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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Activity-Based Travel Demand Modeling for Addis Ababa

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment for the Degree of Master of Science in Civil and Environmental Engineering

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CERTIFICATION

The undersigned certify that he has read the thesis entitled**: Activity-Based Travel Demand Modeling for Addis Ababa** and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science.

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This is to certify that the thesis prepared by Mahlet Demere, entitled: Activity-Based Travel Demand Modeling for Addis Ababa, submitted in partial fulfillment of the requirement for the Degree of Master of Science in Civil and Environmental Engineering (Major in Road and Transport Engineering) complies with the regulations of the University and meets the accepted standards with respects to originality and quality.

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ABSTRACT

Transportation planning has been shifting from an emphasis on capacity expansion to issues like travel management, social equity and environmental justice, quality of life, energy sustainability, and environmental concerns. The trip-based models are not adequate for reflecting these subjects even if they have served the planning needs of metropolitan areas for many years. The activity-based models, on the other hand, are capable of providing estimates of travel demand under a wide range of scenarios at a disaggregate level.

Addis Ababa is currently experiencing high urbanization rates. If this issue is not addressed properly, traffic delays and congestion caused by urbanization will have huge impacts on the environment due to noise and air pollutions. Studying the travel behavior of the residents of Addis Ababa is vital in trying to address the adverse effects of urbanization. In this research, the travel behavior and travel pattern of Bole Sub-City residents were studied.

For the purpose of building up an activity-based travel demand model, a discrete choice model was used. Activity diaries were distributed throughout the study area and the respondents were required to fill in their activiites for a period of two days. The results of the survey were then analyzed so as to build up the travel demand model. Daily activity pattern, time-of-day choice, and mode choice models were developed. These three models were linked with each other using a sequential Nested Logit framework. The result from the analysis showed that the daily activity pattern of work tours was accurately predicted by the model, with a goodness of fit of 0.883, as opposed to non-work tours which had a goodness of fit of 0.436. The relatively low goodness of fit value for non-work trips was attributed to the fact that over half of the surveyed population performed work activities leaving the rest of the percentage share to be distributed among school, maintenance, discretionary, and other types of tours.

This research can be used as a stepping stone for planners and engineers to further develop travel demand models for other sub-cities found in Addis Ababa.

Key Words: Activity Diaries, Logit Model, Nested Logit Model, Logsum, Trips, Tours

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LIST OF ACRONYMS AND SYMBOLS

ρ^2	Likelihood Index
A.M	Morning Peak
DAP	Daily Activity Pattern
E	Expected Maximum Utility
E.M	Early Morning
ETB	Ethiopian Birr
FSM	Four-Step Model
GEV	Generalized Extreme Value
HL	Hierarchical Logit Model
IIA	Independence of Irrelevant Alternatives
LL	Log-likelihood
LRT	Light Rail Transit
M.D	Mid-Day
MNL	Multinomial Logit
N.T	Nighttime
NL	Nested Logit
O-D	Origin Destination
P.M	Evening Peak
RUM	Random Utility Models
TAZ	Traffic Analysis Zone
TOD	Time-of-Day
VDOT	Virginia Department of Transportation

CHAPTER ONE

INTRODUCTION

1.1 Background

Transportation infrastructures have been growing in Addis Ababa, Ethiopia. With the Road Sector Development Plan (RSDP) of the country currently in play, access has been given to areas which were unimaginable to reach to in previous years. Developments of road infrastructures can also be observed in Addis Ababa. Supplementary roads are observed being constructed in the city to relieve the road congestion and traffic volume found on existing roads. This has been taught to satisfy the travel demand that is being generated within the city. In addition to this, various public transportation schemes have been introduced in the city to increase the option of available modes to the city residents. One of the major modes of transportation that was introduced a couple of years ago to alleviate the high travel demand that was being generated from specific areas in the city is the Light Rail Transit (LRT). Other emerging modes of transportation are meter taxi, Sheger Bus, Public Service Bus, and Alliance Bus. These transportation modes are used by the city residents either in combination with other modes like car, walking, minibus taxi or independently.

There is an important need to make these modes of travel available to the residents of the city during peak hours and off-peak hours to satisfy their need of traveling in order to achieve the activity they wish to perform. For this purpose, travel demand models, as defined by Castiglione, et al. (2015), are analysis tools that provide a framework for the representation of interrelated aspects of travel behavior such as what activities people engage in, where and when these activities occur, and finally how people get to these activities. They were traditionally confined to assessing transport demand and capacity as a function of the distribution of dwellings, jobs, and characteristics of the transportation system. The type of travel demand model that is currently in practice for Addis Ababa is the Four-Step Model (FSM). In fact, since its emergence in the 1950s, the FSM has been used widely around the world due to its economic simplicity when it comes to data requirement and operation. In spite of this, the well-known FSM has fundamental flaws like being confined to household characteristics, attributes of the destination, and attributes of the transportation system. (Arentze, et al., 2004) In addition to this, it lacks a valid representation of the underlying travel behavior (VDOT, 2009).

The new and emerging approach for modeling travel demand is the activity-based model. The activity-based model is gaining wide acceptance worldwide since they are able to predict which activities are conducted where, when, with whom, and for how long. The fact that this travel demand model considers travel to be driven by activities makes the results of this model applicable and accurate as compared to the FSM. It considers travel to be derived from needs to participate in activities. Its detail exploration of travel behavior merged with its ability to forecast the impacts of transportation, land use, environmental policies, and energy-related policies makes this travel demand model a better suit for demand calculation.

1.2 Scope

The scope of this study is limited to developing an activity-based travel demand model for Bole Sub-City using a discrete choice model for travel demand analysis. Other sub-cities found in the city were not considered due to budget and time constraints. In addition to this, secondary tours that were conducted by the respondents were also neglected.

1.3 Statement of the Problem

The global urban population has tripled to reach 3.3 billion from 1950 to 2008. By 2030, the global urban population is expected to reach 5 billion. The issue of urbanization is greatly observed in developing countries. By 2030, it is forecasted that the developing world will make up 81 percent of the urban humanity. Social, economic, and infrastructural needs arise as a result of urbanization. These needs are a result of the high growth of private mode of transportation coupled with increased mass transport systems like bus and rail to meet the mobility needs of the urban environment. (Subbarao & Krishna, 2010) Hand in hand with urbanization comes traffic delays and congestion caused by the imbalance with the demand and supply of the infrastructural needs of the urban environment. Traffic delays and congestion, in turn, have adverse effects on the environment due to noise and air pollution.

Addis Ababa, also a developing urban environment, is a victim of traffic delays and congestion along with noise and air pollution that are consequences of high urbanization rate observed in the city. A travel demand model that correctly reflects the travel needs and characteristics of the residents of Addis Ababa could be viewed as a stepping stone to mitigate the undesirable effects that come along with urbanization.

The current practice for travel demand modeling in research institutions as well as planning agencies found in the city is the trip-based approach. The trip-based approach for travel demand modeling comes with basic flaws. The first flaw for the trip-based approach is that it does not recognize the linkage between trips which are conducted by an individual with in a day. Furthermore, the trip-based approach does not study the activities which resulted in the trips.

Since it is essential to develop a travel demand model that correctly reflects the socioeconomic and demographic characteristic as well as the underlying travel behavior of every country, exploring the activity-based approach for travel demand modeling could yield better estimations. Activity-based travel demand models have been used to assess issues that arise with urbanization as they explain out-of-home activities in an accurate manner (Miller, et al., 2015). In addition to this, they recognize travel as a derived demand which arises from the need to participate in activities.

As this study presents an activity-based modeling framework for Bole Sub-City, it will help planners and engineers understand the activity choices of individuals throughout the day. It will be useful in giving a clear picture of how travel looks like when activity participations are considered to be the driving forces.

1.4 Objective

1.4.1 General Objective

The general objective of this research was to develop a travel demand model which reflects the travel decisions and travel patterns of the residents of Bole Sub-City.

1.4.2 Specific objectives

The specific objectives of this research are listed below:

- To develop a daily activity schedule model for work and non-work tours for Bole Sub-City,
- To develop a time-of-day model which reflects the choices of time for both workers and non-workers Bole Sub-City, and
- To develop a mode choice model for work and non-work tours Bole Sub-City.

1.5 Significance of the Study

Activity-based models are capable of providing estimates of travel at a disaggregate level. Therefore, they can be used by planners and engineers found in Addis Ababa for travel demand calculations to address the issues of transportation planning.

Even if this research is only limited to developing a travel demand model just for Bole Sub-City, it can be used as a stepping stone for planners and researchers found within the country to develop a more detailed model for their area of interest. Moreover, the results from this study, after further analysis, can be used to assess and address the issues of congestion and travel delay that have become a major issue in Addis Ababa.

1.6 Limitations

This study has faced some setbacks at different stages. Household travel survey is the most important feature of an activity-based model. Since the respondents were required to fill out the survey forms for a period of 48-hours, the survey consumed the time of the respondents lowering the response rate.

Moreover, respondents tended to neglect activities that were of short duration. Most respondents only reported the major activities of their day like going to work or school and then returning back home.

1.7 Organization of the Paper

The organization of this research paper is as follows. Chapter Two of this paper is the literature review. In this chapter, literature that was relevant to the study is presented in an organized manner. Furthermore, literature pertaining to the study at hand are reviewed and selected activity-demand models developed worldwide are reviewed and summarized. Materials and methods are presented in Chapter Three of this paper. Here the tools and methods used for data collection and analysis are presented. Moreover, the description of the model developed can be found in this chapter. In Chapter Four, the results obtained for the survey along with the estimation results of the model are presented. In Chapter Five, the conclusions drawn from the research as well as the recommendations made can be found.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Travelling is one of the major activities performed by any individual around the world. McNally (1996) states that the demand for travel is derived from the participation of individuals in various activities. One of the major factors that affect an individual's participation in various activities is urban development. According to Bowman (1995), urban development affects the demand for travel not only by influencing mobility and lifestyle decisions, activity and travel scheduling, and rescheduling but also by affecting the performance of the transportation system as a whole. Mobility and lifestyle decisions, such as residential locations, employment, and automobile ownership, occur at irregular and infrequent intervals, in a timeframe of years. Activity and travel scheduling occur at more frequent and regular intervals such as days and weeks. It involves selection of a particular set of activities, assignment for the activities to particular members of the household, sequencing of the activities, and selection of activity locations, times and methods of required travel. On the other hand, rescheduling occurs on the shortest timeframe. *Figure 2-1* below illustrates the urban travel decision framework developed by Bowman (1995).

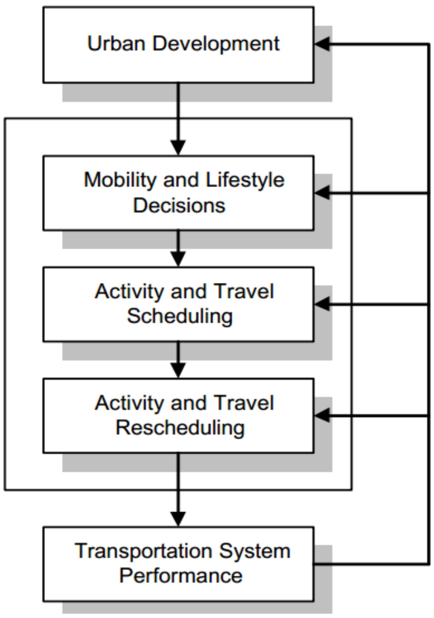

Figure 2-1: Urban travel decision framework

Source: (Bowman, 1995)

Urban development decisions include the decisions of governments, real estate developers, and firms. The effect of urban development on transportation system performance is manifested in several ways including travel volumes, speeds, congestion and environmental impacts. These manifestations directly affect individual and household decisions.

The need for travel demand forecasting models helps in the accurate representation of the decision framework that was presented above in *Figure 2-1*. These forecasting models predict the number, type, origin and destination, and distribution of trips on the transportation network. Furthermore, they help planners, engineers, and economists in policy making and planning of road infrastructures. (Ullah, et al., 2011)

The two widely used travel demand models are the trip-based travel demand model and the activity-based travel demand model. Each of these models is explained in the next section.

2.2 Trip-Based Travel Demand Model

Trips are defined as travel between two activities representing the trip purpose (Home to Work, Home to School, etc.). The basic unit of analysis for the trip-based travel demand model is the individual trip. (Yagi & Mohammadian, 2008)

History of travel demand modeling has been dominated by the trip-based approach. Although travel is derived from the demand for activity participation, it has been modeled using the trip-based approach instead of the activity-based approach, using origin-destination (O-D) surveys rather than activity surveys as a tool for data collection. This diminishes the influence of activity characteristics and increases that of trip characteristics. (McNally, 2007)

2.2.1 Stages of the Four-Step Model

The trip-based travel demand model, also known as the Four-Step Model (FSM), is composed of four basic stages. These are the trip generation, trip distribution, modal split and trip assignment. Jovicic (2001) describes the first three stages of this approach as the travel demand, whereas the final stage is referred to as the travel supply. Each of the stages for the FSM is discussed in detail below.

2.2.1.1 Trip Generation

This stage estimates where and how many individual person-trips are produced and attracted. (VDOT, 2009). Household-level cross-classification methods based on large-scale surveys that forecast trip production totals for all Traffic Analysis Zones (TAZ) by trip purpose are used for the analysis of trip generation. Trip attractions are usually predicted by zonal-level multiple regression models (Zhang, et al., 2011). McNally (2007) states that the objective of this first stage is to define the magnitude of total daily travel in the modal system, at the household and zonal level, for various trip purposes.

2.2.1.2 Trip Distribution

The trip distribution stage links the production-end and attraction-end of each trip between zones (VDOT, 2009). The major purpose of this stage is to recombine the trip-ends from the trip generation into trips where each purpose is utilized in the trip generation model as a function of activity system attributes and network attributes (McNally, 2007).

2.2.1.3 Modal Split

Modal split is also known as mode choice. This stage establishes the type of mode that will be used for each trip converting person-trips to vehicle trips and transit trips (VDOT, 2009). According to McNally (2007), mode choice models reflect the choice probabilities of individual trip makers. They are usually disaggregate models which are often estimated on separate choice-based samples.

2.2.1.4 Trip Assignment

The modal trip tables that were constructed in the modal split stage are assigned to mode-specific networks (McNally, 2007). During this stage, the trips are placed on the transportation network based on parameters such as distance, travel speed, time, transportation cost, and vehicle capacity (VDOT, 2009).

Figure 2-2 below illustrates the FSM in a sequential manner. Socio-economic, demographic, and land use data defined for TAZs are used to represent the *Activity System*. The *Transportation System* is represented via network graphs defined by links and nodes. In the trip generation, the propensity for travel is developed using the measures of trip frequency. The trip distribution stage distributes the trip productions to match the trip attraction and to reflect the underlying travel impedance (time and/or cost), yielding trip tables of person-trip demands. Trip tables are essentially factored to reflect relative proportions of trips by alternative modes during the mode choice stage. Route choice assigns modal trip tables to mode-specific networks. The time dimension (time-of-day) is introduced after trip distribution or mode choice where the production-attraction tables are factored to reflect observed distributions of trips in defined periods (such as A.M or P.M. peaks). Performance characteristics are first introduced in the route choice making the FSM only equilibrating the route choice. In other words, total demand, as specified through generation, distribution, mode choice, and time-of-day models are fixed, with only the route decision to be determined. (McNally, 2007)

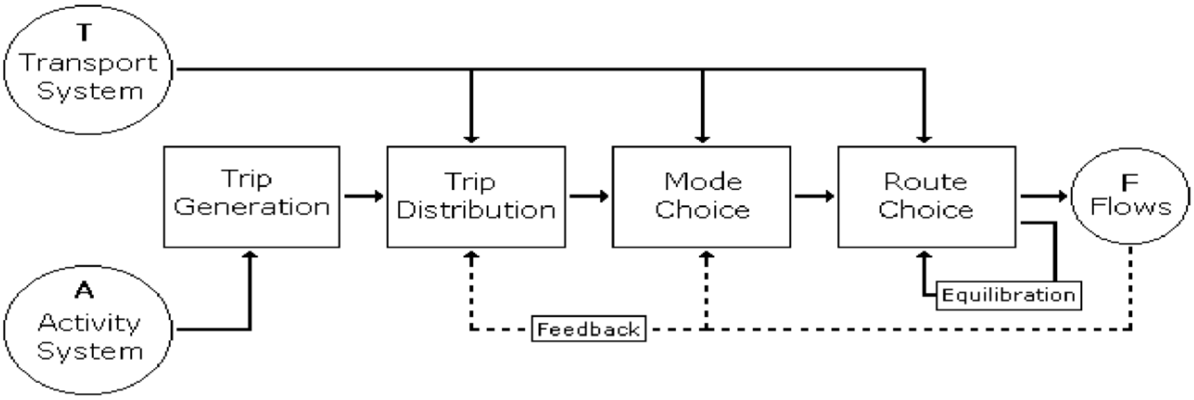

Figure 2-2: The Four-Step Model

Source: *(McNally, 2007)*

According to Zhang, et al. (2011), the basic FSM can be applied to transportation planning and policy analysis including:

- Future travel volume,
- Level of service forecasting,
- Performance measurement and monitoring,
- Corridor-level transportation planning,
- Congestion management,
- Freight analysis,
- Scenario testing, and
- Analysis and environmental impact studies.

Over the past decade, the trip-based approach has been found to have some limitations. According to McNally & Rindt (2007), the limitations are that the trip-based approach does not reflect:

- The linkage between trips and activities;
- The temporal constraints and dependencies of activity scheduling; and
- The underlying activity behavior that generates the trips in the first place.

Miller, et al. (2015) further states the limitations of the trip-based approach as follows.

- Individual trips are modeled in isolation. The trip-based approach ignores the interconnections between trips that can be important in terms of determining mode choice, location choice, trip timing, etc.
- It only focuses on the individual trip-maker and ignores household level constraints and interactions.

2.3 Activity-Based Travel Demand Model

Travel is a major component used for the participation in an activity. While the trip-based approach is concerned with models that generate trips, the activity-based approach is concerned with what generated the activity that resulted in the trips (McNally & Rindt, 2007).

An activity is defined as a physical engagement of an individual in something that satisfies his or her economic, physiological, and sociological needs. A decision to engage in an activity is the result of the complex interaction of household and individual responsibilities, a particular lifestyle of an individual and his/her family, options on activity type, location and duration, and time, space, and budget constraints. (Jovicic, 2001)

The activity-based approach first began as an evolution of research on human behavior, in general, and travel behavior, in particular. The fundamental characteristic of an activity-based approach is that travel decision is driven by a collection of activities that form an agenda for participation which cannot be analyzed on an individual trip basis. The complex travel behavior of an individual is comprised of the activity pattern, the decision process, behavioral rules, and the environment in which they are valid, which together constrain the formation of these patterns (McNally & Rindt, 2007). These models describe which activities people pursue, where, when, for how long, and with whom. They also describe which transport modes are involved, if any, and how these activities are scheduled (Arentze, et al., 2004).

Figure 2-3 gives an illustration of the activity-based model, as described by Jovicic (2001), using a hypothetical example where an individual goes to work in the morning, then for a meeting in the mid-day and later returns back to work. On the way home, he stops at a supermarket for shopping. In the evening, he goes to the cinema and afterward returns home. For this example, four activities were completed within a day. These are work, meeting, shopping, and leisure (cinema) with seven accompanying trips. Two home-based tours (one with an additional stop to the supermarket, and the other without stops) one work-based tour were completed by the individual.

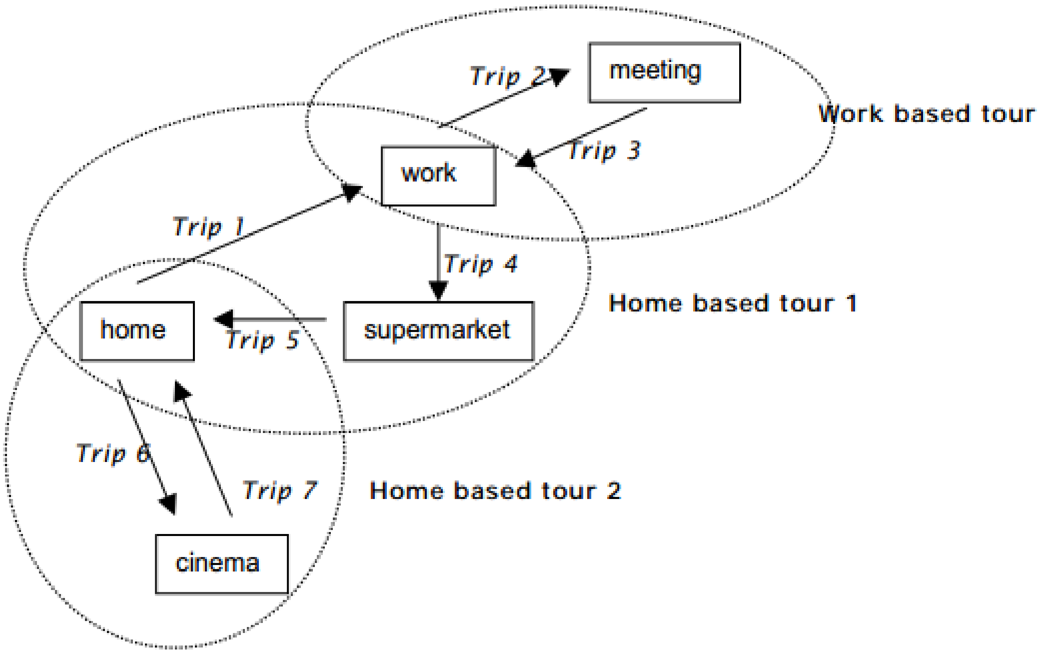

Figure 2-3: A graphical presentation of activities and trips completed in a hypothetical working day by an individual

Source: *(Jovicic, 2001)*

The trip-based travel demand model would model the seven trips independently of each other while tour-based travel demand models would model tour 1 (home-work-home) and tour 2 (home-cinema-home) independently of each other. The work based sub-tour (work-meeting-work) would be modelled as two independent trips. Activity-based models would model the four observed activities and the observed trips as parts of the same decision process thereby capturing the interdependencies between the completed trips. If for example road pricing was introduced as a policy measure for reducing congestion for a road section this individual uses, he might arrange his trips in a way to avoid or reduce the costs he might incur from the road pricing. These changes cannot be captured in the trip-based and tour-based travel demand models because these models cannot recognize the complexity of the newly existing situations (Jovicic, 2001).

A distinctive feature of activity-based models is that they give a detailed representation of time in which one activity gives time constraints for the occurrence of the following activity. Another important feature of these types of travel demand models is their ease of extensibility due to their disaggregate nature. This makes it easy to add a new descriptive variable to the existing model. In addition to this, activity-based models affect policy-making due to their ability to simulate individual travelers (Vuk, 2010).

Activity-based travel demand models give a rich and accurate framework in which travel is analyzed as a daily pattern of behavior, related to and derived from differences in lifestyles and the activity participation among individuals (Jovicic, 2001).

Smith, et al. (2014) stated the advantages of the activity-based travel demand models as follows.

- They provide detailed information about travel patterns of the individual traveler at a highly detailed level and are able to reflect the influence of time-space constraints and interactions among activities and trips in a tour.
- They are able to address emerging policy issues, land use effects, environmental impacts, and demographic and technological shifts by providing detailed information about activity and travel patterns at a highly disaggregate level of resolution.

The disadvantages of these travel demand models were also described by Smith, et al. (2014) as follows.

- The development and implementation are labor and resource intensive, and
- Appropriate computational hardware and software systems need to be in place to ensure that the model systems can be executed within reasonable run times.

Chu, et al. (2012) generalized the five important features of an activity-based travel demand model as follows.

- Travel is derived from activity participation;
- The activity-based approach focuses on sequences of patterns of activities;
- Individuals' activities are both planned and executed in the household context;
- Activities are spread throughout a 24-hour period in a continuous manner, rather than simple categorization of 'peak' and 'off-peak' events; and
- Travel and location choices are limited in time and space by personal constraints.

2.3.1 Data Requirements for Activity-Based Travel Demand Models

Since the purpose of an activity-based travel demand model is to predict which activities will be conducted, where, when, for how long, with whom, and with which transport mode, the data collected must be able to address these questions. This general description of activity-based travel demand model dictates the kind of data needed. Thus, the kind of data needed, as described by Arentze, et al. (2004), are described below.

- **Activities**

The data on activities should be collected at a detailed level. At the very least, data of the out-of-home activities of households found within the study area is required. If a more detailed model is required, the breakdown of the activities should be at a higher level.

- **Location of activities**

Geocoded data on land use and the location of facilities where particular activities are conducted is essential. Moreover, data specifying the attractiveness of the locations is required.

- **Time**

Activity-based travel demand models incorporate the timing of travel decisions. This makes time the third dimension that is required for this type of travel demand model. Data on start and end times of activities and the related travel time should be collected.

- **With whom**

The data on who is participating in the various activities should also be collected. Although most models do not incorporate this feature, it is important to know with whom the activities are conducted since it has implications of how individuals within a household plan to conduct their activities together or alone.

- **Transport mode**

The transportation mode that is used to conduct the activities should be collected. The cost incurred when using the respective transport mode should also be collected since this is one way for measuring the attractiveness of the mode of transportation used. Other descriptors of attractiveness are comfort, frequency, and travel time.

2.3.2.1 Data Collection

Once the data requirements for an activity-based travel demand model are identified, the next question is how to collect the required data. Arentze, et al. (2004) describe the possible ways for collecting the required information as activity diaries, interactive computer experiments, and conjoint experiments. Activity diaries are the widely used data collection instrument. The latter two methods have limited use since comparative methodological research and experience are lacking.

Using an activity-based diary, a detailed log of how people allocate their time during the day is recorded (Crosbie, 2006). They are the best choice for activity-based travel demand models since they are the only instrument that captures the relationships between activity choice, location choice, timing, travel company, and transport mode. (Arentze, et al., 2004)

2.3.2.2 Type of Diary

Diaries for collecting data on travel demand are of three types. These are trip-based diary, full day activity diary, and out-of-home only activities diary. Trip diaries collect trip data and all other information that is related to the trip, while the other two formats collect information that is associated with activities that a respondent is engaged in. The basic difference between full day activity diary and out-of-home activity diary is that the former records all activities conducted by the respondent throughout the day, while the latter only records out-of-home activities. (Arentze, et al., 2004)

The trip diary is used if the data is collected for the conventional FSM, while activity diaries are preferred if it is desired to build an activity-based model. Regarding the choice between using a full activity diary or an out-of-home activity diary, the latter type is cost-saving but limits the analysis of possible substitution of activities. In contrast, the full activity diary is demanding for the respondents which might lead to a lower response rate. (Arentze, et al., 2004)

2.3.2.3 Frequency and Timing

Frequency refers to how long the diary should be kept by the respondent. Although it is preferable to record the respondents' activities over a period longer than 24 hours of a day, it is difficult to induce people to record their daily activities for more than 24 hours with the required level of precision. As the number of days' increases, the burden on the respondents also increases, thereby increasing the chances of having inaccurate results. 48-hour frequency is the maximum that could be attained without compromising the data quality unless resources suffice to offer substantial monetary incentives and build a substantial supervisory network. (Arentze, et al., 2004)

Timing refers to the choice of days that the travel diaries are supposed to be administered. It is important to spread the diaries equally over all seven days of the week as well as throughout the year assuming that sufficient budget is available. (Arentze, et al., 2004)

2.3.2 Categories of Activity-Based Travel Demand Models

Since their emergence as an alternative to the trip-based models, activity-based models have been classified in various ways. According to Miller, et al. (2015), these models fall into two broad categories. These are the tour-based models and activity-scheduling models.

2.3.3.1 Tour-Based Models

Tours are defined as a sequence of trips which start and end at the same location, usually the trip maker's home. Hence, for the tour-based models, tours are the basic units of analysis. These models are in operational use in the United States in states like Columbus, Atlanta, Denver, Sacramento, and Chicago. (Miller, et al., 2015)

One or more activities (purposes) are included in the course of a tour. (Yagi & Mohammadian, 2008) The fact that shorter trips may be explained as links in one longer tour makes tour-based models powerful tools for explaining travel behavior. Although tour-based models model the interrelated decisions a person makes regarding the travel from home to one or more activity locations and back home again, they ignore the interactive effect of decisions people make about multiple potential tours away from home. (Bowman, 1995)

Tour-based models are conditioned by the choice of a daily activity pattern which is in turn influenced by the expected maximum utility derived from the available tour alternatives. The expected maximum utility varies for different daily activity patterns, so does the change in the expected maximum utility when environmental and socioeconomic changes occur. For example, increases in fuel prices might reduce the utility of high mileage daily activity patterns more than low mileage patterns. Hence, the model incorporates the inter-tour trade-offs a person would make in responding to the new prices. The commuters might choose to reduce the number of tours in the pattern or might choose to reduce the length of their primary tour. (Bowman, 1995)

The drawback of tour-based models, as described by Bowman (1995), is the lack of connection among multiple tours for the same person on the same day. It fails to capture trade-offs people consider in light of inter-tour temporal-spatial constraints such as the decision to combine several activities in a single tour versus conducting separate tours to accomplish the same purposes. The fact that the temporal relation among multiple tours in the same day is not captured limits the effectiveness of the time-of-day modeling. These weaknesses also limit the forecasting capabilities of mode and destination choice models.

2.3.3.2 Activity-Scheduling Models

Activity-scheduling models generate out-of-home activity schedules/patterns with the trip chains (tours) required to access the activities being generated. Examples of these models include ADAPTS, CEMDAP, and FAMOS which were developed for the United States. ALBATROSS is an activity-scheduling model that was developed for the Netherlands, while

TASHA was developed for Canada. MATSIM is also a scheduling model that was developed for Germany, Singapore, and Switzerland. (Miller, et al., 2015)

Activity-scheduling models incorporate within themselves daily activity scheduling models. Daily activity schedule models encompass all the possible combinations of activities and travel an individual might choose through the course of a day while viewing an individual's daily demand for activity as one multidimensional choice. (Bowman, 1995)

2.3.3 Modeling Approaches

Jovicic (2001) classify the modeling approaches for activity-based travel demand model in to two from the activity participation point of view. These are discrete choice models and rule-based simulation models.

2.3.4.1 Rule-Based Simulation Models

There are two main groups of rule-based simulation models. These are activity schedule building models and switching models. The difference between the two types of models is that the schedule building models construct the schedules from scratch while the switching models alter the pre-defined schedule as a result of policy changes or infrastructure changes. (Jovicic, 2001)

Rule-based simulation models explain how individuals think when building schedules by learning structures that are incorporated into their structure. Each activity along the day relies on previous activities which might result in making changes in the previously planned activities. Moreover, rule-based simulation models are not probabilistic; they predict decisions in the outcome making it impossible to check their statistical properties. They are suitable for short-term forecasts because they require detailed analysis and the output of the model is very rich in detail taking into consideration different types of constraints. (Jovicic, 2001)

2.3.4.2 Discrete Choice Models

Discrete choice models have been used for modeling complex travel behavior since the 1980s. Even if they were initially developed and applied in the trip-based framework, they are currently being applied to activity-based models. (Chu, et al., 2012)

Discrete choice activity-based models are based on nested logit multinomial logit models where a long-term model is placed at the top of the hierarchy, below that a model for day travel patterns is placed, and finally, at the bottom of the hierarchy are placed tour and trip models associated with the chosen activities from the pattern model. These types of models are applicable for operational models with long-term forecasts. They predict probabilities of the decision outcomes, like the discrete choice trip models making it possible to generate trip matrices from these models. Monte Carlo simulations can be applied to the probabilities to produce activity and trip patterns for a single person. (Jovicic, 2001)

2.4 Discrete Choice Models for Activity-Based Travel Demand Modeling

Sheffi (1985) state that when faced with a choice situation, an individual's preferences toward each alternative can be described by an "attractiveness" or "utility" measure associated with each alternative. This utility is a function of the attributes of the alternatives as well as the decision-makers' characteristics. He further states that the decision-maker is assumed to choose the alternative that yields the highest utility.

Discrete choice models postulate that:

the probability of the individuals choosing a given option is a function of their socioeconomic characteristics and relative attractiveness of the options (Ortuzar & Willumsen, 2001).

According to Ortuzar & Willumsen (2001), the concept of utility is introduced to represent the attractiveness of the alternatives. The value of the utility is contrasted with those of alternative options and transformed into a probability between 0 and 1 in order to predict if an alternative is chosen.

2.4.1 Properties of Discrete Choice Models

According to Ben-Akiva & Bierlaire (1999), the framework for a discrete choice model is represented by the following assumptions.

- A decision-maker,
- Alternatives,
- Attributes, and
- Decision rule.

2.4.1.1 Decision-Maker

The decision-maker can be an individual, a household, or an organization (Ben-Akiva & Bierlaire, 1999). Household interactions, household type, and size, the relationship between family members, age, and gender are factors that affect the decision-maker from choosing alternatives from a set (Jovicic, 2001).

2.4.1.2 Alternatives

A discrete choice set contains a finite number of alternatives that are explicitly listed. (Ben-Akiva & Bierlaire, 1999). Alternatives an individual is considering are assumed to be mutually exclusive and exhaustive so that the individual must choose exactly one of them. Set of alternatives are generally categorized into two. These are the universal set and the choice set. The universal set is the set of all feasible alternatives while the choice set refers to the set of alternatives that the individual is actually considering. (Jovicic, 2001)

Train (2002) articulates the three characteristics a choice set needs to exhibit in order to fit within a discrete choice framework as follows.

- The alternatives must be mutually exclusive from the decision-maker's perspective. The choice of one alternative by the decision-maker necessarily implies not choosing any of the other alternatives.
- The choice set must be exhaustive. This means that all the possible alternatives a decision-maker might choose must be included in the choice set.
- The number of alternatives must be finite, meaning that the researcher should be able to count all the alternatives and eventually be finished counting.

2.4.1.3 Attributes

The characteristic of each alternative that is found in the choice set is called the attribute (Ben-Akiva & Bierlaire, 1999).

2.4.1.4 Decision Rule

According to Ben-Akiva & Bierlaire (1999), the decision rule describes the process that is used by the decision-maker to choose an alterantive. Jovicic (2001) state that a decision rule is a process describing peoples' activity behavior. The choice of one activity is based on decision rules. He further states that decision rules might be multiple criteria, ranked criteria, or composite criteria. Multiple criteria include alternatives that are superior to other alternatives in every aspect and rules that set a minimum standard for every aspect and selects alternatives that satisfy every minimum standard. Ranked criteria include rules in which if two alternatives are equal in most important aspect they are compared on less important aspects until one alternative remains and a rule which sets a minimum standard for every aspect and selects alternatives that satisfy every minimum standard. If two or more alternatives still exist, they are compared on less important aspects until one alternative remains. In the composite criteria, the alternatives in the choice set are described by their utility functions. The alternative with the most positive utility value is chosen.

2.4.2 Derivation of Choice Probabilities

Discrete choice models are derived under the assumption of the utility-maximizing behavior of the decision-maker. Models that entail utility maximization are called random utility models (RUMs) (Train, 2002). The utility in RUMs is modeled as random variables in order to reflect uncertainties which come due to unobserved alternative attributes, unobserved individual characteristics, and measurement errors (Ben-Akiva & Bierlaire, 1999).

Train (2002) derives random utility models as follows. A decision-maker, n, faces a choice among J alternatives. The utility that decision-maker n obtains from alternative j is $U_{nj}, j = 1, \dots, J$. The decision-maker chooses the alternative that provides the greatest utility. The decision-maker choose alternative i if and only if $U_{ni} > U_{nj}, \forall\, j \neq i$. Now let the attributes of the alternatives that are observed to the researcher be labeled as $x_{nj}\ \forall\, j$, and some attributes of the decision-maker be labeled as s_n. Then $V_{nj} = V(x_{nj}, s_n)\ \forall\, j$, where V_{nj} is called representative utility. $V_{nj} \neq U_{nj}$ since there are some aspects of utility that the researcher cannot observe. Hence, utility is decomposed as $U_{nj} = V_{nj} + \varepsilon_{nj}$, where ε_{nj} is the difference between the true utility U_{nj} and part of the utility the researcher captures V_{nj}; it represents the factors that affect utility but are not included in V_{nj}.

Train (2002) further states that ε_{nj} is not known to the researcher for all j and therefore are treated as random. The joint density of the random vector $\varepsilon_n = (\varepsilon_{n1}, \dots, \varepsilon_{nJ})$ is denoted as $f(\varepsilon_n)$. The probability that decision-maker *n* chooses alternative *i* is,

$$P_{ni} = Prob(U_{ni} > U_{nj}\ \forall\, j \neq i) \tag{2.1a}$$

$$= Prob(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}\ \forall\, j \neq i) \tag{2.1b}$$

$$= Prob(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj}\ \forall\, j \neq i) \tag{2.1c}$$

The probability described in equation (1.1) is a cumulative probability distribution that each random term $\varepsilon_{nj} - \varepsilon_{ni}$ is below the observed quantity $V_{ni} - V_{nj}$. Using the density function $f(\varepsilon_n)$, this cumulative probability can be rewritten as:

$$P_{ni} = Prob(U_{ni} > U_{nj}\ \forall\, j \neq i) \quad (2.2a)$$

$$= \int_{\varepsilon} I(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj} \text{ for all } j \neq i)\, f(\varepsilon_n) d\varepsilon_n\,, \quad (2.2b)$$

Where $I(.)$ is the indicator function, equaling 1 when the term in the parenthesis is true and 0 otherwise. The above equation represents a multidimensional integral over the density of the unobserved portion of utility, (ε_n), which takes a closed-form for logit and nested logit discrete choice models.

2.4.3 Logit Model

Logit-based models are widely used for travel demand analysis (Ben-Akiva & Bierlaire, 1999). According to Train (2002), the logit model is the most widely used form of a discrete choice model due to its closed form formula for choice probability and the fact that this choice probability is readily interpretable. The major assumption behind the logit model is that each unknown parameter to the researcher, ε_{nj}, is distributed independently, identically extreme value. Ben-Akiva & Bierlaire (1999) state that the error terms of utility functions are independent and identically Gambel distributed (or Type I exterem value). The density of each unobserved component of utility as stated by Train (2002) is,

$$f\,(\varepsilon_{nj}) = e^{-\varepsilon_{nj}} e^{-e^{\varepsilon_{nj}}} \quad (2.3)$$

The cumulative distribution is given by

$$F(\varepsilon_{nj}) = e^{-e^{-\varepsilon_{nj}}} \quad (2.4)$$

The cumulative probability distribution if ε_{ni} is known is given by

$$P_{ni}|\varepsilon_{ni} = \prod_{j\neq i} e^{-e^{-(\varepsilon_{ni}+V_{ni}-V_{nj}}} \quad (2.5)$$

Since ε_{ni} is not given, the choice probability is the integral of $P_{ni}|\varepsilon_{ni}$ over all values of ε_{ni} weighted by its density (2.3)

$$P_{ni} = \int \left(\prod_{j\neq i} e^{-e^{-(\varepsilon_{ni}+V_{ni}-V_{nj})}}\right) e^{\varepsilon_{ni}}\, e^{-e^{\varepsilon_{ni}}} d\varepsilon_{ni} \quad (2.6)$$

The integral of equation (2.6) results in

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} \quad (2.7)$$

2.4.3.1 *Properties of Logit Models*

The properties of logit models are described by Train (2002) as follows.

- P_{ni} is between zero and one. When V_{ni} rises, P_{ni} approaches to one, and as V_{ni} decreases, P_{ni} approaches to zero.
- The choice probabilities for all alternative sum to one.

$$\sum_{i=1}^{j} P_{ni} = \sum_{i} \exp(V_{ni}) \,/ \sum_{j} \exp(V_{nj}) = 1 \qquad (2.8)$$

- The relation of the logit probability to representative utility is sigmoid, or S-shaped. If the representative utility of an alternative is low compared with other alternatives, a small increase in the utility of the alternative has little effect on the probability of it being chosen since the other alternatives are still better than the small improvement doesn't help much. The point at which the increase in representative utility has the greatest effect on the probability of it being chosen is when the probability is close to 0.5. In this case, a small increase will induce a large change in the probability. *Figure 2-4* below shows the graph of a logit curve.

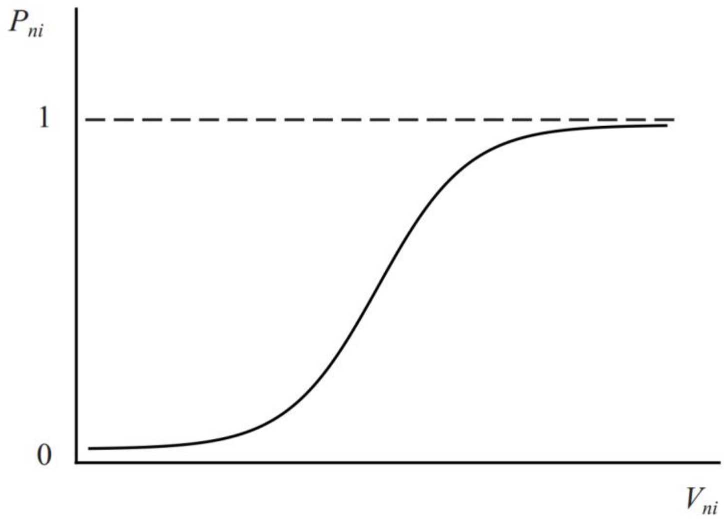

Figure 2-4: Graph of a logit curve

Source: (Train, 2002)

2.4.3.2 Goodness of Fit for Logit Models

Train (2002) states that a likelihood ratio index is used in discrete choice models to measure how well the model, with its estimated parameters, performs compared with a model in which all the parameters are zero. The scenario where all the model's parameters are zero is equivalent to having no model at all. The likelihood ratio index is defined as follows.

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)} \qquad (2.9)$$

Where LL $(\hat{\beta})$ is the value of the log-likelihood function at the estimated parameters and LL (0) is the value of the log-likelihood function when all the parameters are set to 0. When $\rho^2 = 1$ it means that the estimated model has predicted the decision-maker's choice perfectly. On the contrary, having a ρ^2 value of 0 implies that the estimated model is no better than no model. In addition, a higher ρ^2 value fits the data better.

2.4.4 Nested Logit Model

Train (2002) states that a nested logit is suitable when the set of alternatives that are faced by the decision-maker can be partitioned into subsets, commonly referred to as "nests". He further states that following properties must hold for a nested logit model.

- For any two alternatives that are in the same set, the ratio of probabilities is independent of the attributes or existence of all other alternatives; and
- For any two alternatives in different nests, the ratio of probabilities can depend on the attributes of other alternatives in the two nests.

It is important to note that IIA only holds for alternatives that are in the same nest.

Train (2002) further states that the choice probability for a nested logit model can be obtained by partitioning the set of alternatives j into K non-overlapping subsets that are denoted by $B_1, B_2, \dots, B_K$ called nests. The utility that person n obtains from alternative j in nest B_K is denoted as $U_{nj} = V_{nj} + \varepsilon_{nj}$, where V_{nj} is observed by the researcher and ε_{nj} represents the random variable that is not observed by the researcher. The nested logit model is obtained by assuming that the vector of unobserved utility, $\varepsilon_n = \varepsilon_{n1}, \dots, \varepsilon_{nJ}$ has a cumulative distribution

$$exp\left(-\sum_{k=1}^{K}\left(\sum_{j \in B_k} e^{-\varepsilon_{nj}/\lambda_k}\right)^{\lambda_k}\right) \qquad (2.10)$$

The type of distribution observed in equation (2.10) is a GEV distribution which gives rise to the logit model. The parameter λ_k is the measure of the degree of independence in unobserved utility among the alternatives in nest k. The higher the value of λ_k, the less the correlation and the greater the dependence.

The choice probability, as described by Train (2002), for alternative $i \in B_k$

$$P_{ni} = \frac{e^{V_{ni}/\lambda_k}\left(\sum_{j\in B_k} e^{V_{ni}/\lambda_k}\right)^{\lambda_{k-1}}}{\sum_{l=1}^{K}\left(\sum_{j\in B_l} e^{V_{nj}/\lambda_l}\right)^{\lambda_l}} \tag{2.11}$$

NL models are characterized by grouping all subsets of correlated options in hierarchies or nests. Each nest, in turn, is represented by a composite alternative which competes with the others available to the individual. The introduction of lower nests in their immediate superiors is done by means of the utilities of the composite alternatives. (Ortuzar & Willumsen, 2001)

Bowman (1995) summarized the limitations of NL models as follows.

- It can only handle as many interdependencies among options as nests have been specified in the structure; furthermore, alternatives in one nest cannot be correlated with alternatives in another nest.
- The search for the best NL structure might imply the tentative examination of any nesting patterns, as the number of possible structures increases geometrically with the number of options.
- The nested logit model enables the modeling of discrete choices using statistically testable econometric model estimation. It also has the potential for meeting the objectives of integration, consistency, and validity in the context of the complex decision process.

2.5 Previous Works

In this section, researches done in relation to activity-based travel demand modeling are presented.

2.5.1 Analysis of activity-based travel behavior in the context of developing countries (Subbarao & Krishna, 2010)

Subbarao & Krishna (2010) focused their study on designing a new survey instrument called an activity diary in which the survey results were later used for analyzing travel patterns of the people and the distributions obtained from the analysis will be useful for understanding the differences between activity changing the behavior of people in developing and developed countries. The analysis conducted showed that the socio-economic characteristics of the person and household have a considerable effect on the responses and their activity behavior. The results obtained from their survey was helpful for assessing the performance of activity diary and quality of data in the context of developing countries.

The activity diary that was developed by Subbarao & Krishna (2010) was a table kind of format which has some variations from the diary type that is usually developed for the western world. Although their format requires extra effort from the respondents to complete it, it is clear and easy to understand when looked at. Their experience from the activity diary they developed was that most respondents usually lost the activity diary since they take it where ever they go. In addition to this, the high illiteracy rate was a challenge that was faced by the respondents during the survey time. One important thing that was observed from Subbarao & Krishna (2010) experience is the fact that they used three languages as a form of administration. This has become a motivation for the research currently in place to administer the diaries in a language that is comfortable for the users to respond with which in this case is Amharic instead of English.

2.5.2 An activity-based microsimulation model of travel demand in the Jakarta metropolitan area (Yagi & Mohammadian, 2008)

Yagi & Mohammadian (2008) developed an activity-based modeling system for the purpose of serving as better inputs for the evaluation of different transportation policy scenarios. They followed a discrete choice modeling approach based on the random utility maximizing principles. Various household and household member information, zone-based socioeconomic and land use data, and highway and transit network-based data were prepared in order to generate people's daily travel patterns, tours, and trips which can be integrated into origin-destination trips by mode and by time-of-day for full network assignment. The model system developed was comprised of four components which are the daily activity-travel pattern choice, time-of-day choice, mode and destination choice, and additional sub-models which were the model and destination choice for work-based sub-tours (in work tours only) and intermediate stop location choice.

The model system classification used here was adopted from Bowman (1998) which was the continuation of the work done by Bowman (1995) in building up a daily activity scheduling system. The fact that this activity-based model is done for Jakarta, which is also a developing country, is useful for the research currently in place as their experiences can be used to develop a custom model for Addis Ababa as well.

2.5.3 Activity-based travel demand model system with daily activity schedules (Bowman, 1995)

The travel demand model system that was developed by Bowman (1995) was implemented as a set of choice models that was integrated as a sequentially estimated nest logit model system. The model was comprised of three systems which were the daily activity pattern, primary tour, and secondary tour. The daily activity pattern decision includes the decision of whether to travel, the choice of the day's primary activity, the complexity of the primary tour, and the number and purpose of additional tours. On the other hand, the primary and secondary tour models include the choice of time, destination, and mode of travel.

The timeframe considered by Bowman (1995) was classified into four categories causing the aggregation of travel for A.M peak as well as P.M peak. An alternative for this is to adapt Yagi & Mohammadian (2008) method of classification which is classifying the 24 hours found within a day into five categories which are early morning, A.M peak, mid-day, P.M. peak and nighttime.

2.6 Summary

Activity-based travel demand models are used by researchers as well as transportation institutes around the world for defining travel demand in an accurate manner. They were originally introduced in the 1950s to fill the gaps of the trip-based approach. Advanced methods have been developed since then to increase the operational capacity and applicability of these models. Although this is the case, the fact that they are data intensive makes them less attractive for use in the developing world.

Subbarao & Krishna (2010) experience high illiteracy rate combined with lack of awareness during their survey. Individuals filling out the diaries lost it reducing the number of responses gained from the survey. Inaccurate of travel cost estimation was also a gap found in the research of Subbarao & Krishna (2010). Furthermore, accessing slum areas was also one issue which all developing coutries can relate to.

The timeframe classification introducted by Yagi & Mohammadian (2008) is helpful in analzying travel demand as opposed to the currenly applied ones of "peak" and "off-peak" hours. The model of Yagi & Mohammadian (2008) had 15 combinations of dialy activity patterns. Since it was not possible to use the whole data set that was available, samples from each tour type were used. This was possibley attributed to time constraints.

Bownan (1995) developed a discrete choice activity-based model for the Boston area. The model was developed by linking the lower tier models with the upper tier models using a sequential Nested Logit structure. Although this was the case, Bowman (1995) failed to link the mode choice model with the time-of-day choice model both for primary and secondary tours as it was computationally intensive in light of the computational power of the operating system used as well as time constraints faced by the researcher.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study area for this research work was Addis Ababa, Ethiopia. Addis Ababa, the capital city of Ethiopia, is located around the central parts of the country at an average altitude of 2,400 meters (UN-HABITAT, 2008). It is one of the oldest and largest cities in the country. Addis Ababa has 10 sub-cities within it. *Table 3-1* below shows the list of all the ten sub-cities of Addis Ababa along with their population sizes and population densities.

Table 3-1: Sub-cities along with their population sizes

Sub-City	***Area (km^2)***	***Population Size***	***Population Density (person/km^2)***
Akaki Kaliti	118.08	227,182	1923.97
Addis Ketema	7.41	320,053	43,192.04
Arada	9.91	265,141	26,754.89
Bole	122.08	387,355	3,172.96
Gulele	30.18	335,434	11,777.14
Kirkos	14.62	277,346	18,970.31
Kolfe Keraniyo	61.25	537,561	8776.51
Lideta	9.18	252,842	27,542.70
Nifas Silk-Lafto	68.30	396,486	5,805.07
Yeka	85.46	434,599	5805.07
Total		**3,433,999**	

Source: CSA (2013)

The city administration of Addis Ababa has been attempting to harmonize the demand and supply of transportation infrastructures by constructing roads at different sections of the city to meet the growing interest of the city dwellers. According to Addis Ababa City Government (2013) as of 2102, the city had over 3,800 km of roads that have been constructed.

Bole Sub-City, the study area for this research, is located in the eastern part of the city. According to CSA (2013), the 2017 population projection of the Sub-City is a total of 387,355 residents of which 180,782 (53.33%) are male while the rest 206,573 (46.67%) are female. *Figure 3-1* below shows the location of Bole Sub-City in Addis Ababa as well as the Sub-City's woreda classification.

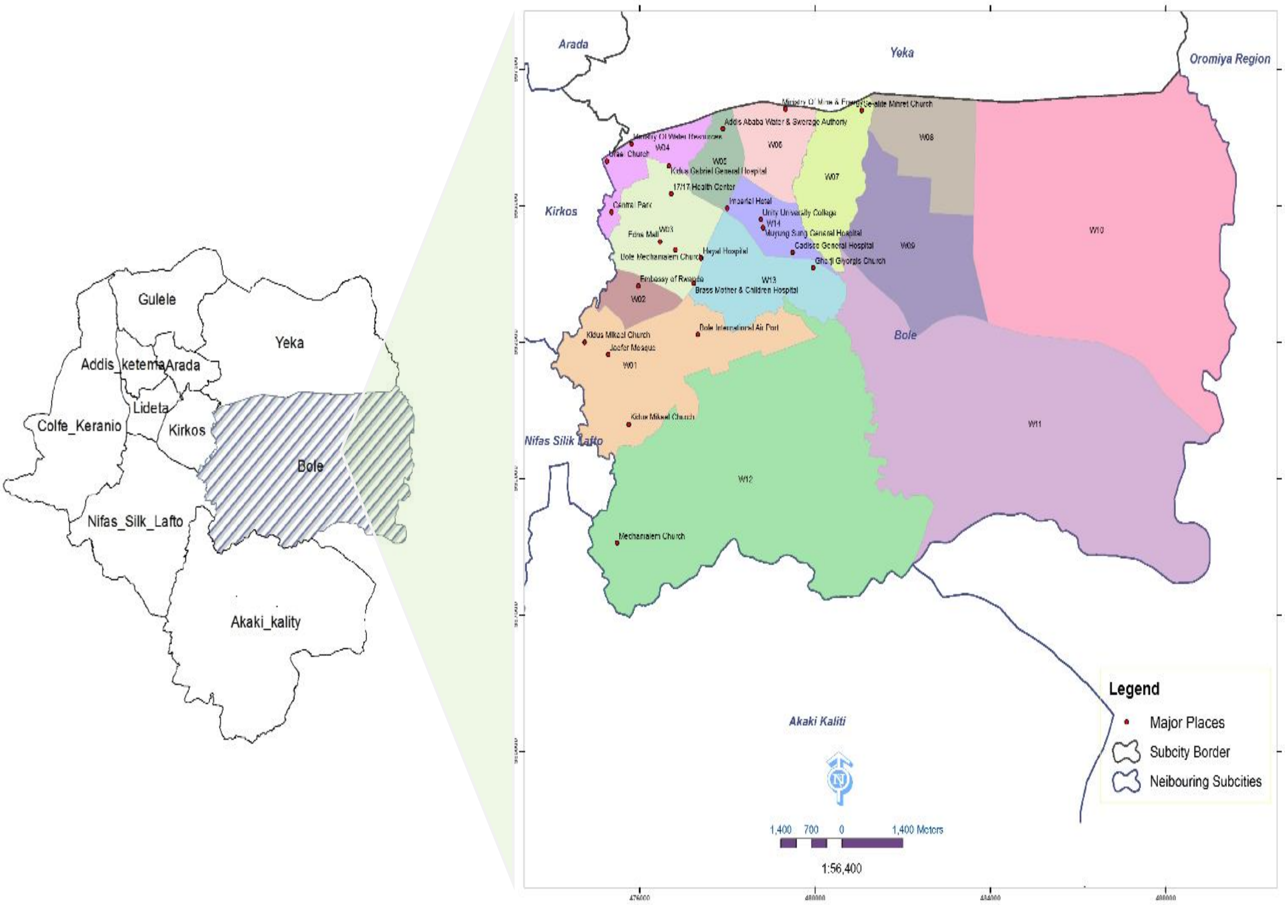

Figure 3-1: Location map of Bole Sub-City

(Source: Addis Ababa Urban Planning Institute, 2011)

Bole Sub-City covers an area of about 122.08 km^2 making it one of the largest sub-cities of Addis Ababa. Moreover, the Sub-City has a population density of 3,172.96 people/km^2. Various land uses are observed in Bole Sub-City including commercial areas, residential areas, plantations and fields, educational institutes, and transportation terminals. According to Addis Ababa Planning Institute (2011), the highest percentage share of the land is occupied by fields, residential areas, and open spaces. Figure 3-2 below shows the existing land use map of the Sub-City. Bole Sub-City was randomly selected for this research work out of the ten sub-cities considering the above factors.

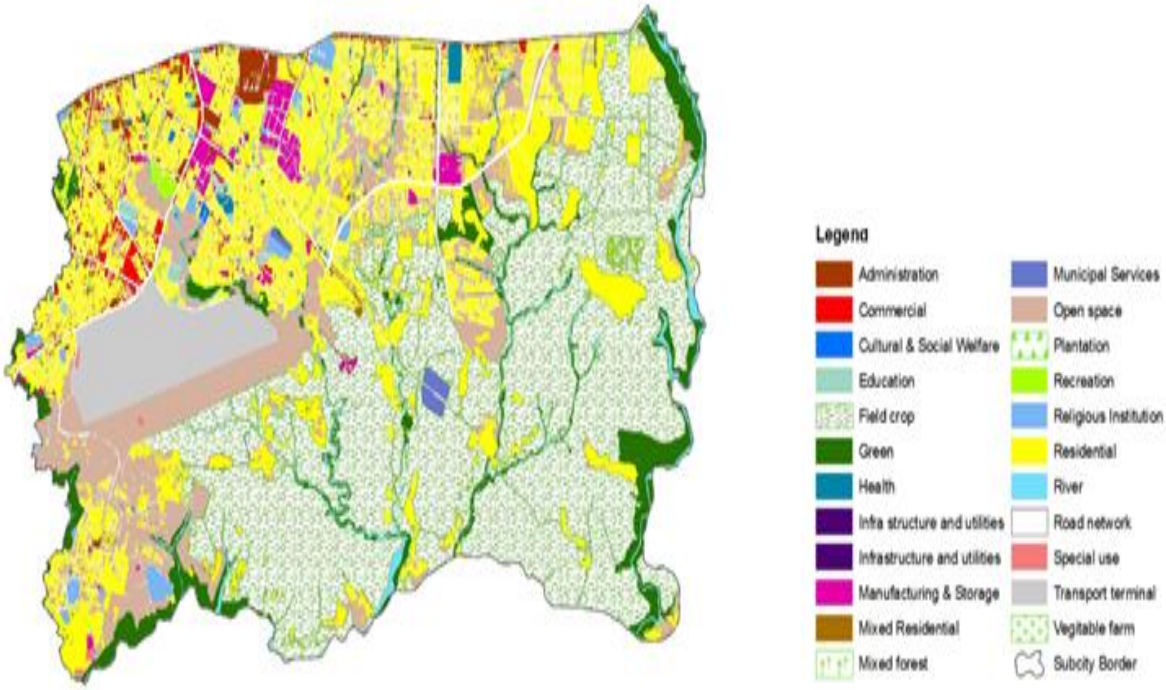

Figure 3-2: Existing land use map of Bole Sub-City

Source: (Addis Ababa Urban Planning Institute, 2011)

3.2 Survey Design

3.2.1 Sampling Technique

Initially, random sampling technique was to be applied to the research. The calculated sample size was to be distributed to each woreda and then samples were going to be taken randomly. The problem with this approach was that the available list of households in Bole Sub-City did not include within it individuals that resided there as tenants.

In the developing world, individuals rent housing units as opposed to owning it. This is usually true in low income households where people cannot possibly meet the expenses of household ownership (UN-HABITAT, 2003). Renting in Bole Sub-City takes many forms. It could be a small room, an apartment, condominium, or a whole compound. Misrepresentation of these portions of the community will not give a well-represented sample. Considering this, the survey was carried out by going to different areas of the Sub-City and distributing the questionnaire and activity diary to all residents found in the area who were willing to participate in the survey.

Since most households had more than a single individual living in them, it ensured a diverse sample with a variety of socioeconomic and demographic characteristics.

3.2.2 Sample Size Selection

The sample size for the research work was determined using Krejcie & Morgan (1970) approach. Using this approach, the sample size for a known population size was calculated as follows.

$$Sample\ size = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)} \tag{3.1}$$

Where X^2= table value of Chi-Square for a desired level of confidence,

N= population size,

P= population proportion (assumed to be 0.50), and

d= degree of accuracy (expressed as a proportion).

Considering a Confidence level of 90%, X becomes 1.645. From section 3, the population size (N) for the study area was 387,355. The population proportion P was assumed to be 0.5 as it is this value that will be us the maximum value. A 5% degree of accuracy was considered (Krejcie & Morgan, 1970). Inserting these values into equation (3.1), the sample size for the study area becomes 270.41 which was rounded to 271. Taking the average household size for Bole Sub-City to be 3.8 (CSA, 2007), the sample size for the study area was calculated to be 72 households. Every individual within the selected households above the age of 5 and who was willing to participate in the survey was given the questionnaire and activity diary.

3.2.3 Questionnaire and Activity Diary

In this research work, both primary and secondary data were used. The primary data for this research work were collected through questionnaires and activity diaries, while the secondary data were gathered from governmental offices located in Addis Ababa. The collected secondary data include the population statistics of Addis Ababa which was obtained from Central Statistical Agency and the Atlas of Bole Sub-City from Bole Sub-City Administration.

For the preparation of the questionnaires and activity diaries, the guidelines and methods recommended by Arentze, et al. (2004), Crosbie (2006) and Subbarao & Krishna (2010) were considered. Reviews were also done on activity diaries that were prepared for the western world but they were found to be inapplicable for this research due to their complexity.

Both the questionnaire and activity diary were translated into Amharic as it is the primary language spoken in the Addis Ababa. This increased the ease while addressing the households selected for the research. The English and Amharic version of the questionnaire for both individual level and household level along with the activity diary are attached in Annex B and Annex C. A detailed explanation of the questionnaire and activity diaries along with factors considered for their development is presented in the following sections.

3.2.3.1 Questionnaire

A questionnaire was used to gather the socio-demographic and economic characteristics of the individuals that were randomly selected. For the purpose of getting accurate results, the questionnaire was divided into two categories. These were the household information and the individual information.

3.2.3.1.1 Household information

This portion of the questionnaire was used to determine the general characteristic of each household unit. It was used to capture the following information:

- Household location,
- Total number of household members,
- Household ownership,
- Household income,
- Vehicle ownership, and
- Total number of licensed drivers in the household.

The above information was used to report a household's basic socioeconomic information.

3.2.3.1.2 Individual Information

The individual information was used to gather information about each individual residing in a household whose age was 5 years or more since it was assumed that kids below this age were usually accompanied by their parents or caregivers for their daily activities. The individual information includes:

- Age,
- Gender,
- Relationship with the household head,
- Education level,

- Mode of travel,
- Driver’s license status,
- Type of workplace, and
- Type of occupation.

3.2.3.1.3 Transportation Mode Specification

In the questionnaire, various modes of transportation were listed out of which the respondents choose the ones they frequently use for travelling. The transportation modes are listed below.

- Walking,
- Bicycle,
- Three-wheelers,
- Motor Cycle,
- Minibus taxi,
- Car,
- Public Bus,
- Higer/Lonchina,
- Light Rail Transit (LRT),
- Company Service, and
- Private Service.

From the modes listed above, walking and bicycle are considered as modes of transportation when an individual uses them as major modes of travel throughout the day. Three-wheelers are common transportation modes in Addis Ababa which have a holding capacity of 3 to 5 individuals. They are usually used by travelers for short distance trips where the other modes of transportation are not readily available. They are common on newly constructed roads in the outskirts of the city. On the other hand, the term minibus taxi in this research refers to minibuses that are used for transportation purposes. They are widely observed in Addis Ababa and have a holding capacity of up to 12 people.

Public buses refer to the large buses found in the city with a holding capacity of up to 100 people. It includes Anbessa bus, Sheger bus, and Alliance bus. Higers/Lonchinas have capacities larger than that of minibus taxis but smaller than public buses.

The Light Rail Transit (LRT) is one of the newly constructed transportation infrastructures in the city. The LRT connects the city from four different directions. Company and private services refer to transportation modes that are provided to employees by their employers.

3.2.3.2 Activity Diary

Activity diary is the other primary data that is vital for the design of an activity-based travel demand model. The major goal of an activity diary is to track the activity of each individual within a household because it is believed that travel is a demand that is derived basically from the desire to participate in certain types of activities.

Activity diaries are usually administered in two types of formats. The first one is a 24-hour format while the second one is a 48-hour format. In order to determine which type is feasible for this research work, various literature was reviewed and also a pilot study was conducted in order to get feedback from the respondents and to decide on which type of format gives a higher response rate.

Taking into consideration the pilot study that was conducted for the research, it was decided to use a 48-hour format activity diary. Although it was clear from the beginning that the 48-hour activity diary format posed to be a lot of burden to the respondents making them frustrated and incapable of filling out the second day with the desired level of accuracy, the results obtained from a 24-hour activity diary might not be representative of what the individual does throughout the weekday.

Arentze, et al. (2004) also suggest that the timing of distribution for the diary to be throughout the year while being equally distributed throughout the week. Due to budget and time constraints, it was not possible to carry out the data collection throughout the year. The activity diary was distributed throughout Bole Sub-City from May 2017 to September 2017 until the required sample size was achieved. Moreover, activity logs of only weekdays were collected since the activities performed during weekdays and weekends is not the same and including weekend entries into the survey will cause bias during the analysis. The activity diary that was distributed included the following information for the respondents to fill out.

- Activity timing (start time and end time),
- Location of the activity,
- Description of the activity,
- Mode of transportation used,
- Number of people accompanying the individual while conducting the activity,

- Travel time, and
- Cost paid for transportation.

Data that were required for the travel survey are summarized in the table in *Table 3-2*.

Table 3-2: Household travel survey data items

Household Data	***Person Data***	***Activity Data***
Household location	Gender	Departure and arrival time
Household size	Age	Origin and destination of the trips
Dwelling type	Education status	Trip purpose
Ownership Status	Frequently used mode	Travel time
Household Income	Drivers' license status	Accompanied travelers
Vehicle ownership status	Employment status	Travel cost
Individuals with drivers' license	Type of work	Mode of transportation used

3.3 Data Collection and Analysis

The questionnaire and activity diary were distributed throughout the study area based on the sample size determined. A response rate of 30% was considered due to the fact that the activity diary is a highly demanding task which is usually considered as a burden for the respondents.

The method of administration used for data collection was the drop-off and pick-up method where the questionnaire and activity diaries were given to members of the household then collected after two days. As most individuals of a household usually return home from work after 5 p.m. in the afternoon and were completed by 7 p.m. Data collection for the next day commenced at the same time.

3.3.1 Data Encoding

The data encoding for this research work was done using IBM SPSS Statistics version 20. This software was selected due to its popularity for statistical data analysis. After inserting all the explanatory variables necessary for the analysis stage, all questionnaires and activity diaries that were filled by the respondents were encoded into the software.

Frequencies and means were computed for every explanatory variable found within the data set. Summaries of the data collected were also done using the descriptive statistics tool found within the software.

3.3.2 Cleaning Data

Individuals with missing values were removed since they affect the quality of the data that is to be analyzed. Outliers found within the data were also cleared in addition to values that were mistakenly entered into the analysis tool.

3.3.3 Descriptive Data Analysis

Once all the data was entered into IBM SPSS Statistics, it was analyzed and the results of the survey were presented in a descriptive manner. The purpose of this phase was to illustrate how the sociodemographic characteristic of each household affects the travel decision and travel behavior they make. The respondents' characteristics, their corresponding travel behaviors, their trip characteristics, their mode choices, and time-of-day that the travel occurred were all analyzed during this stage.

3.4 Model Description

The travel demand model that was developed for this research work was based on the methodology developed by Bowman (1995) and Yagi & Mohammadian (2008). The modeling approach is a discrete choice model based on the random utility maximizing principles. A tour structure is maintained as a unit of modeling travel instead of trips. The model is basically composed of the following.

- Daily activity pattern (DAP),
- Primary tour time-of-day (TOD), and
- Primary tour mode choice.

The estimation of the above models was done using Multinomial Logit (MNL) and Nested Logit (NL) models. Although there are various ways for estimating NL models, a sequential approach is used. This means that the analysis starts from the bottom, i.e. mode choice model is estimated first followed by TOD model and finally DAP model. The explanatory variables obtained from the lower tier model will be used for the analysis of the upper tiers. A sequential nested logit model estimation is described well by Train (2002) and Bowman (1995). Thereby, the model description presented in this section is present in this manner: starting with the primary tour mode choice model, followed by the primary tour time-of-day (TOD), and finally the daily activity pattern (DAP) model.

3.4.1 Mode Choice

The travel modes that are frequently used during the survey by each individual were first identified. Once these models were identified, explanatory variables that were thought to influence mode choice were considered and inserted into IBM SPSS Statistics software where the necessary results were obtained.

A discrete choice multinomial logit (MNL) model was used to build up the mode choice model. The expected maximum utility (logsum) for each tour was also calculated of which the result was used for the estimation of the TOD choice model.

3.4.2 Time-of-Day Choice

The time-of-day choice (TOD) is modeled by first dividing the 24 hours found within a day into five components. These are:

- Early morning (E.M),
- A.M. peak (A.M),
- Mid-day (M.D),
- P.M. peak (P.M), and
- Nighttime (N.T)

Early Morning (E.M) starts at 3:00 a.m. and continues until 6:29 a.m. A.M peak (A.M) is from 6:30 a.m. to 9:59 a.m. Mid-day (M.D) starts at 10:00 a.m. in the morning goes on until 03:59 p.m. and p.m. peak (P.M) is from 04:00 p.m. to 06:59 p.m. while Nighttime (N.T) is from 07:00 p.m. all the way to 2:59 a.m. (Yagi & Mohammadian, 2008). TOD classification along with the corresponding time ranges can be seen in *Table 3-3*.

Table 3-3: TOD Classification

TOD	Abbreviation	Time range
Early Morning	E.M	03:00 a.m. to 06:29 a.m.
A.M Peak	A.M	06:30 a.m. to 09:59 a.m.
Mid-Day	M.D	10:00 a.m. to 03:59 p.m.
P.M Peak	P.M	04:00 p.m. to 06:59 p.m.
Nighttime	N.T	07:00 p.m. to 02:59 a.m.

One assumption in the TOD choice model is that all individuals within a household do not perform an activity overnight and they return home; hence, individuals with overnight activities were excluded from the model. Considering this factor, an individual's tour is put into one of the five timeframes from the time that individual leaves the house until he/she returns back home. Thus, a total of 15 TOD combinations were formed. The combinations of TOD choices can be seen in *Figure 3-3*.

The logsum that was calculated in the mode choice model was used as an explanatory variable in the TOD in addition to other variables that were thought to influence the TOD an individual chooses. The parameters of the TOD model were estimated to using IBM SPSS Statistics software tool.

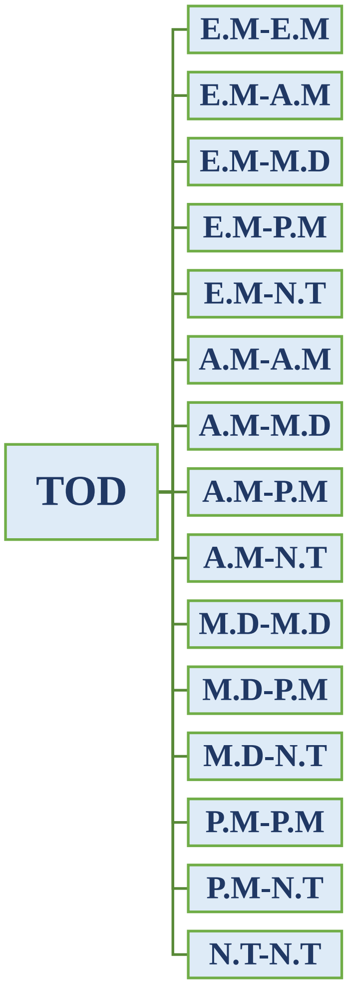

Figure 3-3: Combinations of TOD choices

Source: (Yagi & Mohammadian, 2008)

3.4.3 Daily Activity Travel Pattern Choice

The daily activity travel pattern choice (DAP) was defined into two broad categories. These are staying at home and choosing to go out. When an individual decides to go out he/she has a number of decisions to make about which activities to perform and in what pattern.

For this research, out-of-home activities were classified into 5 categories which are described below (Yagi & Mohammadian, 2008)

- Work (W),
- School (S),
- Discretionary (D),
- Maintenance (M), and
- Other (O).

Within work categories, work-related activities are also included. School activities are performed by students and they are distinguished from the work activities because the travel pattern of students and workers is not the same. Workers usually go out of their homes early in the morning and return back home either during the afternoon peak hour or at nighttime. On the contrary, even if students go to their school during the morning, they tend to return to their respective homes usually by mid-day.

On the other hand, discretionary activities include eating meals, visiting family members or friends, and other social, religious, and recreational activities. Maintenance activities include visiting doctors, shopping, paying bills, banking and so on. The last category is for activities that involve picking up or dropping off kids or other passengers, personal businesses and so on.

The first decision an individual makes is whether to stay home or to perform out-of-home activities. Accordingly, the out-of-home activities an individual chooses are classified in to 11 categories. *Figure 3-4* below illustrates the DAP classification that was used for the purpose of this research.

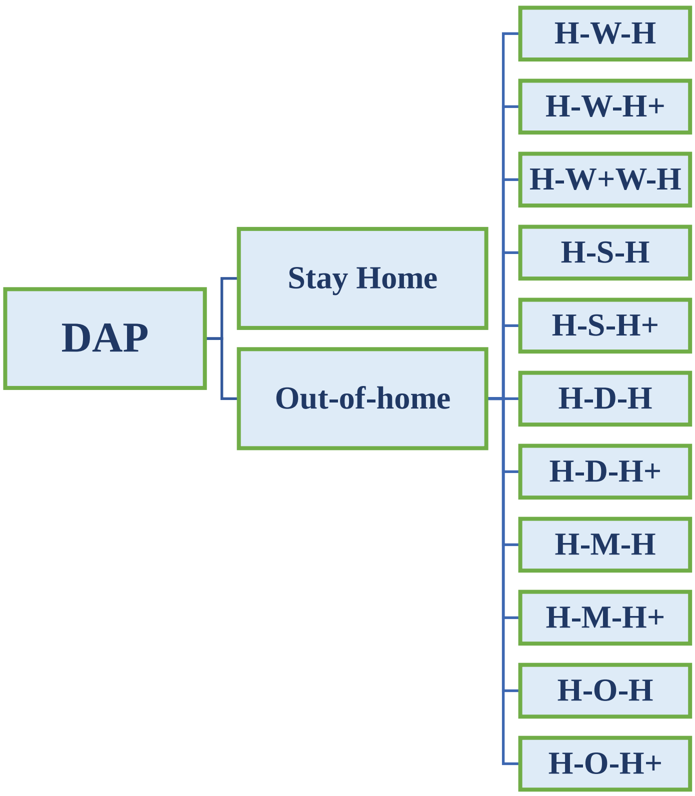

Figure 3-4: Daily activity pattern classification

The daily activity pattern classification was based on the recommendations of Bowman (1995) as well as the observed patterns from the survey. Accordingly, work tours, as it can be observed from *Figure 3-4* above are classified into three. These are:

- H-W-H,
- H-W-H+, and
- H-W+W-H

H-W-H tour is a simple tour in which an individual goes to work from home and returns home after work without any additional stops to perform other activities. H-W-H+ is just like the H-W-H tour but the individual makes at least one additional stop either on the way to work or when returning home. The additional activity performed could be school, maintenance, discretionary, or any other type of activity. The third type of work tour is H-W+W-H. This type of tour involves a work sub-tour within the work tour in which the individual goes to work at first, goes from work to perform additional activities, returns to work, and then finally returns back home.

The classification of school tours is not as complicated as work tours since the pattern observed in these types of tours was mostly simple. The two basic patterns that were observed for school tours are shown below.

- H-S-H, and
- H-S-H+

H-S-H type of pattern is when an individual goes to school and then back home while H-S-H+ is when an individual performs additional activities aside for the school activity before going to school or afterward.

Discretionary, maintenance and other tours have the same patterns observed. H-D-H, H-M-H, H-O-H are the simple patterns where there are no additional stops, activities, or tours observed while H-D-H+, H-M-H+, and H-O-H+ are patterns which involve at least one additional activity before or after performing the primary activity for the day.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 General

In this chapter, the results that were obtained from the survey and model are discussed. The chapter is divided into two sections. In the first section, a description of the survey result is presented. Questionnaires and activity dairies that were collected from the survey were analyzed. Special emphasis is given to the results from the survey that were used for the model development. A detailed description of the survey result can also be found in Annex B. In the second section, the model developed for an activity-based travel demand model with daily activity schedules is presented.

4.2 Survey Results

This section provides the summary of the respondents that participated in the survey. The household income, the age distribution of household members, and the occupation of each household member is described. From the survey, it was observed that 57.2% of the respondents were male while 42.8% of the respondents were female making the survey population dominated by male respondents.

4.2.1 Household Income

The household income represents the aggregated gross income all members of a household earn on a monthly basis. From the household survey, it was observed that 2.8% of the respondents had a household income that was less than ETB 1,000 while 13.9% of the households had a monthly income between ETB 1,000 and ETB 5,000. Incomes ranging between ETB 5,001 and ETB 10,0000 as well as those ranging between ETB 10,000 and ETB 20,000 had a 20.8% share. Furthermore, 12.5% of the households had an income between ETB 20,001 and ETB 30,000 while 23.6% of the households had an income that was more than ETB 30,000. 5.6% of the households to whom the questionnaire and activity diary were given refused to disclose their monthly income due to personal reasons.

The mean and median household incomes were from ETB 10,000 to ETB 20,000 while the mode income was greater than ETB 30,000. *Figure 4-1* shows the summary of the monthly income classification of household members.

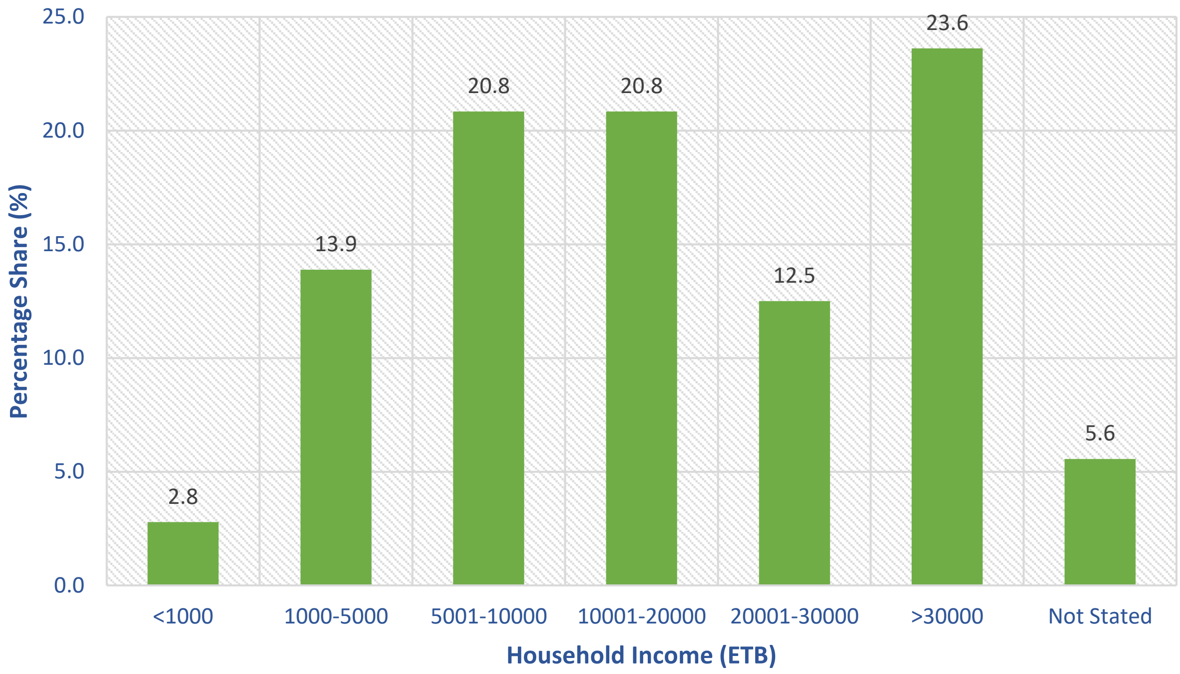

Figure 4-1: Classification of households based on their monthly income

4.2.2 Age Distribution of Household Members

The age group classification used in this research was adopted from CSA (2007). During the travel survey, children with ages less than 5 years were not required to fill out the questionnaire and activity diary. The reason behind this was that it was assumed that children in this age group were usually accompanied by their parents, caregivers, or other adults during their activities.

From *Figure 4-2*, it can be seen that a low percentage value was observed for the age category between 5 and 9 years old. The reason behind this was children in this age group are mostly accompanied by other adults while they were conducting their activities just like those which were under the age of 5. The same reason also holds for the ages between 10-14. In addition to this, 26% of the households were between the ages of 25 and 29. This age category ranked the highest in the survey while the second highest was the age group between 20 and 24 with a 17% share. High percentages were obtained from these age groups since these age categories were the ones that were observed to be the most economically active during the travel survey.

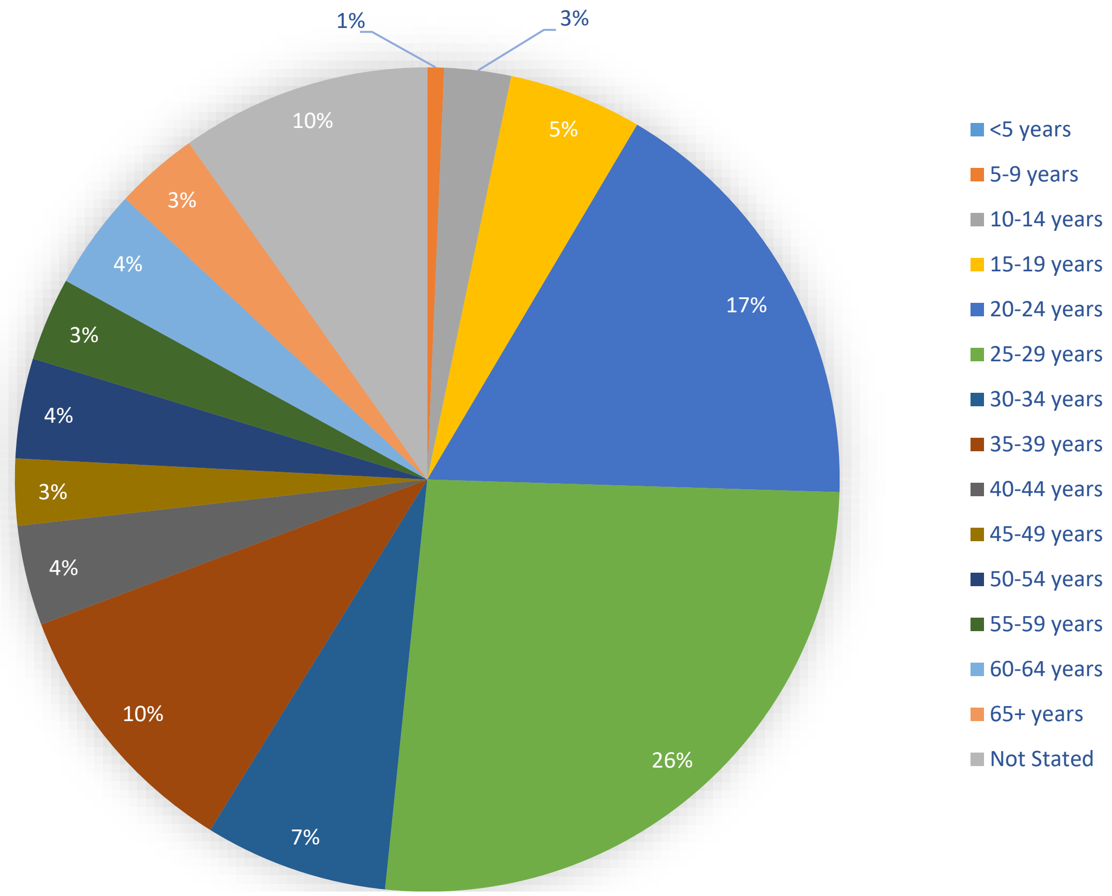

Figure 4-2: Distribution of household members by age group

4.2.3 Occupation Status

The occupation status describes the type of occupation individuals that agreed to participate in the survey were involved in. In addition to this, the type of the workplaces in which they perform their daily activities was also included in the survey in order to get a general perspective of how the working and non-working forces of the survey participants spent their day.

41.8% of the respondents from the survey were observed to be employed fulltime while 23.4% of the respondents were self-employed. 21.5% of the respondents were students while only 3.2% of the population surveyed were retired. *Figure 4-3* illustrates the distribution of household members by their occupation status.

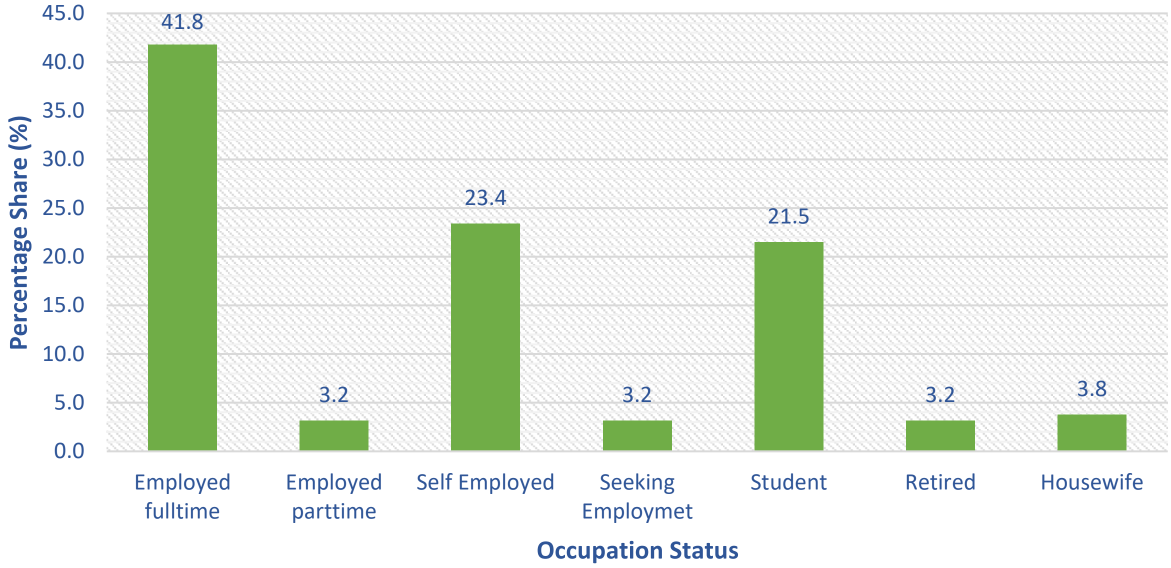

Figure 4-3: Distribution of household members by occupation status

4.2.4 Vehicle Ownership

Vehicle ownership refers to the number of vehicles that are owned by a household. The trip patterns and travel mode chosen for households with one or more vehicles vary from those with no vehicles at all. *Table 4-1* below shows the vehicle ownership of the surveyed households. In this regard, 38.2% of the households did not own any vehicles, while 53.8% of the households owned a single vehicle. Furthermore, 4.9% owned two vehicles and 3.1% owned more than two vehicles.

Table 4-1: Vehicle ownership of households

Number of Vehicles	Percentage (%)
0	38.2
1	53.8
2	4.9
>2	3.1
Total	**100.0**

4.3 Travel Behavior

4.3.1 Household Travel

The average household trip rate for the whole study area, regardless of age and household size, was found to be 2.7. The factors affecting this number were:

- The fact that not all the household members agreed to participate in the survey; and
- The activity diary was also distributed to the residents of the Sub-City during the summer which lasts from July to August where the trip rate during this time of the year is relatively low since most schools are closed.

Figure 4-4 below shows the percentage share of the total number of trips made classified by the household income of each household. From the figure, it can be seen that the highest trip contribution was made by households with salaries more than ETB 30,000 while the least contribution was made by households with incomes less than ETB 2,000. The overrepresentation of households with incomes greater than ETB 30,000 could contribute to this result.

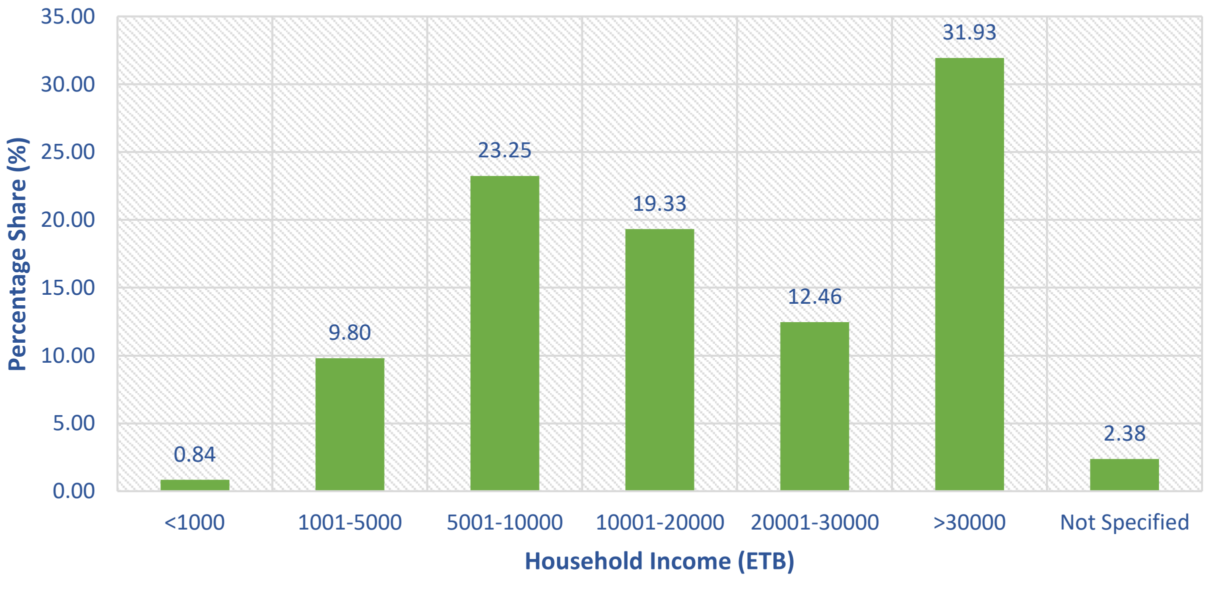

Figure 4-4 Trip distribution by household income

Figure 4-5 shows the percentage share of the total number of trips made classified by the household members' age group. From this figure, it can be observed that the largest share of trips was contributed by those individuals between the ages of 25-29 while the least is for children between the ages of 5 and 9. The reason behind the low trip share of the age category

5 to 9 is that children in this age group were usually accompanied by their parent, caregivers, or other individuals while they were conducting their daily trips.

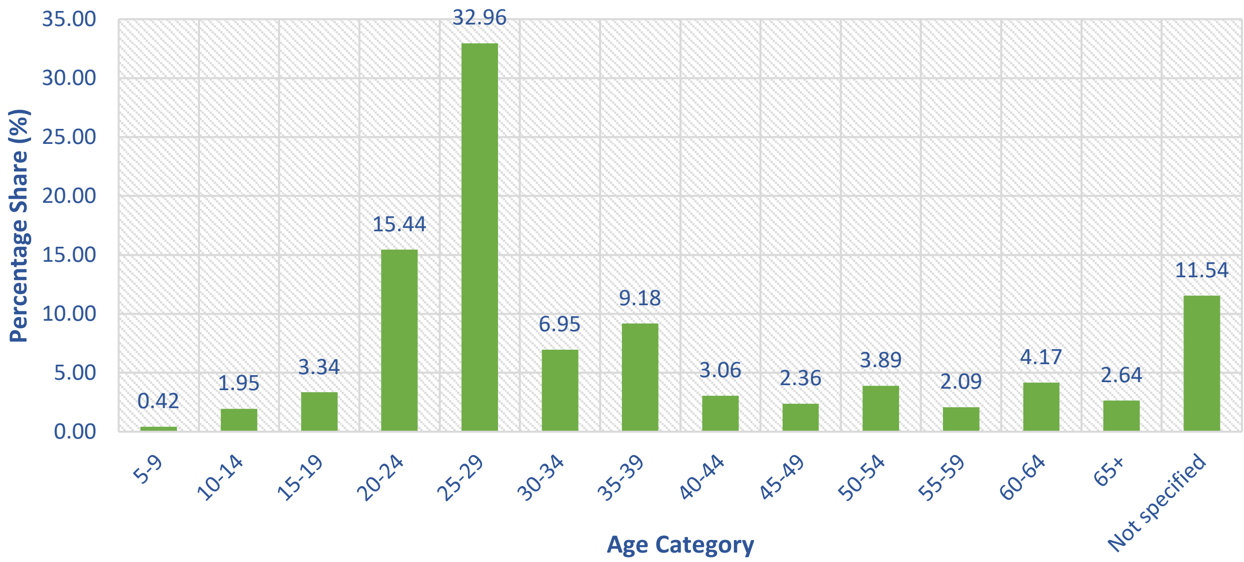

Figure 4-5: Trip distribution by age category

4.3.2 Person Travel

Gender: When considering the gender of individual travelers, male respondents tended to perform more activities during the day compared to female respondents. Out of the total activity data that was collected, 58.3% of the activities were done by male travelers while 41.7% of the activities were performed by female travelers.

Worker: 72.7% of the trips and activities were found to be performed by workers which included everyone who is full-time employed, part-time employed, and self-employed.

Student: 14.3% of the activities that were observed were found to be conducted by students.

Age: Largest share of activities were performed by the age group between 25-29. The second largest share goes to those between 20-24 followed by those between 35-39 and 30-34. This confirms the fact that those that are in their economically active age tend to travel and perform more activities during the day.

4.4 Trip Characteristics

4.4.1 Travel Cost

The average travel cost of an individual using a public transportation, including minibus taxi, public bus, three-wheelers, and Higer, as their mode of travel was found to be ETB 7.01 per day. *Table 4-2* and *Figure 4-6* shows the percentage share of the total cost distribution.

Table 4-2: Cost distribution for trips

Cost (ETB)	Percentage (%)
0-5	64.6
5-10	18.1
10-15	12.2
15-20	3.8
20-25	0.7
>25	0.7
Total	**100**

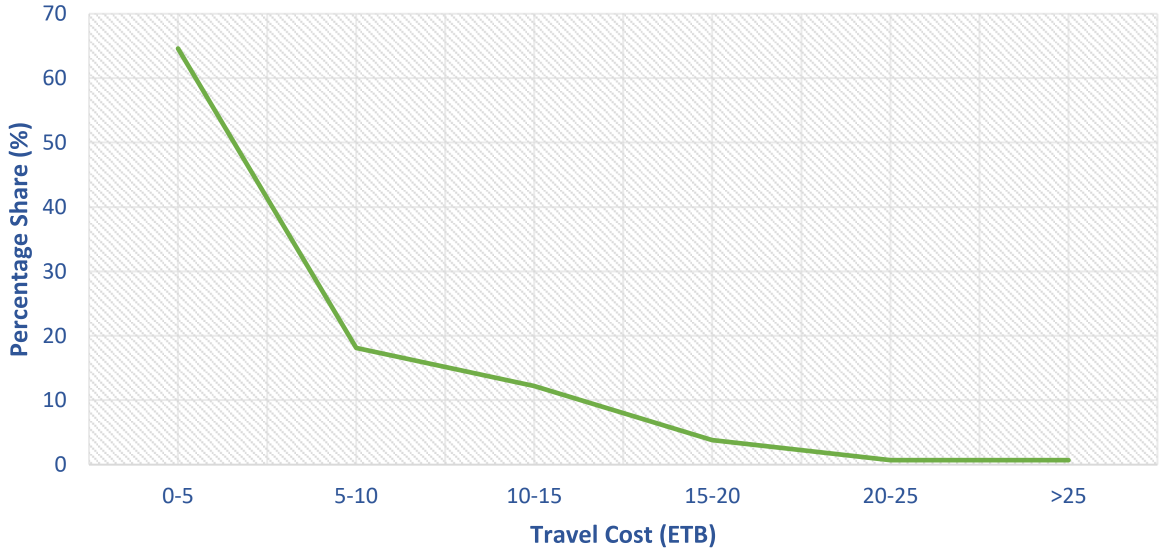

Figure 4-6: Percentage share of cost distribution for trips

Of the trips conducted by individuals, only less than 1% of them payed more that ETB 25 while over 60% of them payed ETB 0-5.

4.4.2 Trip Purpose

The trip purposes that were obtained from the survey were categorized into 12 as depicted in *Table 4-3*. In this regard, the highest share was observed for the trip purpose of returning home which took up 36.5% of the trip purposes. The next highest share was obtained from work trip purpose which had a value of 30.8%. Trips made for medical reasons had the lowest percentage share as it can be seen in *Table 4-3*. This can be attributed to the fact that medical trips are made by individuals seldom.

Table 4-3: Trip purposes and their duration

Activity	***Percentage (%)***	***Average Duration (hrs.)***
Return Home	36.5	0:55
Work	30.8	7:02
School	7.0	5:51
Leisure	6.9	2:24
Personal Business	6.0	2:30
Shopping	3.4	2:02
Religious Purposes	3.0	2:37
Pick up/Drop off passenger	2.3	0:40
Family Visit	1.6	3:25
Eat meal	1.3	1:19
Maintenance	0.9	0:59
Medical	0.3	2:32
Total	**100**	

4.4.3 Time-of-Day

Travel occurs at different times during the day. Even if this is the fact, research shows that the demand for travel is high during peak hours. The results found from this research also confirmed this fact. The highest percentage of travel for both days in which the activity diary was distributed occurred from 6:30 a.m. to 9:00 a.m. during the morning and from 4:30 p.m. to 5:30 p.m. in the afternoon. On Day-2 of the dairy, the travel rate was high from 6:30 a.m. to

9:00 a.m. during the morning just like Day-1 of the dairy, while the afternoon peak was from 4:30 p.m. to 6:30 p.m. The survey also showed that the travel frequency after 9:30 p.m. was very low. The reason behind this was because most residents of the Sub-City do not take night shifts. From the survey, it was observed that mostly, respondents working at hotels or restaurants as well as in companies requiring customer service after hours tended to take night shifts a couple of days during the week. *Figure 4-7* illustrates the distribution of the trips throughout the day.

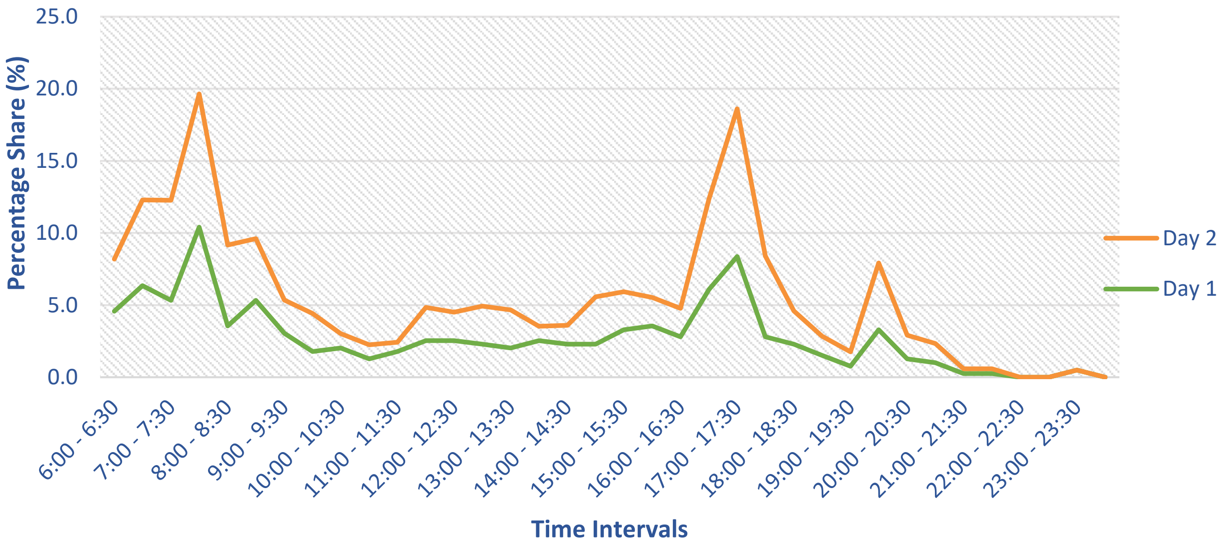

Figure 4-7: Distribution of trips throughout a day

4.4.4 Mode Choice

The widely used modes of travel from the survey were found to be minibus taxis with 40% share and car with 36.26% share. Furthermore, 15 % of the residents from the study area used walking as a mode of transportation. The lowest share goes to household members that used cabs for their travel which only contributed to less than 1% of the mode share. *Figure 4-8* illustrates the distribution of the transportation modes used for travel for the study area.

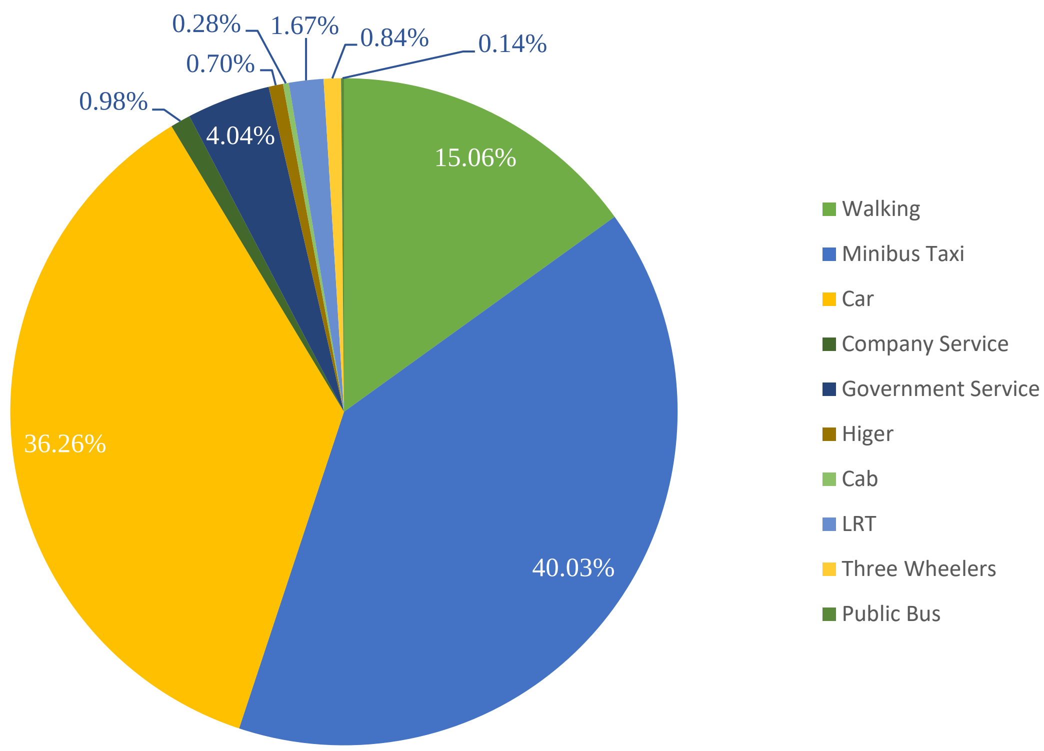

Figure 4-8: Distribution of the transportation modes used for travel in the study area

From *Figure 4-9* it can be seen that 50% of the medical trips that were made during the survey were made using car as a mode of travel while the rest of the time walking was used as a mode of transportation. The highest portion of school trips was made using minibus taxi as a mode of transportation. Walking comes next in line for school trips. The reason behind this fact is that parents usually tend to choose school locations that are closer to their homes in order to reduce the trip distance that is traveled by their children every day as well as to reduce the burden they have to face from picking them up and dropping them off from/to school every day.

In regard to work trips, minibus taxi and car were used as travel modes minibus taxi taking the highest portion followed by car. Maintenance activities were conducted using minibus taxi, car, or walking as a mode of travel, car being used most of the time for maintenance activities. Most respondents from the survey used minibus taxi for the purpose of returning home. Walking and car were the frequent modes of transportation that were used for picking up or dropping off passengers.

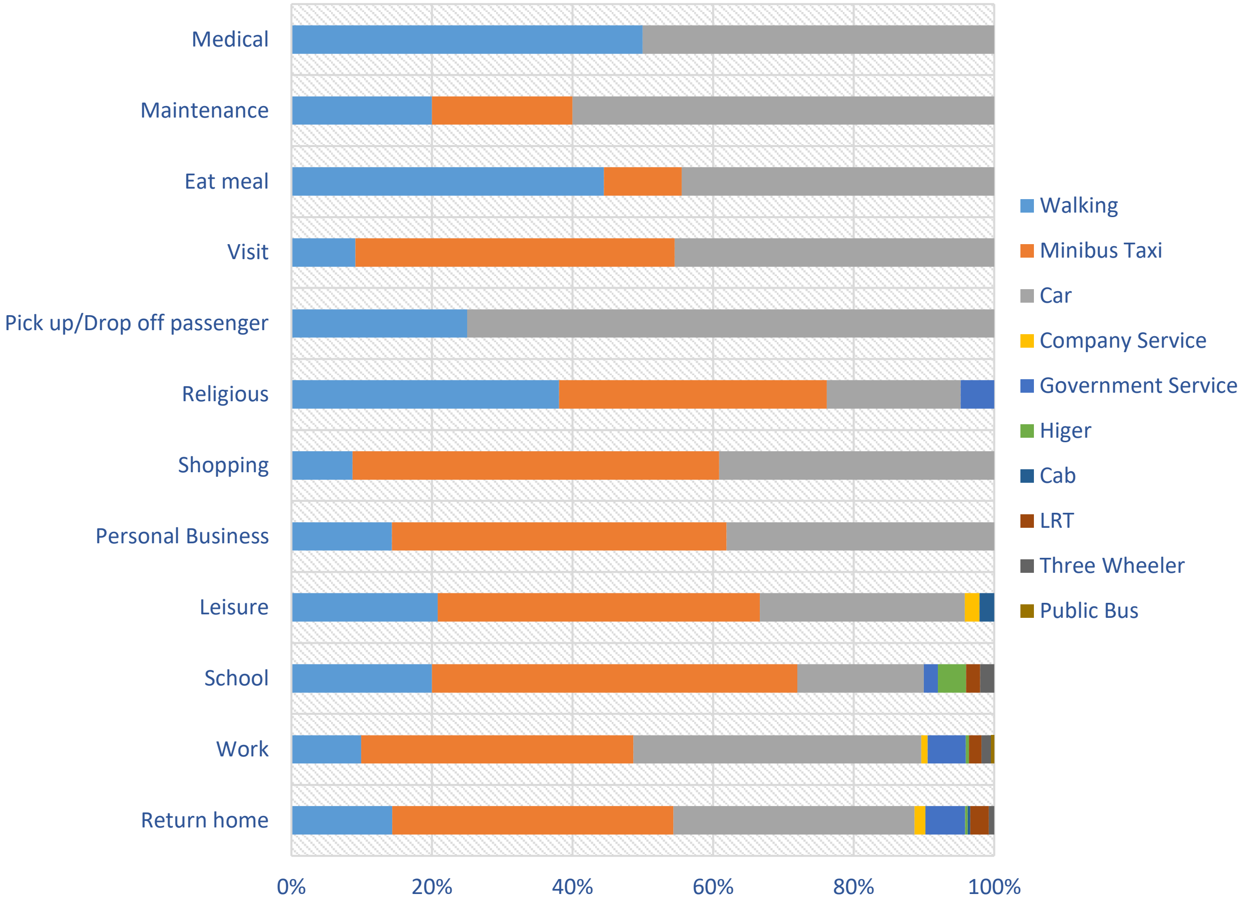

Figure 4-9: Distribution of travel mode based on activity purpose

4.5 Model Development

The activity-based travel demand model that was developed by Bowman (1995) and Yagi & Mohammadian (2008) includes within it a secondary mode choice model for secondary tours. On the contrary, in the model that was developed for this research, the secondary tours were ignored due to lack of sufficient data. Most respondents did not record their daily activities in detail and left out the small trips that they made aside from their major tours for the day. Due to this fact, the analysis of the secondary tours led to misleading results leading to the exclusion of these tours from the model.

Hence, the model that is developed here is only for primary tours which is further disaggregated into three categories that are the daily activity pattern choice model (DAP), the time-of-day choice model (TOD), and the mode choice model. The model development goes from the lower tier to the upper tiers. The linkage between subsequent tiers is done by taking the logsum of the lower tier and using it as an explanatory variable in the upper tier.

The coefficients of the utility function for each tier is described in the sections that follow.

4.5.1 Mode Choice Model

The primary mode of transportation that was used by each respondent during the diary days were considered. By observing the results of the survey, the frequently used modes of transportation by the respondents were identified. The identified modes of transportation along with their percentage share is presented in *Table 4-4*.

Table 4-4: Modes of transportation used for travel

Travel Mode	**Percentage (%)**
Minibus taxi	38.6
Car Alone	15.2
Shared Ride	16.3
Walking	11.4
Service	4.5
LRT	1.1
Higer	0.8
Minibus taxi with Car	5.3
Minibus taxi with Service	3.8
Minibus taxi with LRT	1.9
Minibus taxi with Higer	0.4
Minibus taxi with Walking	0.8
Total	**100**

A separate model was developed for work tours and non-work tours. Non-work tours include all tours other than work including school, maintenance, discretionary, and other types of tours. The reason behind this classification was that the travel pattern and transportation choice for the two categories were different making the splitting of the two tour types crucial.

The variables minibus taxi with car, minibus taxi with service, minibus taxi with LRT, minibus taxi with higer, and minibus taxi with walking represent cases in which a combination of the individual modes of travel were used for a tour. It might represent a case where an individual used more than one mode to reach a destination or where the individual used one mode for getting to his/her destination and a different mode for returning back home for simple tours like going to work or school and then returning back home.

4.5.1.1 Model Estimation

For the primary tour mode choice model for workers estimated in *Table 4-5* below, the variables used for analysis were the number of vehicles owned, travel cost, and gender.

Table 4-5: Primary tour mode choice model for work tours

Mode	Variable Name	Coefficients
Minibus taxi	Intercept	16.328
	Number of vehicles owned	-0.773
	Travel Cost	1.483
	Male	-20.237
	Female	0
Car Alone	Intercept	39.870
	Number of vehicles owned	15.394
	Travel Cost	-18.068
	Male	-38.141
	Female	0
Shared Ride	Intercept	40.394
	Number of vehicles owned	15.022
	Travel Cost	-18.243
	Male	-38.703
	Female	0

Table 4-5: Primary tour mode choice model for work tours continued

Mode	Variable Name	Coefficients
Walking	Intercept	42.519
	Number of vehicles owned	10.518
	Travel Cost	-17.397
	Male	-39.040
	Female	0
Service	Intercept	42.358
	Number of vehicles owned	11.186
	Travel Cost	-17.589
	Male	-38.667
	Female	0
LRT	Intercept	27.028
	Number of vehicles owned	-22.326
	Travel Cost	-1.030
	Male	-24.803
	Female	0
Minibus Taxi with Car	Intercept	17.169
	Number of vehicles owned	-0.070
	Travel Cost	1.135
	Male	-20.503
	Female	0
Minibus Taxi with Service	Intercept	18.088
	Number of vehicles owned	-0.096
	Travel Cost	0.972
	Male	-20.689
	Female	0

Table 4-5: Primary tour mode choice model for work tours continued

Mode	Variable Name	Coefficients
Minibus Taxi with LRT	Intercept	16.388
	Number of vehicles owned	-20.718
	Travel Cost	1.196
	Male	-19.221
	Female	0
Minibus Taxi with Higer	Intercept	-278.016
	Number of vehicles owned	3.437
	Travel Cost	17.752
	Male	-191.063
	Female	0

Coefficients for this model were estimated using minibus taxi with walking as the reference category. Considering this, minibus taxi used with higer was found to be the least attractive of all modes for work tours. Furthermore, individuals with one or more cars in their household tended to choose car alone, shared ride, walking, and service as their modes of travel.

The coefficients found in *Table 4-5* will give us the utility for the mode of transportation in question. When looking at the cost coefficients, higher coefficients were obtained for minibus taxi with higher, and the least coefficients were observed for car alone and shared ride. The reason behind this can be attributed to the fact that most respondents from the survey had a hard time estimating the amount of money they spent for travel if they were using car alone or shared ride as their mode of transportation.

When considering gender, females were more likely to make work tours compared to males for all transportation modes.

Table 4-6 shows the coefficients that are estimated for the mode choice model for non-work tours. The reference category, in this case, was minibus taxi with car.

Table 4-6: Primary tour mode choice for non-work tours

Mode	Variable Name	Coefficients
Minibus taxi	Intercept	1.786
	Number of vehicles owned	-1.107
	Travel Cost	0.133
	Male	1.106
	Female	0
Car Alone	Intercept	27.218
	Number of vehicles owned	-0.007
	Travel Cost	-10.027
	Male	-26.029
	Female	0
Shared Ride	Intercept	29.011
	Number of vehicles owned	-0.511
	Travel Cost	-10.195
	Male	-25.453
	Female	0
Walking	Intercept	28.327
	Number of vehicles owned	-0.521
	Travel Cost	-9.910
	Male	-23.436
	Female	0
LRT	Intercept	14.978
	Number of vehicles owned	-16.423
	Travel Cost	-3.141
	Male	-30.108
	Female	0

Table 4-6: Primary tour mode choice for non-work tours continued

Mode	Variable Name	Coefficients
Higer	Intercept	-19.197
	Number of vehicles owned	-0.370
	Travel Cost	0.034
	Male	19.998
	Female	0

From *Table 4-6* it can be seen that males were more likely to use higer as a mode of transportation for non-work tours compared to females. When it comes to the LRT females used this mode of travel more often than males do. The reason behind this could be the overrepresentation of female LRT users during the survey. Females also had a higher probability of choosing walking, shared ride, and car alone as a mode of travel more often than males while males were more likely to choose minibus taxi as their mode of transportation more often than females.

4.5.1.2 Model Fitting

The value of the log-likelihood function of the estimated parameters, $LL(\hat{\beta})$, was 155.729 while the value of the log-likelihood function when all the parameters are set to 0, $LL(0)$, was 155.729 for work tours. From these values the likelihood ratio index (ρ^2) for work tours was found to be 0.659 which implied that the model was a good fit.

For non-work tours, $LL(\hat{\beta})$ was 69.695 while $LL(0)$ was 201.830 making the value of ρ^2 0.655 which made it in the acceptable range between 0 and 1.

The calculation of the expected maximum utility was done next. The expected maximum utility of a single tour is described by Bowman (1995) as the logarithm of the sum of the exponentiated systematic utilities of all available tour alternatives (logsum). This can be shown as follows.

$$E(maxU_n) = \sum_{l=1}^{L_n} ln \sum_{i \in C_{in}} \exp(V_{iln}) \quad (5.1)$$

Where, E() denotes mathematical expectation;

$maxU_n$ is the maximum utility derived from tours in daily activity pattern *n*;

L_n is the number of tours in daily activity pattern *n*;

ln is the natural logarithm operator;

exp is the exponentiation operator;

V_{iln} is the systematic portion of the utility of alternative *i* for tour *l* in daily activity pattern; and

C_{ln} is the choice set for tour *l* in daily activity pattern *n*.

Using *(5.1)* the expected maximum utility (E) both for work and non-work tours was calculated. This involved calculating the utility for each primary tour, taking the logarithm of the exponentiated value and finally summing the results. The coefficient for this logsum variable was then calculated in the TOD model.

4.5.2 Time-of-Day (TOD) Choice Model

As it was discussed in the previous chapter, the 24-hours of a day were classified into five categories for the purpose of simplicity in the analysis. These were the early morning (E.M), a.m. peak (A.M), mid-day (M.D), p.m. peak (P.M) and nighttime (N.T). This method was adopted from Bowman (1995) and Yagi & Mohammadian (2008). Accordingly, the percentage share of each sub-category within the 24-hours is illustrated in *Figure 4-10* below.

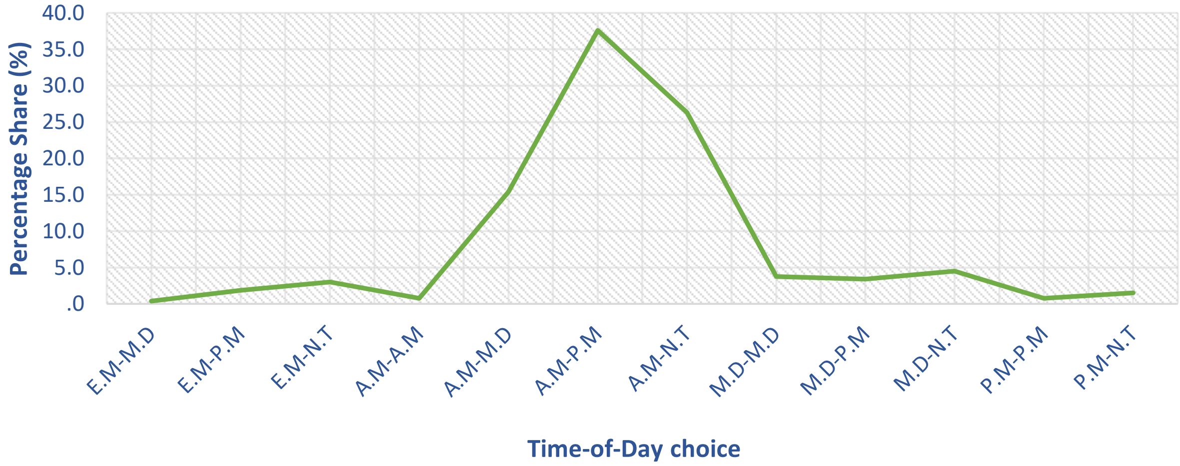

Figure 4-10: Distribution of time-of-day choice

As it can be observed from *Figure 4-10* above, most tours start at A.M and end at P.M. This confirms the fact that most individuals within a household go out of their homes during the morning peak hour and return home during the evening peak hour. The next highest percentage goes to A.M-N.T. This is also true since most individuals usually finish work around 5:00 or 5:30 p.m. and the waiting time for transportation facilities as well as congestion of roads causes them to reach their homes after 7:00 p.m. which is categorized in this research as N.T. A.M-M.D is also observed to have a relatively higher percentage as compared to the other TODs. This is due to the fact that most students are released from their classes starting from 3:00 p.m. and travel to their homes before 4:00 p.m., which is considered as M.D.

4.5.2.1 Model Estimation

Table 4-7 below presents the estimation of coefficients for the time-of-day choice model.

Table 4-7: Time-of-day model

TOD	Variable Name	Coefficients
E.M-M.D	Intercept	-21.646
	Logsum: expected maximum utility from mode choice	0.242
	Work	40.673
	Non-work	0
E.M-P.M	Intercept	-19.895
	Logsum: expected maximum utility from mode choice	0.229
	Work	40.566
	Non-work	0
E.M-N.T	Intercept	-19.640
	Logsum: expected maximum utility from mode choice	0.248
	Work	40.711
	Non-work	0
A.M-A.M	Intercept	2.299
	Logsum: expected maximum utility from mode choice	-0.892
	Work	-20.957
	Non-work	0

Table 4-7: Time-of-day model continued

TOD	Variable Name	Coefficients
A.M-M.D	Intercept	-0.062
	Logsum: expected maximum utility from mode choice	.261
	Work	21.592
	Non-work	0
A.M-P.M	Intercept	0.640
	Logsum: expected maximum utility from mode choice	0.213
	Work	22.660
	Non-work	0
A.M-N.T	Intercept	-1.712
	Logsum: expected maximum utility from mode choice	0.242
	Work	24.926
	Non-work	0
M.D-M.D	Intercept	-0.729
	Logsum: expected maximum utility from mode choice	0.218
	Work	20.482
	Non-work	0
M.D-P.M	Intercept	-0.656
	Logsum: expected maximum utility from mode choice	0.222
	Work	4.361
	Non-work	0
M.D-N.T	Intercept	-1.160
	Logsum: expected maximum utility from mode choice	0.214
	Work	22.159
	Non-work	0

Table 4-7: Time-of-day model continued

TOD	Variable Name	Coefficients
P.M-P.M	Intercept	-0.737
	Logsum: expected maximum utility from mode choice	0.010
	Work	0.236
	Non-work	0

The reference category used for the TOD model found in *Table 4-7* is P.M-N.T. The explanatory variables considered in this model were the logsum variable which was obtained from the model developed for mode choice and the type of tour, which could be a work tour and a non-work tour. The logsum values for all TOD categories were found to be within the acceptable range preserving the nested structure that was being developed. The least coefficient for the tour type was observed for A.M-A.M, M.D-P.M, and P.M-P.M. The occurrence of tours which start and end at A.M is lower. The same case applies also for M.D-P.M and P.M-P.M tours. Most individuals do not choose these TODs when planning to travel.

4.5.2.2 Model Fitting

For the TOD model $LL(\hat{\beta})$ was found to be 511.200 and $LL(0)$ was 646.477. This gives a likelihood ratio index, ρ^2, of 0.209 which is in the acceptable range of 0 to 1. Moreover, both the logsum of the mode-choice model as well as the work variable were found to be significant for the model fitting.

4.5.3 Daily-Activity-Pattern Model (DAP)

A nested logit (NL) model is used to predict the choice of an individual throughout the day. The first choice individuals make is whether to stay home or to go out and perform various activities. Activities that are performed within a household that leads an individual to get out of the house or stay there are not addressed in this research. *Figure 4-11* below shows the percentage distribution of daily activity patterns.

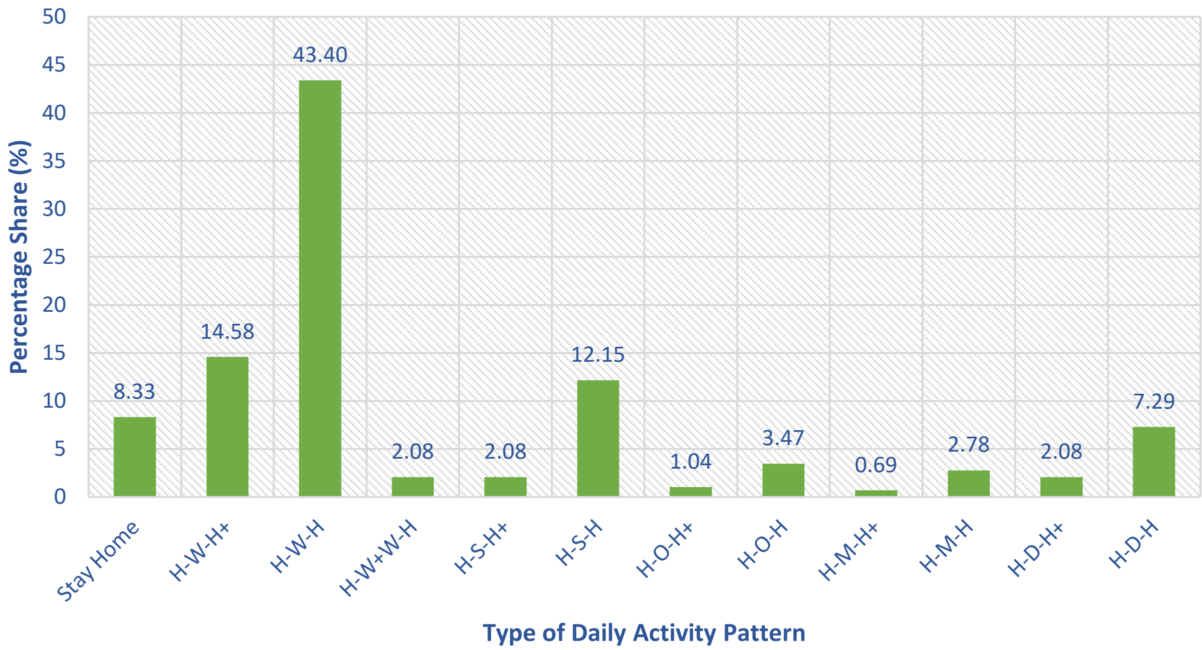

Figure 4-11 Distribution of daily activity patterns

From the survey, it was observed that 8.3% of the respondents stayed at home during the data collection period. The highest percentage of tour type that was observed was H-W-H tours taking 43.4% of the share of the daily activity patterns observed. Furthermore, 14.6% of the respondents had an H-W-H+ type of tour meaning that the main purpose of their trips was to go to work and back home with one or more intermediate stops either on the way to work or on the way back home. H-S-H took 12.2% share of the daily activity patterns observed, while H-S-H+ had 2.1% share. H-M-H and H-M-H+ had a 2.8% and 0.7% share respectively, while H-D-H and H-D-H+ had a 7.3% and 2.1% share respectively. 3.5% of the tours were of the type H-O-H, while 1.0% were of the type H-O-H+.

4.5.3.1 Model Estimation

The DAP model was done for both work tours and non-work tours. The set of alternatives an individual face within a day is to stay home, to conduct a work tour, or to conduct a non-work tour. The estimated model for work tours and non-work tours are presented in *Table 4-8* and *Table 4-9* respectively.

Table 4-8: Daily activity patterns for work tours

DAP	Variable Name	Coefficients
H-W-H	Intercept	22.948
	Number of secondary activities	-46.614
	Logsum: expected maximum utility of TOD	0.161
H-W-H+	Intercept	-0.823
	Number of secondary activities	-1.116
	Logsum: expected maximum utility of TOD	0.186

The explanatory variables considered for work tours were the number of secondary activities involved within a day and the logsum value obtained from the TOD model. The reference category used was H-W+W-H. From *Table 4*-8, it can be seen that the logsum values are within the acceptable range helping to maintain the nested structure for the model developed. The number of secondary activities had little impact on the H-W-H tour type. This is considered valid as these types of tours do not involve any other activity within them since the individuals go to work and return back home without other additional stops. The coefficient for the number of secondary activities for H-W-H+ is a less negative number. This is due to the fact individuals performing these types of tours involve an additional activity in addition to basic H-W-H tour.

The explanatory variables considered for non-work tours are the same as those used for the work tours. The values given in *Table 4-9* are given in reference to H-M-H+ type of tour. The logsum values of non-work tours show a wide range of values. For H-D-H+ and H-O-H+, the coefficients are very high while for the other observed DAPs they are found to be within the acceptable range meaning that they influence DAP structure highly. When considering the number of secondary activities, relatively lower values were obtained for H-S-H, H-M-H, H-D-H, and H-O-H tour types. This confirms the fact that these tour types do not have secondary activities involved within them.

Table 4-9: Daily activity patterns for non-work tours

DAP	Variable Name	Coefficients
H-D-H	Intercept	-14.877
	Number of secondary activities	-41.306
	Logsum: expected maximum utility of TOD	0.652
H-S-H	Intercept	-18.276
	Number of secondary activities	-41.237
	Logsum: expected maximum utility of TOD	0.712
H-M-H	Intercept	-36.107
	Number of secondary activities	-40.822
	Logsum: expected maximum utility of TOD	0.963
H-O-H	Intercept	-26.128
	Number of secondary activities	-41.091
	Logsum: expected maximum utility of TOD	0.814
H-S-H+	Intercept	-40.567
	Number of secondary activities	-11.150
	Logsum: expected maximum utility of TOD	0.842
H-D-H+	Intercept	-1349.230
	Number of secondary activities	64.201
	Logsum: expected maximum utility of TOD	19.184
H-O-H+	Intercept	-1305.544
	Number of secondary activities	76.877
	Logsum: expected maximum utility of TOD	18.169

4.5.3.2 Model Fitting

For the DAP model of work tours $LL(\hat{\beta})$ was found to be 27.854 and $LL(0)$ was 238.298. This gives a likelihood ratio index, ρ^2, of 0.883. On the other hand, the DAP for non-work tours had a $LL(\hat{\beta})$ of 150.325 and $LL(0)$ of 266.937. From these values, ρ^2 was estimated to be 0.436.

4.5.4 *Applicability of DAP*

The DAP model that was described above can be used to estimate the utility of each type of tour for Bole Sub-City. It was found that most respondents of the survey were workers making the DAP model for work tours more applicable than non-work tours.

The DAP model is important as it helps in studying the travel patterns of individuals found in the Sub-City by further understanding their TOD choice as well as mode choice. This is important in generating O-D matrices for the study area once a destination choice model has been added to the current model.

In order to further apply the above DAP model to other sub-cities found in Addis Ababa, the same methodologies that were described in this research should be implemented. Activity diaries, as well as questionnaires, should be distributed to the area in question to study the travel pattern of individuals residing there. Once this is done, a model can be developed for the area of interest.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The goal of this research was to develop a discrete choice activity-based travel demand model. This was done with three major tasks which were to construct a daily activity pattern (DAP) model, a time-of-day (TOD) choice model, and a mode choice model. A multinomial logit (MNL) and a nested logit (NL) discrete choice modeling framework were adopted for modeling these three sequential models. The parameters of the NL model were estimated sequentially.

The following conclusions were made from the research that was conducted on activity-based travel demand models.

- Of all the modes of transportation, minibus taxi had the highest percentage share followed by shared ride.
- Service, minibus taxi with service, and minibus taxi with higher were not used by non-workers while the remaining were common both to workers and non-workers.
- The mode choice model showed that the presence of one or more vehicles in a household affects the transportation mode to be used.
- Individuals with cars in their homes chose to use car alone or shared ride as their travel mode while those who did not own cars preferred to use the remaining transportation modes for their daily travel.
- Most tours started during the A.M peak and ended either during the P.M. peak or at nighttime. This was true, especially for work tours.
- For school tours, even if the tour started during the A.M peak, it ended during mid-day or P.M peak. The TOD model showed that most individuals chose A.M-P.M and A.M-N.T. For this reason, it was concluded that there is high traffic during these hours as it is the time in which workers and students head home.
- The results of the survey showed that the highest portion of activities that were observed were work activities followed by school activities.
- For both work and non-work tours, the presence of the number of secondary activities as an explanatory variable had less impact if the tour type were H-W-H, H-S-H, H-D-H, H-M-H, and H-O-H.

- 43.4% of the trips were of the type H-W-H leaving the rest 56.6% to be shared among the rest tour types. This confirms the fact that individuals choose tours involving work instead of other tour types.

5.2 Recommendations

The following recommendations are forwarded.

- Increase the availability of the modes that are frequently used in the Sub-City.
- As most working individuals choose A.M as the time-of-day to go to work and P.M and N.T for returning home, it is recommended to increase transportation facilities at these times.
- For students, their preferred time-of-day choice is A.M-M.D. Hence, increasing the transport modes during these times will help them reach home at the desired time.

5.2.1 Further Research

- Further research in the area of activity-based travel demand modeling for Addis Ababa is recommended as it is the second-generation modeling for travel demand and it takes into account factors that the trip-based research has neglected.
- Detailed household surveys using activity diaries for the remaining sub-cities of Addis Ababa as this will eliminate the issues arising from data collection and help researchers focus on the modeling process.
- The inclusion of destination choice model and intermediate stop models. Destination choice models are useful for making an origin-destination trip matrix. In addition to this, identifying the stops made by individuals performing their daily tours will help in better understanding their travel patterns. This will enable the full development of activity-based travel demand models.
- Secondary tours were not included in the model developed due to lack of sufficient data. Developing a model which includes these tour types will help in model development.

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ANNEX-A: SURVEY SUMMARY

This section gives a concise summery of the results of the household survey that was conducted for the research work.

Household Composition

The table below gives the frequency of occurrence of 0, 1, 2, 3, 4. 5, and 6 or more males and females within a household.

Table A-1: Household composition by gender

Number	Male Frequency	Female Frequency
0	5.3	5.9
1	21.7	13.2
2	34.9	41.4
3	23.7	29.6
4	7.2	1.3
5	3.9	3.9
6+	3.3	4.6
Total	**100**	**100**

Table A-2 shows the percentage of occurrence of children which are 5 or younger than 5 within a household. The percentage occurrence of students, retirees, and workers is also included in the table.

Table A-2: Household composition by occupation

Type	Percentage (%)
Less than 5 years old	8.25
Students	31.67
Retired	10.75
Workers	49.33
Total	**100**

Household Size

Table A-3: Percentage share by of household sizes

Household size	Percentage (%)
1.00	8.5
2.00	6.5
3.00	11.8
4.00	17.6
5.00	30.7
6.00	14.4
7.00	5.9
9.00	1.3
13.00	3.3
Total	**100.0**

Education Level of Household Members

More than 50% of the surveyed population had a degree or are pursuing their education to get their respective degrees while only less than 1% of the population have only completed kindergarten.

Table A-4: Distribution of household members by their education

Education level	Percentage (%)
Kindergarten	0.7
0-4	2.6
5-8	2.0
9-12	12.6
Certificate	1.3
Diploma	9.9
Degree	50.3
Masters	18.5
Doctorate	1.3
Other	0.7
Total	**100.0**

Drivers' License Status

The ownership of a drivers' license shows the potential of an individual to drive a vehicle if it is present in a household. In addition to this, it has a significant impact in the analysis of travel behavior as household members interact with each other and if there is only one vehicle present in a household, the members of the household will arrange their schedule in a way that is convenient for them. It was observed from the survey that 20.9 % of the individuals within a household did not own a drivers' license 1 or 2 licenses were owned by 46.2% of the individuals within a household.

Table A-5: Drivers' license status of individuals in a household

Individual with license	**Percentage (%)**
0	20.9
1	26.1
2	26.1
3	7.8
4 or more	19.0
Total	**100.0**

From the individuals within a household who agreed to participate in the survey, a detailed status of their drivers' license was observed. The largest share of the individuals who participated in the survey did not own a driver's license while the next highest proportion of the individuals had an 'Auto' driver's license.

Table A-6: Distribution of household members by their drivers' license type

License type	**Percentage (%)**
Auto	43.1
Minibus taxi 2	2.0
Hizb 2	1.3
Derek 3	0.7
Level 2	3.9
Level 3	3.9
Level 5	0.7
None	44.4
Total	**100.0**

Type of Workplace

From the analysis of respondents' workplace type, it was found that 30.7% of the individuals worked in an office. The next highest share was that of an educational institution taking up 26% of the respondents. The reason behind the high percentage share for an educational institution as a type of work place is because the students from the survey considered their workplace type as an educational institution.

Table A-7: Distribution of household members by their type of workplace

Workplace type	**Percentage (%)**
Residential	9.3
Shop	8.0
Aviation	2.7
Office	30.7
Bank	2.7
Construction	8.7
Educational Institution	26.0
Factory/Industry	1.3
Hospital	0.7
Hotel	4.0
Transportation	4.7
Warehouse	0.7
Other	0.7
Total	**100.0**

ANNEX-B: QUESTIONNAIRE AND ACTIVITY DIARY (IN ENGLISH)

The purpose of this survey is to study the travel activities of the residents of Bole Sub-City in order to come up with a solution that will alleviate current transportation problems that are observed.

This questionnaire is composed of three sections.

- The first section is the household information section. In this section, you will fill out the location of your household, your household size and so on.
- This section is to be filled out by every individual found in the household. You will fill out your age, gender, relationship with the household head, education level, frequently used mode of travel, driver's license status, occupation status, and type of workplace.
- The last section is the activity diary. In this section, all activities are that are performed from the time you go out of your home until you finally return back home should be entered.

Your cooperation is important for the success of this research. All information obtained from this survey will only be used for the purpose of this research.

Household Information

Household Address	
Area Name	
Woreda	

Total number of household members ☐

Male ☐ <5 years ☐ Other ____________

Female ☐ Workers ☐

Student ☐ Retired ☐

House Ownership

Residence Type	Owned	Rented	Government Provided	Company Provided	No. of Rooms
Independent Home					
Apartment					
Condominium					
Other					

Vehicle Ownership

Vehicle Type	Owned by Household	Owned by Company	Owned by Others
Automobile			
Minibus			
Motorcycle			
Bajaj			
Bicycle			
Other			

Monthly Household Income

<1,000	
1,000-5,000	
5,001-10,000	
10,001-20,000	
20,001-30,000	
>30,000	

Total number of licensed drivers in the household

Person Information

Age ☐

Gender Male ☐ Female ☐

Relationship with the Household Head

Self ☐	Father/Mother ☐	Not related ☐
Child ☐	Relative ☐	Other _______

Education Level

Kindergarten ☐	Certificate ☐	Doctorate ☐
0-4 ☐	Diploma ☐	Professor ☐
5-8 ☐	Degree ☐	Other _________
9-12 ☐	Masters ☐	

Model of Travel (You can choose more than one mode)

Walking ☐	Taxi ☐	Company Service ☐
Bicycle ☐	Private Car ☐	Government Service ☐
Bajaj ☐	Public Bus ☐	Higer ☐
Motorcycle ☐	LRT ☐	Other _______

Driver's License Status

None ☐	Taxi-2 ☐	Hizb-1 ☐
Motorcycle ☐	Derek-1 ☐	Hizb-2 ☐
Auto ☐	Derek-2 ☐	Fesash-1 ☐
Taxi-1 ☐	Derek-3 ☐	Fesash-2 ☐

Or Level______

Occupation Status

Employed (Full-time) ☐	Student ☐	Retired ☐
Employed (Part-time) ☐	Daily Laborer ☐	Housewife ☐
Self Employed ☐	Seeking Employment ☐	Other _________

Type of Workplace

Residential ☐	Shop ☐	Tourism ☐
Industry/Factory ☐	Educational Institute ☐	Agriculture ☐
Warehouse ☐	Hotel/Restaurant ☐	Construction ☐
Office ☐	Recreational ☐	Other __________
Bank ☐		

Activity Diary

Date______________

No.	Time at which you started your traveling and reached your destination		Location		Activity Purpose	Mode of Travel	No. of Accompanied Travelers		Travel Time	Cost (Birr)
	Start time	End time	Origin	Destination			Family Member	Other		

ANNEX-C: QUESTIONNAIRE AND ACTIVITY DIARY (IN AMHARIC)

የዚህ መጠይቅ አላማ በቦሌ ክፍለ ከተማ ውስጥ የሚኖሩትን ነዋሪዎች የመንገድ እና የትራንስፖርት ተጠቃሚዎችን እንቅስቃሴ ጥናት በማድረግ የመንገዱ ተጠቃሚዎች የሚገጥማቸውን የትራንስፖርት ችግር በመረዳት ዘላቂ የሆነ መፍትሄ መፈለግ ነው።

ይህ መጠይቅ በሶስት ክፍሎች የተከፈለ ነው።

- የመጀመሪያው ክፍል የቤተሰብ መረጃ ሲሆን ይህ መረጃ የሚጠቅመው የሚኖሩበትን አካባቢ፣ አብረዎት የሚኖሩትን የቤተሰብ አባላት ቁጥር፣ እና የመሳሰሉትን መረጃ የሚሞሉበት ክፍል ነው።
- ሁለተኛው ክፍል በቤትዎ ውስጥ ያሉት እያንዳንዱ አባላት የሚሞሉት ነው። በዚህ ክፍል ውስጥ የግለሰቡን እድሜ፣ ፆታ፣ ከቤቱ ራስ ጋር ያለውን/ያላትን ግንኙነት፣ የትምህርት ደረጃ፣ አዘውትረው የሚጠቀሙተን የትራንስፖርት አይነት፣ የመንጃ ፍቃድ ደረጃ፣የስራ ሁኔታ፣ እና የስራ ቦታ አይነት ይሞላል።
- የመጨረሻው ክፍል ደግሞ እያንዳንዱ የቤተሰብ አባል በሁለት ቀናት ውስጥ የሚፈፅማቸውን ዝርዝር እንቅስቃሴዎች መጠይቁ ከተሰጠነት ቀን ጀምሮ የሚያስቀምጥበት ክፍል ነው። በዚህ ክፍል ውስጥ ከቤት ከወጡበት ሰዓት ጅምሮ ሁሉንም ነገር አጠናቀው ወደ ቤት እስኪመለሱ ድረስ ያካሄዱትን ውሎ ከእንቅስቃሴው ዓላማ ጋር ይሞላሉ።

የእርሶ ድጋፍ ለዚህ ጥናት በጣም አስፈላጊ ሲሆን የሰጡን መረጃ ከዚህ ጥናት ውጭ ለሌላ አገልግሎት እንደማይውል እየገለፅን ለሰጡን ጊዜ እና ትብብር ከልብ እናመሰግናለን።

የቤተሰብ መረጃ

የመኖርያ አድራሻ	
ልዩ መጠርያ	
ወረዳ	

ጠቅላላ የቤተሰብ ብዛት ☐

ወንድ ☐	<5 ዓመት ☐	ሌሎች ____________
ሴት ☐	ሰራ ያለው ☐	
ተማሪ ☐	ጡረተኛ ☐	

የቤት ባለቤትነት

የመኖርያ አይነት	የግል	የኪራይ	የመንግስት	የድርጅት	የክፍሎች ብዛት
ግቢ					
የጋራ መኖርያ/አፓርታማ					
ኮንዶሚኒየም					
ሌላ (ይጠቀስ)					

የተሽከርካሪ ባለቤትነት

የተሽከርካሪ አይነት	የግል	የድርጅት	የሌሎች
አውቶሞቢል			
ሚኒ ባስ			
ሞተር ሳይክል			
ባጃጅ			
ብስክሌት			
ሌሎች (ይጠቀስ)			

ወርሃዊ የቤተሰብ የገቢ መጠን

<1,000	
1,000-5,000	
5,001-10,000	
10,001-20,000	
20,001-30,000	
>30,000	

መንጃ ፍቃድ ያለው የቤተሰብ አባል ብዛት

የግል መረጃ

እድሜ ☐

ፆታ ወንድ ☐ ሴት ☐

ከቤቱ ራስ ጋር ያሎት ግንኙነት

የቤቱ ራስ ነኝ ☐	አባት/እናት ☐	ተቀጣሪ ☐
ልጅ ☐	ዘመድ ☐	ሌላ ______

የትምህርት ደረጃ

መዋለ ህፃናት ☐	ሰርተፍኬት ☐	ዶክትሬት ☐
0-4 ☐	ዲፕሎማ ☐	ፕሮፌሰር ☐
5-8 ☐	ዲግሪ ☐	ሌላ ________
9-12 ☐	ማስተርስ ☐	

የመጓጓዣ መንገድ (ከአንድ በላይ መ ምረጥ ይቻላል)

በእግር ☐	ታክሲ ☐	የግል ሰርቪስ ☐
ብስክሌት ☐	መኪና ☐	የመንግስት ሰርቪስ ☐
ባጃጅ ☐	የህዝብ አውቶብስ ☐	ሀይገር ☐
ሞተር ☐	ባቡር ☐	ሌላ ______

የመንጃ ፍቃድ ደረጃ

የለኝም☐	ታክሲ-2 ☐	ህዝብ-1 ☐
ሞተር ሳይክል ☐	ደረቅ-1 ☐	ህዝብ-2 ☐
አውቶ ☐	ደረቅ-2 ☐	ፈሳሽ-1 ☐
ታክሲ-1 ☐	ደረቅ-3 ☐	ፈሳሽ-2 ☐

ወይም ደረጃ______

ስራ ሁኔታ

ቅጥር (ሙሉ ጊዜ) ☐	ተማሪ ☐	ጡረተኛ ☐
ቅጥር (በትርፍ ሰዓት) ☐	የቀን ሰራተኛ ☐	የቤት እመቤት ☐
የግል ☐	ስራ ፈላጊ ☐	ሌላ ________

የስራ ቦታ አይነት

መኖርያ ቤት ☐	ሱቅ ☐	ግብርና ☐
ኢንዱስትሪ/ፋብሪካ☐	የትምህርት ተቋም ☐	ኮንስትራክሽን ☐
መጋዘን ☐	ሆቴል/ሬስቶራንት ☐	ሌላ _________
ቢሮ ☐	መዝናኛ ☐	
ባንክ ☐	ቱሪዝም ☐	

የቀን እንቅስቃሴ ማስታወሻ

ቀን_____________

ቁጥር	ወደ ጉዳዩ ለመሄድ የተነሱበት እና የደረሱበት ሰዓት		`ቦታ		የእንቅስቃሴው ዓላማ	ለመጓጓዝ የተጠቀሙት የትራንስፖርት አይነት	የተጓዥ ብዛት (በቁጥር)		የመጓዣ ሰዓት	የክፍያ መጠን (በብር)
	መነሻ ሰዓት	መድረሻ ሰዓት	መነሻ ቦታ	መድረሻ ቦታ			የቤተሰብ አባል	ሌሎች		