to making essential trips i.e., work trips only by the low income group households.

Residential Area Models

Zones 130, 140, 150, and 260, with average zonal incomes greater than 35,000 Shillings a month, show a variation in behavior compared to the other residential zones with average zonal incomes less than 35,000 Shillings a month. Thus, a classification of the residential area zones into models I and II is done to better explain the behavior.

Residential Area I Models

Zones 130, 140, 150, and 260 with average zonal incomes more than 35,000 Shillings a month belong to the residential area I. These areas are predominantly residential areas and thus, significant differences in travel behavior are expected. Therefore, separate models are developed for these areas.

Similar to the Downtown areas, models based on income stratification are developed for total trips, work trips, non-work trips, and walk trips.

Tables 13a, 13b, 14a, and 14b summarize the trip generation models for the various income groups for the residential area I.

Low Income Model

The total trip generation model for low income groups explains only 17 percent of the total trips generated. The variable that has the highest significance on trips generated is the household size, with a t-statistic of 4.375. Other significant variables in the model

are income, accessibility to motorcycle and bicycle.

Unlike the work trip models, the non-work trip model gives a better fit, explaining 16 percent of the variation in non-work trips generated. The variables significant are the household size, income, motorcycle accessibility. Access to a motorcycle leads to 2.64 additional non-work trips.

Medium Income Model

Like the models in other zones, the trip generation pattern of the medium income groups is less predictable. The total trip generation model developed here, explains only 17.9 percent of the variation in trips generated. The household size, income, vehicle and motorcycle accessibility variables are observed to be significant. It can be observed here that the medium income group households are likely to make more trips with increased vehicle accessibility.

Work trip generation models for low and medium income groups give very poor fits, explaining only 4 percent and 6 percent variation respectively. However, the income and gender of the head of the family variables are found to be significant in the medium income groups, while bicycle accessibility is the only significant variable in the low income model.

Household size is very significant in explaining the non-work trips generated by the medium income groups, with an R^2 value of 17.6 percent. Other variables significant are the income, motorcycle accessibility, having a positive impact, and gender of the head of the family having a negative impact.

High Income Model

The total trip generation model for the high income group explains around 22 percent of the variation in trips generated. It can be observed from the analysis that household size, industry type, vehicle accessibility are significant and have a positive impact on the total trips generated by a household. The other variables, however, are

insignificant.

Unlike the low and the medium income models with very less predictability, the variation in work trips generated in the high income groups can be explained about 28 percent. The only variables significant are the accessibility variables. Thus, an increased access to autos, motorcycles, and bicycles leads to more work trips.

About 17.3 percent of the variation in non-work trips can be explained, with the household size, industry type, and vehicle accessibility variables being significant. These variables have a positive impact on the trips generated.

Very High Income Model

The model for households for very high income groups explains around 36.3 percent of the variation in total trips generated. It can be observed that the household size, gender of the household head and vehicle accessibility are the only significant variables in explaining the number of household trips generated.

Only the very high income groups give better total trip generation model and it can be observed that household size, gender, and vehicle accessibility are found to have a positive effect.

The walk trip pattern is much similar to the other models developed above, for all income groups. It can be observed from Table 13b, that increased household size increases the total walk trips produced by a household belonging to all the income groups. However, accessibility to a private vehicle has no impact on the walk trips generated by the low income groups, while it has a negative impact on the walk trips generated by the medium income groups. Very poor walk trip models are obtained for the residential area I with an R^2 value of 11.7 percent for the very high income groups.

This work trip generation model for the very high income groups explains around 30.6 percent of the variation in work trips generated. The significant variables are the gender of the head of the family, vehicle and bicycle accessibility. Other variables are not

TABLE 13a: RESIDENTIAL AREA I TOTAL TRIP GENERATION MODELS

Variable		Income		
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.329 (4.376)	0.334 (6.979)	0.157 (1.023)	0.639 (3.122)
Income	0.093 (1.663)	0.0187 (1.474)		
Gender				5.483 (2.586)
Age				
Industry			3.254 (1.865)	
Vehicle		0.632 (1.838)	2.394 (2.789)	2.170 (1.905)
Motorcycle	2.837 (2.368)	0.491 (1.407)		
Bicycle	0.753 (1.399)			
R^2	0.172	0.179	0.216	0.362
F / C.L.	7.704 / 99%	17.124 / 99%	3.598 / 95.47%	7.224 / 99%
df	144	310	36	34
N	149	315	40	38

TABLE 13b: RESIDENTIAL AREA I WALK TRIP GENERATION MODELS

Variable		Income		
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.202 (3.135)	0.134 (3.471)	0.147 (1.624)	0.186 (1.811)
Income				
Gender	-0.688 (-2.114)			
Age				-0.055 (-1.567)
Industry				
Vehicle		-0.922 (-3.377)		
Motorcycle			-0.702 (-1.501)	
Bicycle		0.372 (1.186)		
R^2	0.089	0.068	0.108	0.117
F / C.L.	14.603 / 99%	7.686 / 99%	2.418 / 75.97%	2.524 / 80.07%
df	146	311	37	35
N	149	315	40	38

Coef - Coefficient
t-stat - t-statistic

TABLE 14a: RESIDENTIAL AREA I WORK TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Low	Medium	High	Very High
HH Size				
Income		0.005 (1.010)		
Gender		0.115 (1.012)		1.485 (2.421)
Age				
Industry				
Vehicle			0.791 (2.830)	0.800 (2.331)
Motorcycle			0.652 (2.617)	
Bicycle	0.488 (2.601)		0.976 (1.896)	1.162 (2.695)
R^2	0.044	0.006	0.285	0.306
F / C.L.	6.856 / 99%	1.066 / <75%	5.311 / 99%	5.581 / 99%
df	147	312	36	34
N	149	315	40	38

TABLE 14b: RESIDENTIAL AREA I NON-WORK TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.314 (4.518)	0.328 (7.234)	0.202 (1.442)	0.698 (3.683)
Income	0.086 (1.683)	0.020 (1.688)		
Gender		-0.576 (-1.941)		4.017 (2.164)
Age				
Industry			2.594 (1.686)	
Vehicle			1.758 (2.323)	
Motorcycle	2.641 (2.384)	0.473 (1.425)		
Bicycle				-2.554 (-1.928)
R^2	0.166	0.176	0.173	0.329
F / C.L.	9.918 / 99%	16.862 / 99%	2.796 / 80.07%	6.210 / 99%
df	145	310	36	34
N	149	315	40	38

Coef - Coefficient
t-stat - t-statistic

significant in explaining the work trips generated in this group.

Households belonging to the very high income groups give good fit. Gender of household head is found to have a positive impact. Also, vehicle and bicycle accessibility are found to have a positive impact on the work trips generated. Household size does not determine the number of work trips generated, although it is significant in determining the total trips generated.

The nonwork trip generation model for the very high income groups is much similar to that for the work trip model, with an R^2 value of 33 percent. The household size, gender of the head of the family are found to have a positive impact, while bicycle accessibility has a negative influence on the total nonwork trips generated.

It can be observed that only the very high income groups give good fit with household size, gender of household head having a positive impact. Age, and industry are found to have a negative impact. Also, while vehicle accessibility increases total trips and work trips, it has no affect on nonwork trips.

Residential Area II Models

Zones 110, 120, 160, 170, and 270 with average zonal incomes of less than 35,000 shillings a month are grouped together as residential areas II. Separate models are developed for these zones.

Tables 15a, 15b, 16a, and 16b summarize the total trip generation models for the various income groups for the residential area II.

Low Income Model

Compared to the Residential area I model for the low income groups, the total trip generation is better explained for this group, with 26 percent predictability. The most significant variable is the household size. Other significant variables are the age of the household head, and bicycle accessibility. Also, the type of industry, the head of the household is employed in, is significant with a negative impact on the total trips generated.

The non-work trip generation model for the low income groups explains around 25.3 percent of the variation in trips generated, with household size, age of the household head, and bicycle accessibility having a positive impact, while income and industry type have a negative and significant impact.

Medium Income Model

This income group behaves in much a similar manner as the low income groups, with an R^2 value of 20.5 percent. All the variables explained for the low income model except the industry type, are found to be significant in this model.

The walk trips generated for the low and the medium income groups give poor fits, explaining only 18 percent of the variation in travel pattern. However, some of the significant variables are household size, income, gender and age of household head, industry type, vehicle and motor cycle accessibility.

The non-work trip generation model for medium income groups gives a better fit than that for the low income groups, with an R^2 of 32.4 percent. The income variable has a positive impact on the trips generated, for this model. Also, access to private vehicle is likely to decrease the number of nonwork trips, while increased bicycle accessibility increases total nonwork trips generated. Other significant variables are the household size, gender of the household head, and bicycle accessibility. However, industry type and age of the head, have no significant impact on the trip generation.

High Income Model

It can be observed from the table 14 that there is not much variation in the behavior of the trip making pattern across various income groups. The developed model explains about 29.3 percent of the variation in total trips generated. The size of the household and bicycle accessibility have a positive impact on the total trips generated, while the household income, gender of the household head, and the type of industry have a negative impact.

The walk trip patterns for high income groups are better explained, with an R^2 value of 33 percent. The only significant variables are household size, and motorcycle accessibility with positive impacts, and gender of household head, and industry type with negative impacts.

While vehicle accessibility has no significance in non-work trip generation, motor and bicycle accessibility have a positive impact. Industry type and gender of household head have a negative impact on number of trips generated. Household size continues to have the highest significance, in all these models. Around 30 percent of the variation in non-work trip pattern is predictable for the high income groups.

Very High Income Model

The total trip generation is better explained in the very high income groups with 45 percent explainability. It can be observed that the accessibility to bicycle continues to have a positive and significant impact on the total trip generation. Other significant variables are the size of the household having a positive impact and the industry type with a negative impact.

Likewise the residential area I, the residential area II models are better explained for very high income groups, while other groups give poor fits. However, there is a significant difference in the travel behavior between the two groups.

It can be seen that around 45 percent of the total trips generated are explained for the very high income groups, while it is only 36 percent for area I. It can also be observed that household size is significant in explaining the total trip generation models for area II. Also, vehicle accessibility has no significant effect on trips generated in area II, while it has a positive impact on the households of area I. Industry type is found to be significant with a negative impact on trips generated in area II.

TABLE 15a: RESIDENTIAL AREA II TOTAL TRIP GENERATION MODELS

Variable	Income			
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.321 (6.024)	0.379 (9.459)	0.509 (3.062)	0.365 (3.436)
Income			-0.057 (-1.012)	
Gender			-1.409 (-1.134)	
Age	0.058 (4.381)	0.013 (1.032)		
Industry	-0.713 (-2.215)		-1.423 (-1.188)	-2.626 (-2.884)
Vehicle				
Motorcycle				
Bicycle	0.736 (1.735)	1.118 (2.948)	2.794 (2.283)	1.803 (2.094)
R^2	0.255	0.205	0.283	0.452
F / C.L.	22.107 / 99%	42.426 / 99%	4.502 / 99%	10.694 / 99%
df	253	490	51	35
N	258	494	57	39

TABLE 15b: RESIDENTIAL AREA II WALK TRIP GENERATION MODELS

Variable	Income			
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.168 (3.315)	0.193 (5.503)	0.199 (1.545)	0.093 (1.277)
Income	-0.041 (-1.079)	0.034 (3.258)		
Gender	-0.561 (-1.883)	-0.595 (-2.376)	-3.608 (-3.717)	
Age	0.057 (4.398)	0.012 (1.092)		
Industry	-0.338 (-1.101)	-0.487 (-1.905)	-2.235 (-2.537)	
Vehicle	-1.168 (-1.836)	-0.598 (-1.703)		
Motorcycle	-1.668 (-1.954)	-0.415 (-1.013)	1.254 (1.091)	
Bicycle				
R^2	0.181	0.178	0.328	0.042
F / C.L.	8.162 / 99%	15.243 / 99%	6.948 / 99%	1.717 / <75%
df	250	486	52	37
N	258	494	57	39

Coef - Coefficient
t-stat - t-statistic

TABLE 16a: RESIDENTIAL AREA II WORK TRIP GENERATION MODELS

Variable	Income			
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.037 (1.911)	-0.039 (-2.788)	0.077 (1.357)	0.093 (2.288)
Income	0.029 (1.957)		-0.034 (-1.396)	
Gender	0.539 (4.648)	0.454 (4.342)	0.755 (1.764)	
Age		-0.006 (-1.305)		
Industry	0.218 (1.783)	0.238 (2.207)		
Vehicle			0.568 (1.493)	
Motorcycle		0.254 (1.408)		0.553 (1.263)
Bicycle		-0.276 (-2.076)	0.869 (2.099)	
R^2	0.125	0.103	0.188	0.175
F / C.L.	9.189 / 99%	9.419 / 99%	2.646 / 95.23%	4.127 / 95.40%
df	253	487	51	36
N	258	494	57	39

TABLE 16b: RESIDENTIAL AREA II NON-WORK TRIP GENERATION MODELS

Variable	Income			
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.297 (5.848)	0.351 (9.069)	0.406 (2.662)	0.274 (2.459)
Income	-0.069 (-1.867)	0.074 (6.213)		
Gender		-0.817 (-2.870)	-2.428 (-2.110)	1.075 (1.012)
Age	0.051 (3.994)			
Industry	-0.888 (-2.881)		-1.501 (-1.395)	-2.617 (-2.707)
Vehicle		-0.863 (-2.097)		
Motorcycle			2.013 (1.461)	
Bicycle	0.716 (1.767)	1.075 (2.914)	2.054 (1.818)	1.539 (1.673)
R^2	0.254	0.324	0.298	0.392
F / C.L.	17.535 / 99%	47.332 / 99%	4.839 / 99%	6.277 / 99%
df	252	488	51	34
N	258	494	57	39

Coef - Coefficient
t-stat - t-statistic

Unlike the other zones studied so far, the variation in walk trips for the very high income groups can be explained only 4 percent, with the household size variable being the only significant one.

Around 39 percent of the variation in non-work trips generated are explained by this model. This model is similar to the high income model. One interesting observation is that, households with male heads are likely to make more trips than those for female heads, unlike that observed in the high income model.

The work trip models for all income groups give poor fits, explaining only 18 percent of the variation in work trips generated, in all income groups. However, it can be observed that household size, gender of the head of the household, industry type, motor cycle and bicycle accessibility are some of the significant variables in explaining the work trip models. The work trip models developed for the residential areas, in general are poor.

It can be concluded that vehicle accessibility has no affect on walk trips, while it increases work trips. Thus, it can be observed that households belonging to these zones make only essential trips.

Total nonwork trips generated are better explained compared to the work trip models. While vehicle accessibility decreases total nonwork trips, bicycle accessibility is found to increase work trips among all the income groups. Industry type has a positive affect compared to other groups with a good fit of 33 percent for medium income groups for nonwork trips is obtained. Bicycle accessibility has a positive impact on nonwork trips in residential area II, while it has a negative impact on nonwork trips in residential area 1 for very high income groups.

Industrial Area Models

Zones 70, 80, and 90 are primarily industrial locations. Thus, separate models are developed for this group of zones.

Tables 17a, 17b, 18a, and 18b summarize the trip generation models for the various income groups for the industrial area.

It can be observed from the analysis that trips generated for the very high income groups gives a good fit, explaining 33 percent of the variation in total trips, while all other groups explain less than 25 percent variation. While all the variables are significant to an extent among the low income groups, only household size variable is significant among the high income groups.

It can be observed that increase in income leads to less number of total trips. Increased motor cycle accessibility leads to more total trips generated, while increased vehicle accessibility decreases the total number of trips.

The walk trip models developed for the industrial area give very poor fits, with a predictability of less than 10 percent. Household size is the most significant variable in explaining the walk trips in this region. Other significant variables are age of the household head, type of industry in which the household head is employed, and vehicle accessibility.

The very high income groups give a good fit of the model, explaining 44.4 percent of the variation in work trips generated, while it is only 5 to 10 percent among the other groups. The only significant variable in the very high income model is the accessibility to a motorcycle. Household size is a significant variable among the other groups. It can also be noticed that vehicle accessibility and bicycle accessibility measures are significant among certain income groups to explain the total work trips generated in the areas. Increased motor cycle accessibility leads to less work trips.

TABLE 17a: INDUSTRIAL AREA TOTAL TRIP GENERATION MODELS

Variable	Income			
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.352 (4.833)	0.292 (5.106)	0.590 (2.851)	
Income				
Gender				6.100 (1.452)
Age		0.0318 (1.848)		
Industry				-5.900 (-1.653)
Vehicle				
Motorcycle				
Bicycle	0.893 (1.719)	-0.489 (-1.193)		
R^2	0.144	0.135	0.203	0.334
F / C.L.	14.006 / 99%	13.736 / 99%	8.638 / 99%	3.758 / 80.87%
df	164	261	32	12
N	167	265	34	15

TABLE 17b: INDUSTRIAL AREA WALK TRIP GENERATION MODELS

Variable	Income			
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.204 (3.199)	0.124 (2.310)	0.153 (1.024)	-0.255 (-0.870)
Income				
Gender				
Age		0.016 (1.001)		
Industry	0.629 (1.383)		1.113 (1.204)	
Vehicle		-0.378 (-1.046)		
Motorcycle				
Bicycle				
R^2	0.070	0.034	0.078	0.055
F / C.L.	6.327 / 99%	3.105 / 95.57%	1.437 / <75%	0.873 / <75%
df	164	261	31	13
N	167	265	34	15

Coef - Coefficient
t-stat - t-statistic

TABLE 18a: INDUSTRIAL AREA WORK TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.043 (1.597)	0.043 (2.056)	0.093 (1.478)	
Income			-0.032 (-1.775)	
Gender	0.188 (1.229)	0.284 (2.072)		
Age				
Industry				
Vehicle				
Motorcycle				2.916 (3.221)
Bicycle		-0.214 (-1.327)		
R^2	0.025	0.034	0.087	0.444
F / C.L.	2.132 / 75.57%	3.128 / 95.55%	1.622 / <75%	11.971 / 99%
df	164	261	31	13
N	167	265	34	15

TABLE 18b: INDUSTRIAL AREA NON-WORK TRIP GENERATION MODELS

	Income			
Variable				
Coef (t-stat)	Low	Medium	High	Very High
HH Size	0.310 (4.576)	0.281 (5.399)	0.513 (2.491)	-0.782 (-1.823)
Income	0.109 (2.261)			
Gender		0.415 (1.220)		
Age				
Industry				-4.688 (-1.644)
Vehicle		0.4998 (1.353)		
Motorcycle				
Bicycle		-0.454 (-1.134)		
R^2	0.141	0.116	0.162	0.382
F / C.L.	13.690 / 99%	8.674 / 99%	6.593 / 95.71%	4.633 / 95.24%
df	164	260	32	12
N	167	265	34	15

Coef - Coefficient
t-stat - t-statistic

Around 38.2 percent of the variation in non-work trips generated among the very high income groups are explained by the model, while it is less than 20 percent among the other groups. Household size, income, gender of the head of the household, and accessibility to a private vehicle and motor-cycle are the most significant variables among the low income groups. The medium income group household non-work trip generation is mostly influenced by the household size, age of the head of the household, and accessibility to a private vehicle. However, it can be observed that increased vehicle accessibility is either insignificant, or reduces non-work trips among the high and the very high income groups respectively.

Among the very high income groups, vehicle accessibility, household size, and income have a negative affect on the nonwork trips generated, while gender of household head, and motor cycle accessibility has a positive impact.

In general, only the high income groups are giving better models with good fits, and the very high income households are found to be less sensitive to nonwork trips. Also, industrial area which is primarily a work zone, attracting trips explains very less work trip generation models.

Sensitivity Analysis

Sensitivity of income variable for non-work trips across groups (table 19) reveals that low income households in the downtown areas are much more sensitive to income than similar households in other areas. Households living in downtown areas have access to different places because of good public transit service system (Wilbur Smith Associates, 1991). Low income households in residential area II tend to make less non-work trips with increase in household income. The average household income of the households in this area is less than those in residential area I which could possibly result in a fewer non-work trips.

Analysis of income sensitivity for work trips across different groups (table 20) reveals that low income groups in downtown area are more sensitive to work trips. It can also be observed that as income increases, very high income households in downtown area make less work trips. These group of households who are classified as high and very high often hire maids to make short trips to grocery stores, shopping etc.

It can be observed from table 20 that low income households in downtown area are likely to generate more work trips with access to private vehicles, while the work trip generation by low income groups of other areas remains unaffected with increased access to private vehicles. As expected, high and very high income households are likely to generate more non-work trips with increased access to private vehicles (table 21). However, vehicle accessibility has no affect on non-work trip generation among low income households in the study area. While medium income groups in downtown and industrial areas generate more non-work trips with increased vehicle accessibility, households in residential area II, in fact, generate 0.86 fewer trips. Non-work trip generation remains unaffected in the residential areas. Households living in these areas live far from work places, compared to those in downtown and industrial areas. Also, gasoline cost is very high thereby discouraging individuals from using vehicles to make recreational trips. Thus, access to private vehicles does not affect non-work trip generation.

It can be observed from table 23 that low income groups in downtown area make more trips with increase in household size and high income groups make more total trips in other areas. High and very high income groups in residential and industrial areas are more likely to make more non-work trips compared to other groups, thereby adding more number of total trips. These groups of households can afford recreational and social trips more often than the low and medium income groups.

Low income groups in residential and industrial areas make more walk trips (table 24). As expected, high and very high income groups generate less walk trips compared to other groups in the study area.

Table 19: Income sensitivity for non-work trip models

	Income			
Area Type	Low	Medium	High	Very High
Downtown	0.422	0.027	0.075	-0.002
Residential I	0.086	0.020		
Residential II	-0.069	0.074		
Industrial	0.109			

Table 20: Income sensitivity for work trip models

	Income			
Area Type	Low	Medium	High	Very High
Downtown	0.089			-0.001
Residential I		0.005		
Residential II	0.029		-0.034	
Industrial			-0.032	

Table 21: Sensitivity of auto accessibility for work trip models

	Income			
Area Type	Low	Medium	High	Very High
Downtown	0.4663			
Residential I			0.791	0.8
Residential II			0.568	
Industrial				

Table 22: Sensitivity of auto accessibility for non-work trip models

	Income			
Area Type	Low	Medium	High	Very High
Downtown		0.961		2.622
Residential I			1.758	
Residential II		-0.863		
Industrial		0.499		

Table 23: Sensitivity of household size for total trip models

		Income		
Area Type	**Low**	**Medium**	**High**	**Very High**
Downtown	0.530		-0.248	0.165
Residential I	0.329	0.334	0.157	0.639
Residential II	0.321	0.379	0.509	0.365
Industrial	0.352	0.292	0.590	

Table 24: Sensitivity of household size for walk trip models

		Income		
Area Type	**Low**	**Medium**	**High**	**Very High**
Downtown			0.141	0.243
Residential I	0.202	0.134	0.147	0.186
Residential II	0.168	0.193	0.199	0.093
Industrial	0.204	0.124	0.153	-0.255

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

From the findings in chapter 5, it can be concluded that zonal-based modeling is not suitable for third-world countries because of non-homogenous socio-economic characteristics, and significant differences in the behavior of similar groups residing in different areas.

The travel behavior of the low income groups in the downtown area is found to be more sensitive to income. While high income households are more sensitive to motorcycle accessibility, very high income groups are sensitive to vehicle accessibility. The travel demand of the medium income groups are not as well explained by the models developed in this research, although they are found to be sensitive to bicycle accessibility.

Among low income groups in the Downtown area, access to private vehicles leads to a reduction in walk trips and an increase in work trips. This income group uses vehicles mostly to make work trips. Medium income groups are likely to produce more non-work trips with access to vehicles and bicycles. Motorcycle accessibility among high income groups increases work and non-work trips. The very high income groups are likely to generate more non-work trips due to vehicle accessibility, and more work trips due to motorcycle accessibility.

While low income groups belonging to Residential Area I are found to be sensitive to income, and motorcycle accessibility, medium income groups are more sensitive to household size, and high and very high income groups are sensitive to vehicle accessibility.

Access to motorcycles increases non-work trips generated by the all income groups. Vehicle accessibility measure results in generation of more work and non-work trips among high and very high income group households of Residential Area I. Households with male heads are likely to generate more non-work trips among very high income groups, while they are likely to generate less non-work trips among medium income groups.

Analysis of the Residential Area II shows that low income groups are more sensitive to income, and high income groups are more sensitive to household size. An increase in household size increases the total trips generated by the household in the areas. Access to any motorized or non-motorized vehicle is likely to reduce walk trips among all income groups in the Residential Area II, while it increases work trips among medium income groups, and increases non-work trips among very high income groups.

Travel demand of Households residing in the industrial areas are found to be less sensitive to income. Vehicle accessibility measure increases non-work trips among the medium income groups, and access to motorcycles increases work trips among very high income groups. Low income groups are more sensitive to the gender of the household head. Households with male head are likely to generate more work trips among low income groups, while they are likely to generate more non-work trips among medium income groups.

The trip making pattern of the high income groups and the low income groups is more predictable. A large proportion of the medium income group households rely on a number of additional economic activities outside of the regular employment in order to supplement family income. This may result in inaccurate reporting of the income. On the other hand, the low income groups have more consistent economic activities. Similarly, the high income group households have a more predictable life-style. Thus, the travel behavior of high and low income groups is more stable and predictable than medium income households.

Gender of the household head and accessibility to bicycles are not found to be significant. However, increased access to motorcycles leads to more trips generated. Bicycles are, in general, thought of as unsafe for travel and thus, their usage is less compared to motorized vehicles. Also, the advantage of a motorized vehicle over a non-motorized vehicle, in terms of speed and comfort leads to a large proportion of people using motorized vehicles.

While accessibility to a private automobile is common among the high income groups, other income groups mostly have access to bicycles and motorcycles. The primary reasons that can be attributed to this observation is that private automobiles have high maintenance and operational costs, including the large capital investments. One interesting observation is that, in the Downtown areas, low income households are observed to have more access to private vehicles than in other areas, which was not expected. Although, this group of people has access to private vehicles, they are less used for making either work or nonwork trips. It is relevant to note that a common practice in Dar-es-Salaam, among the low income and high income groups is to operate their vehicles as private taxis for generation of additional income.

Also, though the household head is primarily employed in a particular industry, a number of other economic activities may be carried out, such as small businesses, the income from which is likely to remain unreported. Some of these inconsistencies in the reporting of the information leads to poor understanding of actual travel pattern. Often, servants and maids hired by the rich households of the society make a greater proportion of their trips for the employers, such as short trips to grocery stores etc. Thus, these trips may remain unreported. Unlike the high income groups, low income groups live on a day-to-day wage basis, and thus, make the required trips for living on a day-to-day basis, as opposed to the rich families making weekly or bi-weekly trips. For similar reasons, there is no accurate account of the income earned by low income families.

Gasoline and other vehicular fuels are very expensive in most of the third world countries. Also, capital, operational, and maintenance costs for private vehicles are highly unaffordable for the low, medium and high income groups, to a large extent. Thus, there is a very small proportion of the households owning and operating private vehicles.

In general, it is observed from the research that low income groups in Dar-es-Salaam are more sensitive to income, medium income group trip pattern is less predictable, and high and very high income groups are sensitive to vehicle and motorcycle accessibility. While vehicle accessibility reduces walk trips among all income groups, it increases work trips among low income groups, increases non-work trips among medium income groups, and increases both work and non-work trips among high and very high income groups. Medium income group households in residential area I are likely to generate more non-work trips with access to private motorcycles, while those residing in Residential Area II are likely to generate more work trips with access to private motorcycles. Households with male heads in Downtown area are likely to generate less trips while those in industrial areas generate more trips. People living in the Downtown area are closer to commercial and shopping centers. Thus, head of the household, if male, is likely to produce only work trips, while the women in the house make all the shopping trips etc. However, people living in industrial areas live far from the commercial centers of the town and thus, are often required to make long trips. Thus, men in the family are often required to make such additional trips.

RECOMMENDATIONS

It has been observed that some of the trip generation models developed have very low R^2 values. Thus, several factors can be considered for improving the performance of models. For example, non-linear functional forms should be considered for developing models, which are likely to give better explanation of the travel behavior in the areas.

Another factor relates to the accuracy of the data collected. Households are usually very skeptical about the privacy of surveys and interviews. Thus, it is recommended that the households be assured that the interviews done for such study purposes are held in strict confidence and that enough privacy is maintained from the state income tax agencies. Also, it may be necessary to develop a procedure to estimate the household income based on family activities and life-style. For example, the size of the apartment or house, rent paid, whether or not a household hires a maid for services etc. This can help in obtaining a more accurate measure of the income earned by the families. Also, average age of the labor force in the household, instead of the age of the household head, may be a better explanatory variable. One reason validating this substitution is that in many families the oldest member in the household is considered to be the head of the household whether or not he or she is an income earning member.

Further, it can also be observed that many variables originally thought of, as influencing the trip making behavior, are now found to be not significant, and there is still a scope for improving the existing models. This lays a foundation for considering many other underlying factors that were not considered for study so far, such as accessibility to and frequency of transit services in different areas, ethnicity, labor force, and auto-ownership of the household etc. Other important variables not included in the study, such as distance to the downtown, labor force of the household, ethnic origin etc., may prove to be significant in explaining the travel pattern. While the downtown areas have good access to public transit with many bus terminals, the transit service along the residential and industrial routes is poor (Wilbur Smith Associates 1991). Increased access to public transit services, and affordable transit fares would generate more transit trips, thereby developing a systematic trip generation pattern.

In general, population in the Third-World countries comprises of a large proportion of low income groups. It can be observed from the above study that low income groups tend to make only the essential trips, and are sensitive to income. These

groups inevitably rely most heavily on the cheapest form of transport, namely, non-motorized movement and particularly walking. Since such communities are expected to grow, non-motorized transport, especially, walking will increase in improtance for the urban poor. According to World Bank estimates the most economic mode of transport, next to non-motorized modes such as cycle rickshaws etc., is the bus. Minibuses are somewhat more costly than buses, but the reverse often prevails where efficiently run private minibuses run side by side with inefficiently operated bus companies. Taxis are even more costly. With cars there appears to be a leap to almost four times the cost of a taxi, some eight times the cost of a bus, and fifty seven times the cost of a bicycle trip. Not only is a private car expensive, but also consumes more road space per passenger than does a bus, thereby increasing the road maintenance expenses [Dimitriou, 1992].

The urban transport models are viewed as those not designed in response to policy issues but initially to answer transport planning questions within a given policy framework from which questions of design are then addressed. Thus, taking these concerns into consideration, improved transit service facilities, such as, frequency, low public transport fares, developing area-wide transit network, with concentration in the residential areas render better road network performance and opportunities for low income groups in particular, and other groups in general, reducing congestion, pollution, and other environmental issues. It can be observed that a wide variety of transportation modes are available for use in Dar-es-Salaam. One such mode is walk, which is very common in the third-world countries. Thus, research on mode choice calibration can be recommended for further study. Improvements in the operations of transit facilities and services, frequency, travel fare are likely to affect the travel behavior of the poor to a large extent.

Some of the remedial measures for better performance of the UTP models include evaluating the performace level of the existing models and identifying key deficiencies, thorough understanding of the travel needs of a community with due attention to various groups, and setting short-term plans to implement procedure to address the concerns.

BIBLIOGRAPHY

Allaman, Peter M., Timothy J. Tardiff, and Frederick C. Dunbar. (September 1982). "New Approaches to Understanding Travel Behavior". *National Cooperative Highway Research Program Report 250.* Transportation Research Board. National Research Council. Washington, D.C.

Dimitriou, Harry T. (1992). *Urban Transportation Planning: A developmental approach.* Chapman and Hall, Inc. New York.

Elshabani, Abdelgader. (1981). *Short Range Quick Response to meet the needs of the Transportation Problems in the Developing Countries.* Dissertation. University of Pittsburgh, Pittsburgh.

Gakenheimer, Ralph. (1993). "Land Use/Transportation Planning: New Responsibilities for Developing and Developed Countries". *Transportation Quarterly, Vol. 47, No. 2.* April, Lansdowne, Virginia.

Goulias, Konstadinos G. and Ryuichi Kitamura. (1989). "Recursion Model System for Trip Generation and Trip Chaining". *Transportation Research Record 1236.* Transportation Research Board. National Research Council. Washington, D.C.

Gujarati, Damodar. (1992). *Essentials of Econometrics.* McGraw-Hill, Inc. New York.

Hamburg, Creighton. (1971). "Data Requirements for Metropolitan Transportation Planning. National Cooperative Highway Research Program Report 120". *Highway Research Board. National Research Council.* New York.

Hamburg, John R., George T. Lathrop, and Edward J. Kaiser. (1983). "Forecasting Inputs to Transportation Planning". *National Cooperative Highway Research Program Report 266.* Transportation Research Board. National Research Council. Washington, D.C.

Hutchinson B.G. (1974). *Principles of Urban Transport Systems Planning.* McGraw-Hill Book Company. New York.

Institute of Transportation Engineers. (1987). Trip Generation. Washington, D.C.

Kostyniuk, Lidia P. and Ryuichi Kitamura. (1986). "Changing Effects of Automobile Ownership on Household Travel Patterns". *Transportation Research Record 1085*. Transportation Research Board. National Research Council. Washington, D.C.

Meyer, Michael D. and Eric J. Miller. (1984). *Urban Transportation Planning: A Decision-Oriented Approach*. McGraw-Hill, Inc. New York.

National Transport Corporation. (1985). Dar-es-Salaam Urban Passenger Transport Study.

Said, Galal M., David H. Young, and Hassan K. Ibrahim. (1991). "Trip Generation Procedure for Areas with Structurally Different Socioeconomic Groups". *Transportation Research Record 1328*. Transportation Research Board. National Research Council. Washington, D.C.

Salvatore, Dominick. (1982). *Theory and Problems of Statistics and Econometrics*. Schaum's Outline Series. McGraw-Hill, Inc. New York.

Swait, Joffre D., Jr. (1986). "Constraints on Individual Travel Behavior in a Brazilian City". *Transportation Research Record 1085*. Transportation Research Board. National Research Council. Washington, D.C.

Wilbur Smith Associates. (July 1991). Dar-es-Salaam Urban Passenger Transport Study. Columbia.

APPENDICES

APPENDIX I-FORTRAN PROGRAM FOR DATA MANIPULATION

APPENDIX II-TRIP GENERATION MODELS (FULL MODELS) FOR DOWNTOWN, RESIDENTIAL, & INDUSTRIAL AREAS

APPENDIX III-STATISTICAL CALCULATIONS FOR INCOME CLASSIFICATION

APPENDIX I

FORTRAN PROGRAM FOR DATA MANIPULATION

```
*********************************************************************
c       program for data manipulation
*********************************************************************
        integer zone(146),sqfm(146),sqper(146),fmsz(146),
     *  inc(146),home(146),work(146),sex(146),age(146),
     *  ipmode(146),x(146,24),purp(146),trtime(146),num(146),
     *  occp(146),inds(146),veh(146),motor(146),ffmode(146),
     *  bic(146),tripnum(146),origin(146),deptime(146),
     *  fsmode(146),smode(146),tmode(146),fmode(146),desti(146),
     *  new0(146),new1(146),new2(146),new3(146),
     *  new4(146),new5(146),new6(146),mod0(146),mod1(146),
     *  mod2(146),mod3(146),mod4(146),mod5(146),mod6(146),
     *  mod7(146),mod8(146),mod25(146),mod99(146),
     *  temp0,temp1,temp2,temp3,temp4,temp5,temp6,total
        real time(146)

        open(3,file = 'zone270.prn')
        open(4,file = 'sample.prn',status = 'new')

        write(*,*)'value of n ='
        read(*,*)n
        do 150 i=0,n
        k=i-1
        m=i+1
        read(3,1000)zone(i),sqfm(i),sqper(i),fmsz(i),inc(i),home(i),
     *  work(i),sex(i),age(i),occp(i),inds(i),veh(i),motor(i),bic(i),
     *  tripnum(i),origin(i),deptime(i),trtime(i),purp(i),fsmode(i),
     *  smode(i),tmode(i),fmode(i),ffmode(i)
1000    format (24(i8))

        if(zone(i).eq.0) then
                zone(i)=zone(k)
        endif
        if(sqfm(i).eq.0) then
                sqfm(i)=sqfm(k)
        endif
        if(sqper(i).eq.0) then
                sqper(i)=sqper(k)
        endif
        if((sqfm(i).eq.sqfm(k)).and.(fmsz(i).eq.0)) then
                fmsz(i)=fmsz(k)
        endif
        if((sqfm(i).eq.sqfm(k)).and.(sqper(i).eq.sqper(k))) then
                if(home(i).eq.0) then
                        home(i)=home(k)
                endif
                if(work(i).eq.0) then
                        work(i)=work(k)
                endif
                if(occp(i).eq.0) then
                        occp(i)=occp(k)
                endif
                if(inds(i).eq.0) then
                        inds(i)=inds(k)
                endif
                if(veh(i).eq.0) then
                        veh(i)=veh(k)
                endif
                if(motor(i).eq.0) then
```

```
                motor(i)=motor(k)
            endif
            if(bic(i).eq.0) then
                bic(i)=bic(k)
            endif
            if(sex(i).eq.0) then
                sex(i)=sex(k)
            endif
            if(age(i).eq.0) then
                age(i)=age(k)
            endif
        endif
        if(sex(i).eq.2) then
            sex(i)=0
        endif

*********************************************************************
c       total household income calculation
*********************************************************************
        if((sqfm(i).eq.sqfm(k)).and.(sqper(i).eq.sqper(k))) then
                inc(i)=inc(k)
        else
           if((sqfm(i).eq.sqfm(k)).and.(sqper(i).ne.sqper(k))) then
                inc(i)=inc(i)+inc(k)
            do 102 j=0,i
              if((sqfm(j).eq.sqfm(i)) .and. (inc(j).le.inc(i)))then
                    inc(j)=inc(i)
                 endif
102             continue
           endif
        endif
150     continue
        do 160 i=0,n
        do 160 j=19,19
        x(i,j)=fsmode(i)
160     continue
        do 170 i=0,n
        do 170 j=20,20
        x(i,j)=smode(i)
170     continue
        do 180 i=0,n
        do 180 j=21,21
        x(i,j)=tmode(i)
180     continue
        do 190 i=0,n
        do 190 j=22,22
        x(i,j)=fmode(i)
190     continue
        do 300 i=0,n
        do 300 j=23,23
        x(i,j)=ffmode(i)
300     continue

*********************************************************************
c       primary mode selection
*********************************************************************
        do 101 i=0,n
        num(i)=0
        do 105 ll=19,23
```

```
      if(x(i,11).gt.0) then
              num(i)=num(i)+1
      endif
105   continue
      if(num(i).eq.0) then
             ipmode(i)=0
      else
          if((num(i).eq.3).and.(x(i,19).eq.x(i,21))) then
                 ipmode(i)=x(i,20)
          else
                 if(num(i).eq.1) then
                        ipmode(i)=x(i,19)
                 else
                        if(num(i).eq.2.and.x(i,19).gt.x(i,20)) then
                               ipmode(i)=x(i,19)
                        else
                               ipmode(i)=x(i,20)
                        endif
                 endif
          endif
      endif
      if((num(i).eq.3).and.x(i,19).ne.x(i,21)) then
          ipmode(i)=25
      endif
      if(num(i).gt.3) then
          ipmode(i)=99
      endif
101   continue

*********************************************************************
c     trips by purpose
*********************************************************************
      do 201 i=0,n
      if(i .eq. 0)then
             call xyz(purp,i,new0,new1,new2,new3,new4,new5,new6)
      else
             count=0
             if(sqfm(i).eq.sqfm(k)) then
                    count=count+1
                    if(sqper(i) .eq. sqper(k))then
                    count=count+1
             call xyz(purp,i,new0,new1,new2,new3,new4,new5,new6)
             else
                    if(sqper(i).ne.sqper(k)) then
             call xyz(purp,i,new0,new1,new2,new3,new4,new5,new6)
                    endif
             endif
             else
             call xyz(purp,i,new0,new1,new2,new3,new4,new5,new6)
        endif
      endif
201   continue
      do 450 i=1,n
      k=i-1
      if(sqfm(i).eq.sqfm(k).and.sqper(i).eq.sqper(k)) then
      new0(i)=new0(i)+new0(k)
      new1(i)=new1(i)+new1(k)
      new2(i)=new2(i)+new2(k)
      new3(i)=new3(i)+new3(k)
```

```
      new4(i)=new4(i)+new4(k)
      new5(i)=new5(i)+new5(k)
      new6(i)=new6(i)+new6(k)
      endif
450   continue

**********************************************************************
c     trips by mode
**********************************************************************
      do 361 i=0,n
      if(i .eq. 0)then
         call abc(ipmode,i,mod0,mod1,mod2,mod3,mod4,mod5,mod6,mod7,
     *   mod8,mod25,mod99)
      else
            countm=0
            if(sqfm(i).eq.sqfm(k)) then
                  countm=countm+1
                  if(sqper(i) .eq. sqper(k))then
                  countm=countm+1
         call abc(ipmode,i,mod0,mod1,mod2,mod3,mod4,mod5,mod6,mod7,
     *   mod8,mod25,mod99)
            else
                  if(sqper(i).ne.sqper(k)) then
         call abc(ipmode,i,mod0,mod1,mod2,mod3,mod4,mod5,mod6,mod7,
     *   mod8,mod25,mod99)
                  endif
            endif
            else
         call abc(ipmode,i,mod0,mod1,mod2,mod3,mod4,mod5,mod6,mod7,
     *   mod8,mod25,mod99)
        endif
      endif
361   continue
      do 550 i=1,n
      k=i-1
      if(sqfm(i).eq.sqfm(k).and.sqper(i).eq.sqper(k)) then
      mod0(i)=mod0(i)+mod0(k)
      mod1(i)=mod1(i)+mod1(k)
      mod2(i)=mod2(i)+mod2(k)
      mod3(i)=mod3(i)+mod3(k)
      mod4(i)=mod4(i)+mod4(k)
      mod5(i)=mod5(i)+mod5(k)
      mod6(i)=mod6(i)+mod6(k)
      mod7(i)=mod7(i)+mod7(k)
      mod8(i)=mod8(i)+mod8(k)
      mod25(i)=mod25(i)+mod25(k)
      mod99(i)=mod99(i)+mod99(k)
      endif
550   continue

**********************************************************************
c     origin destination zones
**********************************************************************
      ivar=1
      do 333 i=1,n
      idiff=sqfm(i)-ivar
      if (sqfm(i) .eq. ivar) then
            desti(i-1)=origin(i)
      else
```

```
            ivar=ivar+idiff
        endif
333     continue

**********************************************************************
c       average time calculation
**********************************************************************
        mvar=1, nvar=1, ave=0,total=0
        do 337 i=0,n
        mdiff =sqfm(i) - mvar
        ndiff =sqper(i) - nvar
        if(sqfm(i) .eq. mvar) then
                if(sqper(i) .eq. nvar) then
                        ave=ave + trtime(i)
                        total=total+1
                else
                        if(total .eq.1)then
                                time(i-1)=ave
                                nvar=nvar+ndiff
                                ave=trtime(i)
        write(4,210)zone(i-1),sqfm(i-1),sqper(i-1),fmsz(i-1),
     *  inc(i-1),sex(i-1),age(i-1),occp(i-1),inds(i-1),veh(i-1),
     *  motor(i-1),bic(i-1),time(i-1),new0(i-1),new1(i-1),new2(i-1),
     *  new3(i-1),new4(i-1),new5(i-1),new6(i-1),mod0(i-1),mod1(i-1),
     *  mod2(i-1),mod3(i-1),mod4(i-1),mod5(i-1),mod6(i-1),mod7(i-1),
     *  mod8(i-1),mod25(i-1),mod99(i-1)
                                total=1
                        else
                                time(i-2)=ave/(total-1)
                                nvar=nvar+ndiff
                                ave=trtime(i)
        write(4,210)zone(i-2),sqfm(i-2),sqper(i-2),fmsz(i-2),
     *  inc(i-2),sex(i-2),age(i-2),occp(i-2),inds(i-2),veh(i-2),
     *  motor(i-2),bic(i-2),time(i-2),new0(i-2),new1(i-2),new2(i-2),
     *  new3(i-2),new4(i-2),new5(i-2),new6(i-2),mod0(i-2),mod1(i-2),
     *  mod2(i-2),mod3(i-2),mod4(i-2),mod5(i-2),mod6(i-2),mod7(i-2),
     *  mod8(i-2),mod25(i-2),mod99(i-2)
                                total=1
                        endif
                endif
        else
                if(total .eq. 1)then
                        nvar=1
                        time(i-1)=ave
                        mvar=mvar+mdiff
                        ave=trtime(i)
        write(4,210)zone(i-1),sqfm(i-1),sqper(i-1),fmsz(i-1),
     *  inc(i-1),sex(i-1),age(i-1),occp(i-1),inds(i-1),veh(i-1),
     *  motor(i-1),bic(i-1),time(i-1),new0(i-1),new1(i-1),new2(i-1),
     *  new3(i-1),new4(i-1),new5(i-1),new6(i-1),mod0(i-1),mod1(i-1),
     *  mod2(i-1),mod3(i-1),mod4(i-1),mod5(i-1),mod6(i-1),mod7(i-1),
     *  mod8(i-1),mod25(i-1),mod99(i-1)
                        total=1
                else
                        time(i-2)=ave/(total-1)
                        nvar=1
                        mvar=mvar+mdiff
                        ave=trtime(i)
        write(4,210)zone(i-2),sqfm(i-2),sqper(i-2),fmsz(i-2),
```

```
     *  inc(i-2),sex(i-2),age(i-2),occp(i-2),inds(i-2),veh(i-2),
     *  motor(i-2),bic(i-2),time(i-2),new0(i-2),new1(i-2),new2(i-2),
     *  new3(i-2),new4(i-2),new5(i-2),new6(i-2),mod0(i-2),mod1(i-2),
     *  mod2(i-2),mod3(i-2),mod4(i-2),mod5(i-2),mod6(i-2),mod7(i-2),
     *  mod8(i-2),mod25(i-2),mod99(i-2)
                         total=1
                endif
210     format(12i8,f8.3,18i8)
        endif
337     continue
c        do 200 i=0,n
c        write(4,100)zone(i),sqfm(i),sqper(i),fmsz(i),inc(i),home(i),
c      *  work(i),sex(i),age(i),occp(i),inds(i),veh(i),motor(i),bic(i),
c      *  tripnum(i),origin(i),desti(i),deptime(i),trtime(i),time(i),
c      *  purp(i),fsmode(i),smode(i),tmode(i),fmode(i),ffmode(i),
c      *  ipmode(i),new0(i),new1(i),new2(i),new3(i),new4(i),new5(i),
c      *  new6(i)
c100      format (19(i8),f8.2,14(i8))
c200      continue
        stop
        end

*******************************************************************
*       Subroutine for trips by purpose
*******************************************************************
        subroutine xyz(tv,l,sony0,sony1,sony2,sony3,sony4,sony5,sony6)
        integer tv(146),sony0(146),sony1(146),sony2(146),sony3(146),
     *  sony4(146),sony5(146),sony6(146),pan0,pan1,pan2,pan3,pan4,
     *  pan5,pan6
        pan0=0,pan1=0,pan2=0,pan3=0,pan4=0,pan5=0,pan6=0
        if(tv(l) .eq. 0)then
                pan0=pan0+1
                sony0(l)=pan0
        endif
        if(tv(l) .eq. 1)then
                pan1=pan1+1
                sony1(l)=pan1
        endif
        if(tv(l) .eq. 2)then
                pan2=pan2+1
                sony2(l)=pan2
        endif
        if(tv(l) .eq. 3)then
                pan3=pan3+1
                sony3(l)=pan3
        endif
        if(tv(l) .eq. 4)then
                pan4=pan4+1
                sony4(l)=pan4
        endif
        if(tv(l) .eq. 5)then
                pan5=pan5+1
                sony5(l)=pan5
        endif
        if(tv(l) .eq. 6)then
                pan6=pan6+1
                sony6(l)=pan6
        endif
        return
```

```
      end
************************************************************************
*     Subroutine for trips by mode
************************************************************************
      subroutine abc(tv,l,sony0,sony1,sony2,sony3,sony4,sony5,sony6,
     * sony7,sony8,sony25,sony99)
      integer tv(146),sony0(146),sony1(146),sony2(146),sony3(146),
     * sony4(146),sony5(146),sony6(146),sony7(146),sony8(146),
     * sony25(146),sony99(146),pan0,pan1,pan2,pan3,pan4,pan5,pan6,
     * pan7,pan8,pan25,pan99
      pan0=0,pan1=0,pan2=0,pan3=0,pan4=0,pan5=0,pan6=0,pan7=0,pan8=0
      pan25=0,pan99=0
      if(tv(l) .eq. 0)then
              pan0=pan0+1
              sony0(l)=pan0
      endif
      if(tv(l) .eq. 1)then
              pan1=pan1+1
              sony1(l)=pan1
      endif
      if(tv(l) .eq. 2)then
              pan2=pan2+1
              sony2(l)=pan2
      endif
      if(tv(l) .eq. 3)then
              pan3=pan3+1
              sony3(l)=pan3
      endif
      if(tv(l) .eq. 4)then
              pan4=pan4+1
              sony4(l)=pan4
      endif
      if(tv(l) .eq. 5)then
              pan5=pan5+1
              sony5(l)=pan5
      endif
      if(tv(l) .eq. 6)then
              pan6=pan6+1
              sony6(l)=pan6
      endif
      if(tv(l) .eq. 7)then
              pan7=pan7+1
              sony7(l)=pan7
      endif
      if(tv(l) .eq. 8)then
              pan8=pan8+1
              sony8(l)=pan8
      endif
      if(tv(l) .eq. 25)then
              pan25=pan25+1
              sony25(l)=pan25
      endif
      if(tv(l) .eq. 99)then
              pan99=pan99+1
              sony99(l)=pan99
      endif
      return
      end
```

APPENDIX II

TRIP GENERATION MODELS (FULL MODELS) FOR DOWNTOWN, RESIDENTIAL, & INDUSTRIAL AREAS

TRIP GENERATION MODELS BASED ON INCOME CLASSIFICATION (FULL MODELS)

TABLES 25 & 26: DOWNTOWN AREA MODELS

Variable	Total Trip Generation Models				Walk Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.527(1.572)	0.072(0.620)	-0.229(-1.461)	0.162(1.294)	-0.120(-0.707)	0.041(0.451)	-0.085(-0.715)	0.235(2.769)
Income	0.509(1.739)	0.025(0.862)	0.082(0.957)	-0.002(-2.331)	0.059(0.399)	-0.000(-0.463)	0.166(2.552)	-0.001(-1.920)
Sex	-0.974(-0.651)	0.253(0.285)	-0.055(-0.051)	-2.330(-2.140)	-2.237(-2.960)	0.438(0.623)	0.124(0.150)	-1.679(-2.283)
Age	0.024(0.375)	-0.014(-0.383)	0.052(1.089)	0.065(1.756)	0.0189(0.580)	-0.014(-0.509)	0.032(0.882)	0.045(1.807)
Industry	-2.248(-1.237)	-0.504(-0.642)	-1.349(-1.127)	-1.563(-1.432)	0.396(0.431)	0.769(1.244)	0.707(0.777)	-0.767(-1.041)
Vehicle	0.826(0.548)	1.030(1.561)	0.674(0.675)	2.956(2.646)	-1.118(-1.467)	-0.941(-1.676)	-1.307(-1.721)	-1.172(-1.552)
Motorcycle	-1.444(-0.308)	-0.222(-0.223)	8.032(3.571)	1.835(1.666)	-2.637(-1.114)	-0.563(-0.658)	1.428(0.834)	-0.339(-0.456)
Bicycle	2.191(0.661)	1.924(1.724)	0.288(0.170)	0.115(0.098)	0.068(0.040)	0.808(0.846)	2.645(2.049)	-0.814(-1.020)
R^2	0.415	0.154	0.640	0.309	0.534	0.091	0.589	0.360
F	1.245	1.300	2.674	2.863	2.011	0.740	2.156	3.593
df	14	57	12	51	14	59	12	51
N	23	66	21	60	23	68	21	60

Variable	Work Trip Generation Models				Nonwork Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.063(0.796)	0.084(1.936)	-0.006(-0.094)	0.114(2.363)	0.463(1.588)	-0.0126(-0.114)	-0.223(-1.446)	0.048(0.401)
Income	0.083(1.188)	-0.005(-0.499)	-0.009(-0.265)	-0.000(-1.059)	0.426(1.672)	0.030(1.109)	0.092(1.093)	-0.002(-2.007)
Sex	-0.749(-2.093)	0.715(2.142)	0.212(0.444)	-0.063(-0.151)	-0.225(-0.173)	-0.461(-0.549)	-0.267(-0.249)	-2.266(-2.173)
Age	0.012(0.820)	-0.007(-0.502)	0.009(0.466)	0.0134(0.930)	0.011(0.206)	-0.007(-0.205)	0.042(0.902)	0.052(1.459)
Industry	0.024(0.055)	-0.060(-0.206)	-0.280(-0.536)	-0.426(-1.013)	-2.272(-1.437)	-0.443(-0.596)	-1.069(-0.909)	-1.137(-1.087)
Vehicle	0.497(1.378)	0.071(0.286)	0.193(0.442)	0.339(0.788)	0.328(0.250)	0.959(1.535)	0.481(0.491)	2.617(2.445)
Motorcycle	-0.378(-0.338)	0.037(0.099)	1.037(1.056)	1.009(2.380)	-1.065(-0.261)	-0.259(-0.275)	6.994(3.167)	0.825(0.782)
Bicycle	0.996(1.256)	-0.103(-0.247)	-0.188(-0.254)	-0.516(-1.137)	1.195(0.414)	2.028(1.919)	0.477(0.286)	0.632(0.559)
R^2	0.476	0.119	0.238	0.229	0.394	0.162	0.574	0.243
F	1.593	0.962	0.468	1.889	1.138	1.384	2.027	2.046
df	14	57	12	51	14	59	12	51
N	23	66	21	60	23	68	21	60

TABLES 27 & 28: RESIDENTIAL AREA I MODELS

Variable	Total Trip Generation Models				Walk Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.273(4.411)	0.277(6.686)	0.214(1.966)	0.677(3.695)	0.150(2.432)	0.154(4.580)	0.101(1.428)	0.365(2.783)
Income	0.087(1.942)	0.025(2.450)	0.037(0.757)	0.000(0.112)	-0.014(-0.320)	0.009(1.078)	-0.008(-0.262)	-0.001(-0.554)
Sex	-0.329(-0.979)	-0.242(-0.859)	0.289(0.470)	3.178(2.244)	-0.632(-1.879)	0.039(0.172)	-0.658(-1.659)	0.229(0.225)
Age	0.011(0.670)	0.007(0.566)	-0.014(-0.428)	-0.036(-0.564)	0.006(0.377)	-0.009(-0.886)	0.003(0.180)	-0.067(-1.477)
Industry	0.190(0.469)	-0.077(-0.278)	1.892(1.907)	-1.062(-0.789)	-0.236(-0.581)	-0.160(-0.704)	-0.117(-0.183)	-0.469(-0.486)
Vehicle	-0.223(-0.027)	0.364(1.164)	2.121(2.914)	1.249(1.244)	-0.683(-0.840)	-0.893(-3.464)	-0.892(-1.898)	-1.359(-1.888)
Motorcycle	2.753(2.299)	0.536(1.691)	0.440(0.623)	0.146(0.093)	-0.336(-0.280)	-0.232(-0.872)	-0.582(-1.277)	-0.529(-0.472)
Bicycle	1.037(0.483)	0.083(0.257)	1.051(1.116)	-1.324(-0.999)	-0.246(-0.511)	0.442(1.657)	0.489(0.804)	-1.434(-1.510)
R^2	0.157	0.1287	0.241	0.278	0.070	0.072	0.146	0.286
F	4.828	8.733	2.613	2.319	1.959	4.596	1.413	2.402
df	206	473	66	48	206	473	66	48
N	215	482	75	57	215	482	75	57

Variable	Work Trip Generation Models				Nonwork Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.005(0.085)	-0.000(-0.014)	-0.006(-0.174)	0.031(0.537)	0.266(4.325)	0.281(7.172)	0.221(2.335)	0.645(3.975)
Income	0.011(0.264)	0.005(1.498)	0.004(0.255)	-0.001(-0.541)	0.075(1.678)	0.023(2.214)	0.032(0.770)	0.001(0.324)
Sex	0.041(0.124)	0.103(1.044)	-0.035(-0.167)	0.991(2.162)	-0.371(-1.103)	-0.305(-1.144)	0.324(0.609)	2.186(1.743)
Age	-0.002(-0.138)	0.003(0.887)	0.001(0.054)	-0.005(-0.283)	0.013(0.808)	0.008(0.730)	-0.014(-0.515)	-0.030(-0.534)
Industry	0.035(0.086)	-0.028(-0.289)	0.244(0.711)	-0.295(-0.677)	0.155(0.382)	-0.066(-0.249)	1.647(1.913)	-0.767(-0.643)
Vehicle	-0.313(-0.385)	0.080(0.724)	0.868(3.442)	0.735(2.261)	0.291(0.358)	0.191(0.641)	1.253(1.983)	0.514(0.577)
Motorcycle	0.229(0.191)	0.125(1.089)	0.536(2.195)	-0.192(-0.380)	2.524(2.107)	0.521(1.686)	-0.096(-0.157)	0.339(0.245)
Bicycle	0.441(0.913)	-0.158(-1.367)	0.688(2.109)	0.874(2.036)	0.596(1.234)	0.186(0.600)	0.363(0.444)	-2.198(-1.872)
R^2	0.047	0.021	0.204	0.270	0.153	0.141	0.212	0.280
F	1.295	1.243	2.115	2.221	4.647	9.737	2.215	2.333
df	206	473	66	48	206	473	66	48
N	215	482	75	57	215	482	75	57

TABLES 29 & 30: RESIDENTIAL AREA II MODELS

Variable	Total Trip Generation Models				Walk Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.326(6.052)	0.344(9.100)	0.470(2.706)	0.324(2.476)	0.168(3.314)	0.193(5.534)	0.184(1.345)	0.118(1.279)
Income	-0.035(-0.881)	-0.006(-0.326)	-0.074(-1.016)	-0.000(-0.028)	-0.041(-1.847)	0.0338(3.250)	0.037(0.649)	0.001(0.165)
Sex	0.232(0.726)	-0.029(-0.116)	-1.668(-1.313)	1.039(0.896)	-0.551(-1.826)	-0.594(-2.369)	-3.631(-3.632)	-0.241(-0.293)
Age	0.057(4.183)	0.049(4.911)	0.020(0.357)	0.008(0.200)	0.056(4.388)	0.0115(1.081)	0.020(0.450)	0.013(0.335)
Industry	-0.699(-2.140)	-0.536(-2.064)	-1.726(-1.391)	-2.523(-2.486)	-0.335(-1.088)	-0.489(-1.909)	-1.843(-1.885)	0.225(0.313)
Vehicle	0.444(0.658)	0.182(0.356)	1.153(0.975)	0.830(0.931)	-1.172(-1.838)	-0.599(-1.707)	-0.820(-0.881)	-0.459(-0.727)
Motorcycle	-0.289(-0.319)	-0.159(-0.229)	1.494(0.954)	-0.354(-0.271)	-1.664(-1.945)	-0.489(-1.182)	1.254(1.017)	-0.331(-0.356)
Bicycle	0.573(1.397)	0.803(2.448)	2.776(2.197)	1.360(1.246)	-0.077(-0.201)	0.114(0.360)	0.605(0.608)	-0.331(-0.429)
R^2	0.258	0.265	0.318	0.478	0.181	0.178	0.347	0.090
F	10.831	21.866	2.795	3.446	6.898	13.176	3.193	0.373
df	249	485	48	30	249	485	48	30
N	258	494	57	39	258	494	57	39

Variable	Work Trip Generation Models				Nonwork Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.034(1.669)	-0.038(-2.612)	0.096(1.598)	0.090(1.781)	0.292(5.689)	0.335(8.150)	0.373(2.320)	0.232(1.732)
Income	0.0285(1.886)	-0.002(-0.564)	-0.033(-1.311)	-0.005(-0.314)	-0.063(-1.673)	0.071(5.791)	-0.041(-0.605)	0.000(0.090)
Sex	0.530(4.382)	0.443(4.188)	0.836(1.893)	-0.323(-0.719)	-0.298(-0.978)	-0.846(-2.868)	-2.504(-2.129)	1.363(1.141)
Age	0.003(0.659)	-0.005(-1.241)	-0.019(-0.967)	-0.008(-0.505)	0.054(4.129)	0.012(0.979)	0.039(0.742)	0.0172(0.384)
Industry	0.224(1.817)	0.232(2.149)	0.086(0.199)	0.037(0.095)	-0.924(-2.968)	-0.149(-0.495)	-1.813(-1.575)	-2.561(-2.448)
Vehicle	-0.017(-0.066)	0.100(0.675)	0.645(1.569)	0.101(0.293)	0.461(0.717)	-0.877(-2.123)	0.508(0.463)	0.728(0.792)
Motorcycle	0.157(0.458)	0.290(1.664)	-0.229(-0.422)	0.583(1.149)	-0.446(-0.517)	0.062(0.127)	1.724(1.188)	-0.938(-0.695)
Bicycle	-0.096(-0.624)	-0.275(-2.050)	0.900(2.047)	0.083(0.198)	0.669(1.714)	1.082(2.893)	1.876(1.603)	1.276(1.135)
R^2	0.128	0.105	0.212	0.211	0.256	0.326	0.315	0.422
F	4.584	7.098	1.612	1.001	10.728	29.281	2.759	2.735
df	249	485	48	30	249	485	48	30
N	258	494	57	39	258	494	57	39

TABLES 31 & 32: INDUSTRIAL AREA MODELS

Variable	Total Trip Generation Models				Walk Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.341(4.707)	0.298(5.205)	0.609(2.343)	-0.412(-0.641)	0.212(3.244)	0.123(2.259)	0.169(1.067)	0.237(0.642)
Income	0.094(1.786)	-0.006(-0.414)	0.074(0.706)	-0.080(-1.432)	-0.036(-0.760)	-0.004(-0.269)	0.088(1.384)	0.009(0.298)
Sex	0.859(2.081)	0.590(1.614)	0.926(0.401)	7.056(1.387)	0.302(0.812)	-0.085(-0.244)	1.339(0.953)	1.648(0.563)
Age	0.002(0.117)	0.021(1.197)	-0.001(-0.011)	-0.028(-0.176)	-0.004(-0.281)	0.017(1.032)	-0.055(-1.158)	-0.117(-1.284)
Industry	-0.503(-0.964)	0.175(0.439)	-0.855(-0.565)	-2.617(-0.758)	0.559(1.186)	0.063(0.167)	0.927(1.008)	1.031(0.519)
Vehicle	0.968(1.196)	0.825(2.101)	-0.888(-0.584)	-3.546(-1.007)	-0.367(-0.503)	-0.355(-0.951)	-2.583(-2.794)	-4.583(-2.264)
Motorcycle	1.748(1.087)	0.039(0.087)	0.984(0.524)	5.855(1.562)	0.261(0.179)	0.363(0.793)	-1.069(-0.936)	3.373(1.564)
Bicycle	0.546(0.978)	-0.697(-1.659)	-1.216(-0.813)	-4.396(-0.702)	-0.211(-0.419)	-0.252(-0.631)	-1.042(-1.143)	0.894(0.248)
R^2	0.201	0.1601	0.272	0.7353	0.083	0.038	0.383	0.628
F	4.996	6.102	1.167	2.084	1.802	1.294	1.939	1.269
df	158	256	25	6	158	256	25	6
N	167	265	34	15	167	265	34	15

Variable	Work Trip Generation Models				Nonwork Trip Generation Models			
Coef (t-stat)	Low	Medium	High	Very High	Low	Medium	High	Very High
HH Size	0.037(1.373)	0.041(1.863)	0.113(1.449)	0.090(0.386)	0.303(4.433)	0.256(4.646)	0.495(1.917)	-0.502(-1.009)
Income	0.001(0.050)	-0.002(-0.449)	-0.031(-0.999)	0.004(0.208)	0.094(1.872)	-0.003(-0.248)	0.106(0.104)	-0.084(-1.947)
Sex	0.172(1.096)	0.275(1.938)	0.504(0.724)	1.403(0.759)	0.687(1.762)	0.315(0.893)	0.421(0.183)	5.653(1.434)
Age	0.005(0.895)	-0.002(-0.316)	0.002(0.064)	-0.014(-0.244)	-0.003(-0.235)	0.023(1.368)	-0.002(-0.303)	-0.013(-0.113)
Industry	-0.039(-0.198)	-0.049(-0.317)	0.019(0.042)	-0.658(-0.525)	-0.464(-0.941)	0.225(0.583)	-0.874(-0.582)	-1.959(-0.732)
Vehicle	-0.117(-0.381)	0.393(2.584)	0.033(0.074)	0.394(0.308)	1.085(1.419)	0.431(1.138)	-0.922(-0.610)	-3.941(-1.445)
Motorcycle	-0.051(-0.083)	-0.137(-0.734)	0.034(0.059)	2.351(1.726)	1.799(1.185)	0.176(0.379)	0.951(0.510)	3.504(1.206)
Bicycle	0.468(2.211)	-0.262(-1.612)	-0.165(-0.366)	-0.559(-0.245)	0.078(0.148)	-0.434(-1.071)	-1.051(-0.705)	-3.836(0.791)
R^2	0.059	0.059	0.119	0.597	0.176	0.124	0.235	0.7699
F	1.244	2.041	0.421	1.115	4.232	4.524	0.962	2.511
df	158	256	25	6	158	256	25	6
N	167	265	34	15	167	265	34	15

APPENDIX III

STATISTICAL CALCULATIONS FOR INCOME CLASSIFICATION

STATISTICAL CALCULATIONS FOR INCOME CLASSIFICATION

Assuming a normal distribution of income across the study area:

Sample size = N = 1389
Mean income = 35812 Shillings/month
Standard deviation = 34933 Shillings/month

At 95% confidence interval:
Mean +/- 1 Standard deviation = 70745 Shillings/month - 878 Shillings/month

At 70% confidence interval:
Mean +/- 0.41 Standard deviation = 50134 Shillings/month - 21489 Shillings/month

The 95% confidence interval gives a very wide range of income distributions. The 70% confidence interval which is based on the median gives a better range values. Thus, assuming reasonable income levels, the following classification is obtained:

Household Income 0 - 15000 Shillings/month	Low Income Group
Household Income 15001 - 50000 Shillings/month	Medium Income Group
Household Income 50001 - 79999 Shillings/month	High Income Group
Household Income 80000 Shillings/month and over	Very High Income Group

(Low income groups are classified as those belonging to households with income less than or equal to twice the minimum salary = 7500 Shillings/month [Wilbur Smith Associates 1991]).